6.8 Infiltration Systems

6.8.1 Device Description

Infiltration systems, illustrated in Figure 6-8.1, are designed to provide temporary underground storage and infiltration for stormwater runoff. Infiltration systems can provide significant stormwater runoff improvements, including reduced peak rates, volumes, and velocities, improved water quality, and reduced downstream erosion and flooding. The runoff which is stored below surface will infiltrate into the ground recharging the groundwater supply.

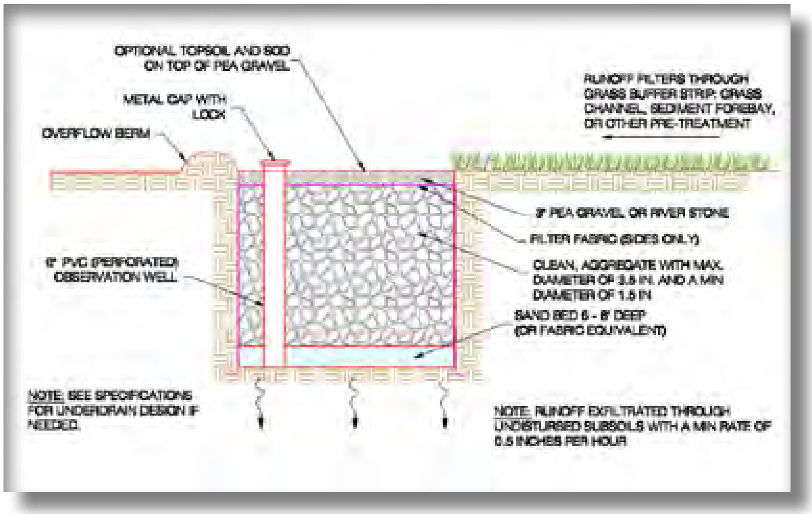


Figure 6-8.1
Subsurface Infiltration

Infiltration systems can underlie a vegetated or hardscape surface. They are suited for large flat areas or a substantial area of open space downhill from nearby residential or commercial property where runoff would occur.

6.8.2 Key Elements

- Infiltration testing is required for this BMP.
- Reduce volume of runoff from a drainage area by promoting infiltration through uncompacted subgrade.
- Flexible design can be sited beneath lawns, parking areas, and recreational areas.
- Maintain minimum distance from structure foundation.
- Open-graded aggregate or other approved material provides storage.
- System must be designed to drain down in less than 48 hours.
- Greater than two (2) feet from any limiting zone such as groundwater or bedrock.
- Pretreatment is required.
- Overflow structures are required for large storms.
- Areas of soil contamination or areas of unstable soils should be avoided.

6.8.3 Device Uses and Applicability

Potential applications for infiltration systems:

- Residential subdivision
- Commercial
- Urban
- Industrial
- Redevelopment
- Along roadways

Infiltration systems address:

- Water quality / infiltration
- Volume reduction
- Storm event peak discharge

6.8.4 Infiltration in the Urban Landscape

Infiltration systems are typically stone filled beds or trenches beneath landscaped or paved surfaces. Stormwater flows into the infiltration system, collects within the aggregate void space, and slowly infiltrates into surrounding soils, see Figures 6-8.1 and 6-8.2 for examples of infiltration systems.

Infiltration is a versatile management practice suitable for many different types of land uses. Both high-density development and individual residences can implement infiltration systems for stormwater control. Their flexibility also makes them an option for a stormwater retrofit. Several uses for infiltration system are provided below.

Parking Lots and Roadways

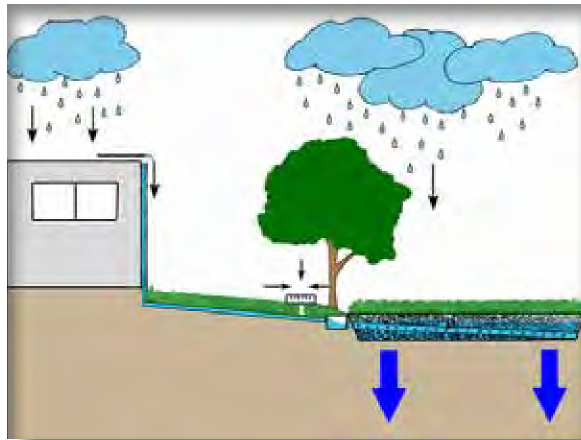
Stormwater inlets in parking lots or streets can be directly connected to infiltration systems. Sumped or trapped inlets prevent sediment and debris from migrating into the infiltration bed. The inlets can be connected to infiltration systems located underneath landscaped areas, recreation areas, or under the impervious surfaces themselves.

Lawns and Recreational Areas

Open green spaces can collect, store, and infiltrate runoff from impervious surfaces, see Figure 6-8.4.

Direct Connection of Rooftops

Downspouts can be connected to infiltration beds at both residential and commercial sites. Small infiltration areas that manage roof runoff from residential roofs or that are distributed around building to manage runoff from smaller sections of roof are often called dry wells. Although roofs do not often generate high sediment loads, sump cleanouts should be located between the roof and the infiltration area. The roof leader connects to perforated piping when it reaches the subsurface infiltration area.



Courtesy of Philadelphia Stormwater Manual V 2.0

Figure 6-8.2
Direct Connection of a Roof into a Infiltration System

Courtesy of Philadelphia Stormwater Manual V 2.0

Figure 6-8.3
Infiltration System Beneath Picnic Area

Courtesy of Philadelphia Stormwater Manual V 2.0

Figure 6-8.4
Infiltration system under lawn

6.8.5 Components of a Subsurface Infiltration System

There are many variations of subsurface infiltration systems, but they are often comprised of these components:

- Inflow/Pretreatment
- Storage
- Observation Well
- Infiltration
- Overflow/Outflow

- Inflow/Pretreatment

Infiltration systems are capable of intercepting stormwater inflow from many sources, including rooftops, parking lots, roads, sidewalks, and driveways. It is important to prevent coarse sediments and debris from entering infiltration systems, because they could contribute to clogging and failure of the system. The following are acceptable forms of pretreatment:

- Roof leader sump, or an intermediate sump box, see Figure 6-8.5
- Roof gutter guard (may require additional sump unit depending on structure design)
- Filter Strips (Section 6-5)
- Vegetated Swales (Section 6-4)

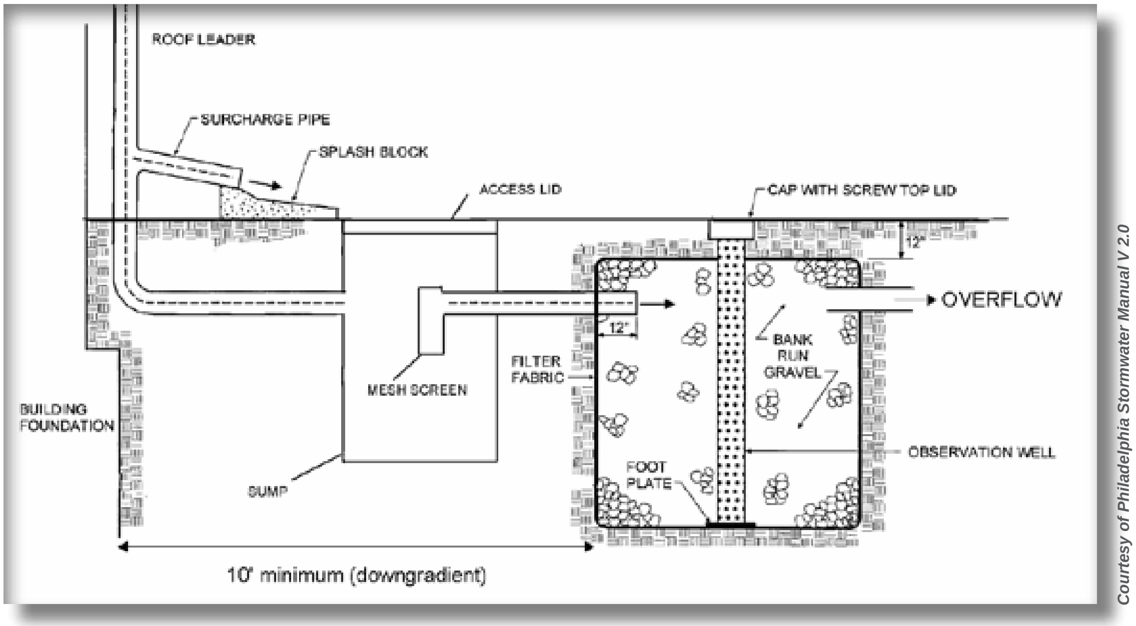


Figure 6-8.5
Sump Box and Dry Well

- Storage

The storage component of an infiltration area is typically provided by a stone filled, level-bottomed bed or trench. The void space between the stones stores stormwater until it can percolate into surrounding soils.

Alternative subsurface storage products may also be used to provide temporary storage, illustrated in Figure 6-8.6 (page 6-44). These include a variety of proprietary, interlocking plastic units with much greater storage capacity than stone fill (up to 96% void space). Perforated pipe in a stone bed can also increase the effective void space of the system. The higher void space allows for a smaller footprint and can allow more flexibility in an urban environment.

Infiltration Systems

- Observation Well

  An observation well should be located at the center of the trench to monitor water drainage from the system see Figure 6-8.7. In a subsurface infiltration system, the water level is the primary means of measuring infiltration rates and draining times. A lockable above ground cap is recommended. Adequate inspection and maintenance access to the observation well should be provided. Observation wells not only provide necessary access to the system, but they also provide a means through which pumping of stored runoff can be accomplished if the system fails.

- Infiltration

  Outflow occurs via infiltration through subsurface soil surrounding the infiltration storage area. Proper analysis should be completed to ensure that the insitu soils will adequately drain with the additional loading and that loading ratio and effective head maximums are not exceeded.

- Overflow/Outflow

  A bypass system is recommended for all infiltration systems to convey high flows around the system to downstream drainage systems. Depending on the level of stormwater management required at the site, overflows can connect to an approved discharge point or other BMPs.

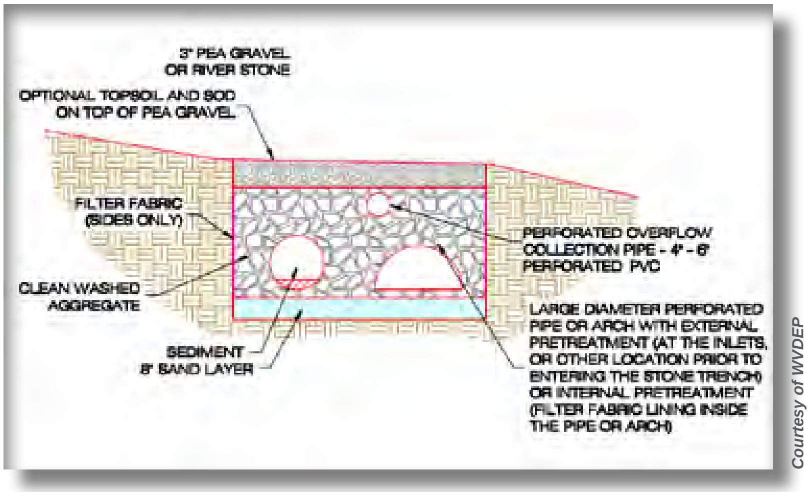


Figure 6-8.6
Infiltration section with Supplemental Pipe Storage and Overflow Pipe

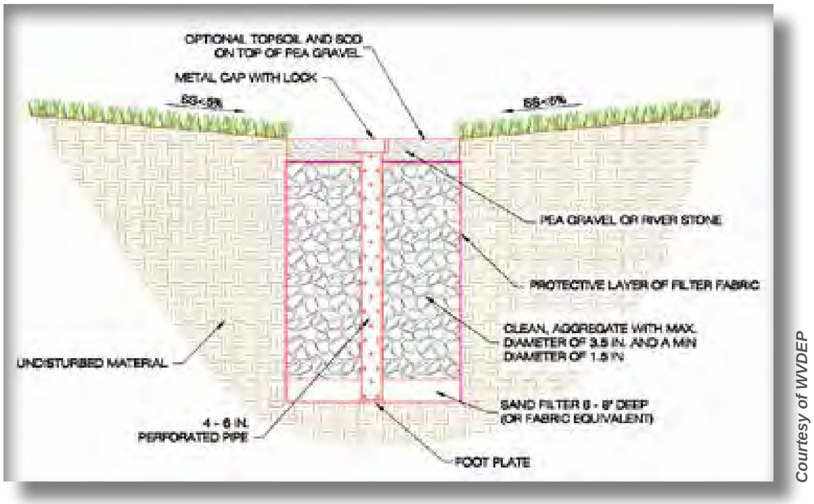


Figure 6-8.7
Typical detail of observation well

6.8.6 Recommended Design Procedures

Infiltration design must be considered early in site planning. Soils intended for infiltration must be preserved in the site design.

Early site planning should identify the best soils for Infiltration, and the site design should set these aside for infiltration practice locations. The site, utility, and erosion and sediment control plans should identify how the soils will be protected during construction to avoid disturbance and compaction.

Sites that have been previously graded or disturbed do not typically retain their original soil permeability. Such sites are often not good candidates for infiltration practices unless the geotechnical investigation shows that the soil infiltration rate is adequate. The following are general guidelines to ensure proper design:

1. Evaluate the site for infiltration design consideration, included in Section 4.2.6 of the WVDEP Stormwater Management and Design Guidance Manual. These considerations include site topography, minimum depth to water table or bedrock, soils, contributing drainage area, hotspot land uses, floodplains, setbacks and proximity to utilities.
2. Geotechnical investigation is necessary to detect the soil infiltration rate. Infiltration testing must be within 25 feet of the infiltration footprint.
3. Infiltration practices should not be hydraulically connected to structure foundations or pavement in order to avoid harmful seepage. Setbacks to structures vary based on the contributing drainage area of the infiltration practice. The following can be used as guidelines:
   - 250 to 2,500 square feet = 5 feet if down-gradient from building; 25 feet if up-gradient.
   - 2,500 to 20,000 square feet = 10 feet if down-gradient from building; 50 feet if up-gradient.
   - 20,000 to 100,000 square feet = 25 feet if down-gradient from building; 100 feet if up-gradient
4. Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the surface ponding and soil storage will take to drain. The maximum drain down time for the entire storage volume is 48 hours, but the designer may choose a shorter time based on site conditions and owner preference. If storage does not drain in this time, adjust the depth and/or surface area. Adjust the design until the volume and drainage time constraints are met.
5. Create a conceptual design for the infiltration system using Table 6-8.1 as a reference.

Table 6-8.1: Design Parameters	
Area (surface area and infiltration area)	Largest feasible in moderately sloped areas of the site (Minimum of 1 square foot of infiltration area for every 5 square feet of contributing Directly Connected Impervious Area recommended.)
Minimum distance above limiting zone	2 feet
Maximum drain down time	48 hours

6. Estimate the total storage volume and adjust area and/or depths as needed to provide required storage. Open-graded aggregate sub-base may be assumed to have 40% void space for storage.

7. Design overflow/outflow for larger storm events. Overflow structures should convey at least a 10-year storm event.

8. Include acceptable form(s) of pretreatment into design.

9. Observation well shall be designed with four (4) inch diameter perforated plastic pipe, and placed at the invert of inflation bed with a lockable above-ground cap.

6.8.7 Infiltration Credit

Post-Construction Stormwater Management, located in Section 2.3.4 requires the first one (1) inch of rainfall to be managed. The volume to be considered managed is equal to the volume infiltrated in native soil within 48 hours.

6.8.8 Materials

The following materials in Table 6-8.2 will provide the project with efficient and effective infiltration.

Table: 6-8.2: Material Specifications

Material	Specification	Notes
Surface Layer (optional)	Topsoil and grass layer	
Surface Stone	3-inch layer of river stone or pea gravel.	This provides an attractive surface cover that can suppress weed growth.
Stone Layer	Clean, aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches.	
Observation Well	Vertical 6-inch PVC perforated pipe, with a lockable cap and anchor plate.	Install one per 50 feet of length of Infiltration practice.
Overflow/Outflow	4-inch or 6-inch rigid PVC pipe, with 3/8” perforations at 6 inches on center, with each perforated overflow pipe installed at a slope of 1% for the length of the Infiltration practice. An overflow structure may be installed to convey larger storm events.	
Trench Bottom	6 to 8 inch sand layer (e.g., ASTM C 33, 0.02-0.04 inch).	
Buffer Vegetation	Keep adjacent vegetation from forming an overhead canopy above Infiltration practices, in order to keep leaf litter, fruits and other vegetative material from clogging the stone.	

Courtesy of WVDEP

6.8.9 Construction Guidelines

Infiltration practices are particularly vulnerable to failure during the construction phase. If the construction sequence is not followed correctly, construction sediment can clog the practice. Heavy construction can result in compaction of the soil, which can then reduce the soil's infiltration rate. For this reason, a careful construction sequence needs to be followed. Ideally, the infiltration practice should remain outside of the limit of disturbance during construction.

During site construction, the following steps are absolutely critical:

- Avoid excessive compaction by preventing construction equipment and vehicles from traveling over the proposed location of the infiltration practice.
- Keep the infiltration practice "off-line" until construction is complete. Prevent sediment from entering the infiltration site by using appropriate erosion control devices. In the erosion and sediment control plan, indicate the earliest time at which stormwater runoff may be directed to an infiltration practice. The erosion and sediment control plan must also indicate the specific methods to be used to temporarily keep runoff from the infiltration site.
- Infiltration practice locations should never serve as the sites for temporary sediment control devices (e.g., sediment traps, etc.) during construction.
- Upland drainage areas need to be completely stabilized with a thick layer of vegetation prior to commencing excavation for an infiltration practice.

The actual installation of an infiltration practice is done using the following steps:

- Step 1. Excavate the infiltration practice to the design dimensions from the side, using a backhoe or excavator. The floor of the pit should be completely level, but equipment should be kept off the floor area to prevent soil compaction.
- Step 2. Install filter fabric on the trench sides. Large tree roots should be trimmed flush with the sides of infiltration trenches to prevent puncturing or tearing of the filter fabric during subsequent installation procedures. When laying out the filter fabric, the width should include sufficient material to compensate for perimeter irregularities in the trench and for a 6-inch minimum overlap at the top of the trench. The filter fabric itself should be tucked under the sand layer on the bottom of the infiltration trench. Stones or other anchoring objects should be placed on the fabric at the trench sides, to keep the trench open during windy periods. Voids may occur between the fabric and the excavated sides of a trench. Natural soils should be placed in all voids, to ensure the fabric conforms smoothly to the sides of excavation.
- Step 3. Scarify the bottom of the infiltration practice, and spread 6 inches of sand on the bottom as a filter layer.
- Step 4. Anchor the observation well(s), and add stone to the practice in 1-foot lifts.
- Step 5. Use sod, where applicable, to establish a dense turf cover for at least 10 feet around the sides of the infiltration practice, to reduce erosion and sloughing. Sod should not be used over the infiltration bed itself. For designs that call for a turf cover over the infiltration bed, seeding and use of a biodegradable erosion control matting are good alternatives for establishing the turf cover.
- Step 6. Conduct the final construction inspection, then log the GPS coordinates for each infiltration facility and submit to the City's Stormwater Department.

6.8.10. Maintenance

As with all infiltration practices, infiltration systems require regular and effective maintenance to ensure prolonged functioning. Table 6-8.3 describes the minimum maintenance requirements for infiltration systems.

Table 6-8.3: Subsurface Infiltration Maintenance Guidelines

Activity	Schedule
▪ Regularly clean out gutters and catch basins to reduce sediment load to infiltration system. Clean intermediate sump boxes, replace filters, and otherwise clean pretreatment areas in directly connected systems. ▪ Mow grass surface over (if applicable) as necessary and remove the clippings.	As needed
▪ Inspect and clean as needed all components of and connections to infiltration systems. ▪ Evaluate the drain-down time of the infiltration system to ensure the drain-down time of 24-48 hours. ▪ Check observation wells 3 days after a storm event in excess of 1/2 inch in depth. Standing water observed in the well after three days is a clear indication of clogging. ▪ Repair undercut and eroded areas at inflow and outflow structures.	Biannually
▪ Clean out accumulated sediments from the pretreatment cell.	Annually
▪ Maintain records of all inspections and maintenance activity.	Ongoing

It is highly recommended that annual site inspections be performed for infiltration practices to ensure the practice performance and longevity.

Design of infiltration systems are not limited to the examples shown within this manual. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

6.9 Green Roofs

6.9.1 Device Description

Green or vegetated roofs, as illustrated by Figure 6-9.1, consist of a layer of vegetation that covers an otherwise conventional flat or pitched roof. Unlike conventional roofing, green roofs promote retention, slow release, and evapotranspiration of precipitation. This stormwater management technique is very effective in reducing the volume and velocity of stormwater runoff from roofs.

Courtesy of National Endowment for the Humanities

Figure 6-9.1
Green Roof

Green roofs can be installed on many types of roofs, from small slanting to large commercial flat roofs. Green roofs are an ideal option for new buildings that are taking long term cost savings and energy conservation into consideration. Many existing buildings can also be retrofitted with green roofs.

The green roof essentially restores the evapotranspiration component of the hydrologic cycle to the otherwise impervious roof surface where runoff would occur. In any rain event, the amount retained by the green roof depends on the water holding capacity of the media and the plants, and how much is still retained from the last rain event.

6.9.2 Key Elements

- Extensive green roofs with growing media at least 4 inches in depth can be considered pervious in stormwater design calculations.
- Vegetated roof covers intended to achieve water quality benefits should maintain a soluble nitrogen level of four (4) parts per million (ppm).
- Internal drainage, including provisions to cover and protect deck drains or suppers, must be designed to manage large rainfall events without inundating the cover.
- A tray system may be used to simplify the installation and make it easier to place, maintain, repair and replace sections of the roof. Figure 6-9.2.
- Provide urban green space and aesthetically pleasing views.
- Act as heat sink to reduce heating and cooling costs.
- Can extend roof life by two to three times.
- Improve air quality by filtering dust particles.

Courtesy of Marshall University Stormwater Dept.

Figure 6-9.2
Green Roof Tray System at Marshall University

6.9.3 Device Uses and Applicability

Potential applications for green roofs:

- Residential
- Commercial
- Urban
- Industrial
- Redevelopment

6.9.4 Green Roofs in the Urban Landscape

Although green roofs are initially more expensive than conventional roofs, they may provide long term benefits and cost savings. The vegetated cover assembly should be designed to protect and be compatible with the underlying waterproofing materials. By protecting the waterproofing from mechanical damage, shielding it from UV radiation, and buffering temperature extremes, the service life of the roof can be extended by two to three times. Green roofs also may also reduce energy costs by acting as a heat sink. The roof slowly absorbs energy from the sun during the day and releases it as the air cools, thereby reducing heating and cooling costs. The benefits will be greatest during the summer months, especially for low buildings. Green roofs also reduce the urban heat island effect by providing evaporative cooling and can improve air quality by filtering dust particles.

6.9.5 Components of a Green Roof

There are two basic types of green roofs. An extensive green roof system is a thin (usually less than 6 inches), lighter weight system planted predominantly with drought-tolerant succulent plants and grasses. An intensive green roof is a deeper, heavier system designed to sustain more complex landscapes. A green roof system, extensive or intensive, is often comprised of the same components as shown in Figure 6-9.1.

- Plant Material
- Growing Medium
- Filter Fabric
- Drainage Layer
- Waterproof Membrane/Root barrier
- Roof Structure

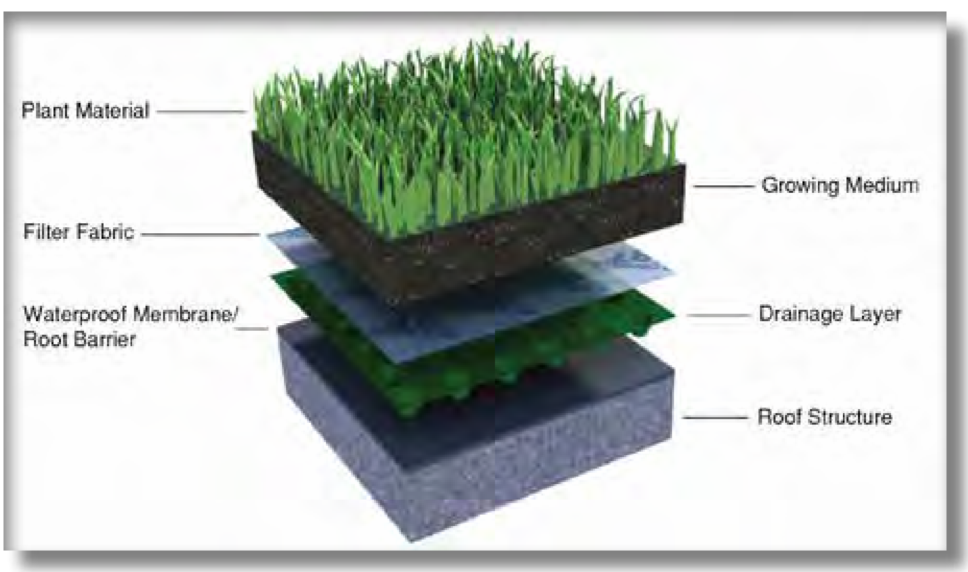


Figure 6-9.1
Green Roof Components

- Plant Material

  The plant material chosen for green roofs is designed to uptake much of the water that falls on the roof during a storm event. Plant selection is very important to the sustainability of the roof. About 50% of the vegetation on an extensive green roof should be Sedums.

- Growing Medium

  The growing medium is a critical element of stormwater storage on a green roof, and provides a buffer between the roof structure and vegetation for root development. Storage is provided by a green roof primarily through water held in tension in the growing medium pores. The growing medium in an extensive green roof should be a lightweight mineral material with a minimum of organic material and should stand up to freeze/thaw cycles.

- Filter Fabric

  An engineered filter fabric prevents fine soil particles from passing into the drainage layer of the green roof system.

- Drainage Layer

  The drainage layer may be either a lightweight granular medium or a synthetic layer that underlays and promotes free drainage of the planting medium. In some assemblages, synthetic drainage layers may also incorporate depressions that can intercept and retain small quantities of runoff. A tray system may be used to simplify the installation and make it easier to place, maintain, repair and replace sections of the roof, see Figure 6-9.2.

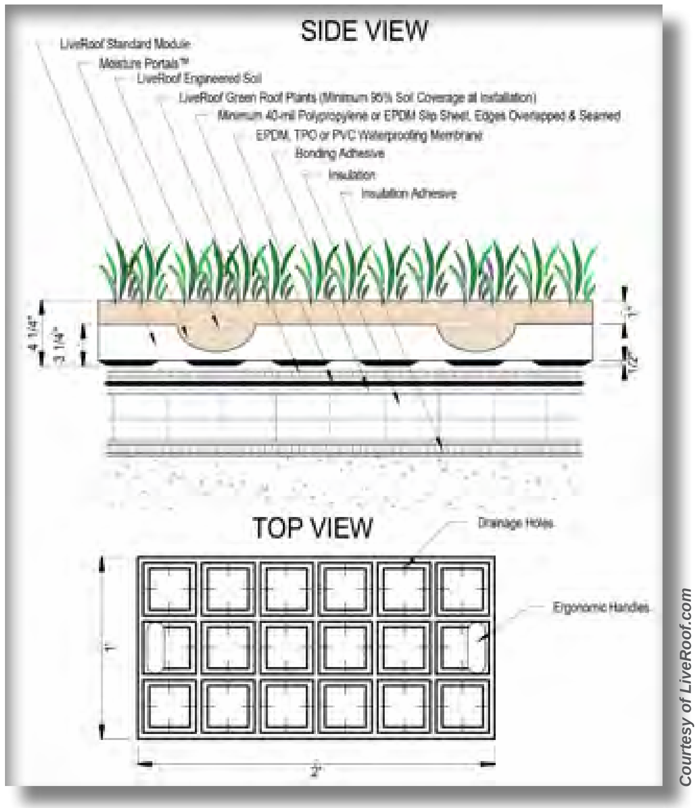


Figure 6-9.2
Green Roof Tray System Components

- Waterproof Membrane/Root Barrier

  To maintain structural integrity of the roof, a waterproof material is laid above the roof structure. Some waterproofing materials are inherently root resistant, whereas others require an additional root barrier.

- Roof Structure

  The load capacity of a roof structure must be taken into account when considering the installation of a green roof. Extensive green roofs typically weigh between 15 and 30 lbs per square foot and are compatible with wood or steel decks. Intensive green roofs weigh more than 36 lbs per square foot and typically require concrete supporting decks.

6.9.6 Recommended Design Procedures

The following are general guidelines to ensure proper design:

1. Investigate the feasibility of the installation of a green roof. A structural designer should verify that the roof will support the weight of the green roof system. t is important to consider the wet weight of the roof in the design calculations.
2. Determine the portion of roof that will have a green roof.
3. Extensive green roofs that have a growing media at least four (4) inches thick are permitted a (directly connected impervious area) reduction equal to the entire area of the green roof.
4. The green roof area can be considered pervious open space in good condition with moderate soils when determining post-development flow rates for the storm event peak discharge requirement.
5. Although green roofs are not considered as impervious surfaces when determining applicability of stormwater management requirements, they are not zero discharge systems. The roof drainage system and the remainder of the site drainage system must safely convey roof runoff to the storm sewer, combined sewer, or receiving water.
6. Green roofs with a media thickness less than four (4) inches can only be considered pervious if the designer can demonstrate that the initial abstraction of the green roof will be 0.5 inches or greater.
7. Develop planting plan based on the thickness of the planting media.

6.9.7 Infiltration Credit

Post-Construction Stormwater Management, located in Section 2.3.4 requires the first one (1) inch of rainfall to be managed. See Table 6-9.1 for credit guidelines.

Table 6-9.1: Green Roof Credit

Credit	Description	Application
100% volume reduction for the Design Volume of the practice[1]	Standard Design[2] • Soil media ≥ 4” • No more than 20% organic matter	Well-suited to ultraurban areas and retrofits.

[1]The Design Volume includes the storage volume of the growing media as defined by the porosity of the media (usually 0.25 to 0.35) and the media depth. Additional volume reduction credit is not provided for oversized (deeper) media storage.

[2]All designs must be in conformance with ASTM international standards for Vegetated Roofs referenced in Section 6.9.8.

6.9.8 Materials

Standard specifications for vegetated roofs continue to evolve, and no universal material specifications exist that cover the wide range of roof types and system components currently available. The ASTM has recently issued several overarching vegetated roof standards, Designers and reviewers should also fully understand manufacturer specifications for each system component, particularly if they choose to install proprietary "complete" vegetated roof systems or modules.

The following materials in Table 6-9.2 will provide the project with efficient and effective vegetated roof.

Table: 6-9.2: Material Specifications

Materials	Specification
Roof	Structural Capacity should conform to ASTM E-2397-05, Practice for Determination of Live Loads and Dead Loads Associated with Green Roof Systems. In addition, use standard test methods ASTM E2398-05 for Water Capture and Media Retention of Geocomposite Drain Layers for Green (Vegetated) Roof Systems, and ASTME 2399-05 for Maximum Media Density for Dead Load Analysis
Waterproof Membrane	See Chapter 6 of Weiler and Scholz-Barth (2009) for waterproofing options that are designed to convey water horizontally across the roof surface to drains or gutter. This layer may sometimes act as a root barrier.
Root Barrier	Impermeable liner that impedes root penetration of the membrane.
Drainage Layer	Depth of the drainage layer is generally 0.25 to 1.5 inches thick for extensive designs. The drainage layer should consist of synthetic or inorganic materials (e.g., gravel, recycled polyethylene, etc.) that are capable of retaining water and providing efficient drainage. Designers should consult the material specifications as outlined in ASTM E2396 and E2398. Roof drains and emergency overflow should be designed in accordance with all applicable building codes.
Filter Fabric	Needled, non-woven, polypropylene geotextile. Density (ASTM D3776) > 16 oz./sq. yd., or approved equivalent. Puncture resistance (ASTM D4833) > 220 lbs., or approved equivalent.
Growth Media	80% lightweight inorganic materials and 20% organic matter (e.g. well-aged compost). Media should have a maximum water retention capacity of around 30%. Media should provide sufficient nutrients and water holding capacity to support the proposed plant materials. Determine acceptable saturated water permeability using ASTM E2396-05.
Plant Materials	Sedum, herbaceous plants, and perennial grasses that are shallow-rooted, self-sustaining, and tolerant of direct sunlight, drought, wind, and frost. See ASTM E2400-06, Guide for Selection, Installation and Maintenance of Plants for Green (Vegetated) Roof Systems.

Courtesy of WVDEP

References to ASTM International. 2006. Standard Guide for selection, installation and maintenance of green roof systems are available online: http://www.astm.org/.

6.8.9 Construction Guidelines

Given the diversity of extensive vegetated roof designs, there is no typical step-by-step construction sequence for proper installation. The following general construction considerations are noted:

- Ensure the roof deck has the appropriate slope and material.
- Install the waterproofing method according to manufacturer's specifications.

- Conduct a flood test to ensure the system is water tight by placing at least 2 inches of water over the membrane for 48 hours to confirm the integrity of the waterproofing system.
- Add additional system components (e.g., insulation, root barrier, drainage layer and interior drainage system, and filter fabric), taking care not to damage the waterproofing. Drain collars and protective flashing should be installed to ensure free flow of excess stormwater.
- The growing media should be mixed prior to delivery to the site. Media should be spread evenly over the filter fabric surface. The growing media should be covered until planting to prevent weeds from growing. Sheets of exterior grade plywood can also be laid over the growing media to accommodate foot or wheelbarrow traffic. Foot traffic and equipment traffic should be limited over the growing media to reduce compaction.
- The growing media should be moistened prior to planting, and then planted with the ground cover and other plant materials, per the planting plan, or in accordance with ASTM E2400. Plants should be watered immediately.
- It generally takes 12 to 18 months to fully establish a vegetated roof. An initial fertilization using slow release fertilizer (e.g., 14-14-14) with adequate minerals is often needed to support growth. Temporary watering may also be needed during the first summer, if drought conditions persist. Hand weeding is also critical in the first two years .
- Most construction contracts should contain a care and replacement warranty that specifies a 75% minimum survival after the first growing season off species planted and a minimum effective vegetative ground cover of 75% for flat roofs and 90% for pitched roofs.

Inspections during construction are needed to ensure that the vegetated roof is built in accordance with these specifications. Detailed inspection checklists should be used that include sign-offs by qualified individuals at critical stages of construction and confirm that the contractor's interpretation of the plan is consistent with the intent of the designer and/or manufacturer.

An experienced installer should be retained to construct the vegetated roof system. The vegetated roof should be constructed in sections for easier inspection and maintenance access to the membrane and roof drains. Careful construction supervision is needed during several steps of Vegetated Roof installation, as follows:

- Placement of the waterproofing layer, to ensure that it is properly installed and watertight.
- Placement of the drainage layer and drainage system.
- Placement of the growing media, to confirm that it meets the specifications and is applied to the correct depth.
- Installation of plants, to ensure they conform to the planting plan.
- Issuing use and occupancy approvals.
- At the end of the first or second growing season, to ensure desired surface cover specified in the care and replacement warranty has been achieved.

6.9.8 Maintenance

All facility components, including plant material, growing medium, filter fabric, drainage layer, waterproof membranes, and roof structure should be inspected for proper operations, integrity of the waterproofing, and structural stability throughout the life of the green roof. Table 6-9.3 provides recommended guidelines for the maintenance of green roofs.

Table 6-9.3: Green Roof Maintenance Guidelines

Activity	Schedule
▪ Roof drains should be cleared when soil substrate, vegetation, debris or other materials clog the drain inlet. Sources of sediment and debris may be identified and corrected. ▪ Plant material should be maintained to provide 90% plant cover. Weeding should be manual with no herbicides or pesticides used. Weeds should be removed regularly. ▪ Irrigation can be accomplished either through hand watering or automatic sprinkler systems if necessary during the establishment period.	As needed
▪ Growing medium should be inspected for evidence of erosion from wind or water. If erosion channels are evident, they can be stabilized with additional growth medium similar to the original material.	Quarterly
▪ Inspect drain inlet pipe and containment system. ▪ Test growing medium for soluble nitrogen content.	Annually
▪ Fertilize plant material.	As Needed
▪ Maintain a record of all inspections and maintenance activity.	Ongoing

Fertilization should be minimized. Fertilization should be applied according to soil test in order to maintain soluble nitrogen (nitrate and ammonium ion) levels between one (1) and four (4) ppm. The best source of nutrients for fertilization is mature compost.

During the plant establishment period, a maintenance staff should conduct three (3) to four (4) visits per year to perform basic weeding, fertilization, and in-fill planting. Thereafter, only two annual visits for inspection and light weeding should be required (irrigated assemblies will require more intensive maintenance).

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Rainwater Harvesting

6.10 Rainwater Harvesting

6.10.1 Device Description

Rainwater harvesting systems intercept, divert, store and release rainfall for future use. Because rooftop runoff is relatively free of pollutants, the water can later be used in landscaping and other non-potable applications. The capture and reuse of rainwater can reduce stormwater runoff volumes and pollutant loads. By providing a reliable and renewable source of water to end users, rainwater harvesting systems can also have environmental and economic benefits beyond stormwater management. Rainwater that falls on a rooftop is collected and conveyed into an above- or below-ground storage tank where it can be used for non-potable water uses and on-site stormwater infiltration or treatment.

Rain harvesting systems range from a rain barrel, Figure 6-10.1, to a cistern, Figure 6-10.2, up to a tank that can hold several thousand of gallons of rainwater.

Courtesy of Philadelphia Stormwater Manual V 2.0

Figure 6-10.1
Rain Barrel

6.10.2 Key Elements

- Storage devices designed to capture a portion of small, frequent storm events.
- Systems must provide for overflow or bypass of large storm events.
- Placement of storage elements higher than areas where water will be reused may reduce or eliminate pumping needs.
- For effective stormwater control, water must be used or discharged before the next storm event.
- Most effective when designed to meet a specific water need for reuse.

Courtesy of Stormsver.com

Figure 6-10.2
Cistern

6.10.3 Device Uses and Applicability

Potential applications for rainwater harvesting:

- Residential
- Commercial
- Urban
- Industrial
- Redevelopment

Rainwater harvesting address:

- Volume reduction
- Channel protection
- Storm event peak discharge

6.10.4 Rain Barrels, Cisterns, and Tanks in the Urban Landscape

Rain barrels, cisterns, and other tanks are storage devices meant to promote detention of small volumes of stormwater runoff. Collectively, these systems can be effective at preventing large volumes of stormwater from entering the sewer system The design of these systems is flexible, because there are many ways to capture and reuse stormwater. The application and use of rain barrels, cisterns, or other tank storage systems are not limited to the examples provided below.

Figure 6-10.3
Residential Rain Barrels

Rain Barrels on Individual Homes

The most common use of rain barrels is connection of one roof leader (downspout) to a single barrel on a residential property. Stored water can be used for lawn and garden watering. Barrels can either be purchased or can be built by the homeowner, see Figure 6-10.3. They are ideal for gardeners and concerned citizens who want to manage stormwater without a large initial investment. They are also an easy retrofit.

Figure 6-10.4
Rainwater Tank System

Large Surface Tanks

Surface tanks may be larger tan rain barrels but serve the same function. They can be integrated into commercial sites or homes where a significant water need exists. They may drain by gravity or be pumped.

Subsurface Storage and Water Reuse

Subsurface systems can be larger and more elaborate than rain barrels, see Figure 6-10-4. These systems are typically pumped and may be used to supply water to a variety of reuse applications. Because the cisterns are below the surface, they do not interfere with the landscape. These systems have higher initial costs than rain barrels and are appropriate for commercial and residential applications.

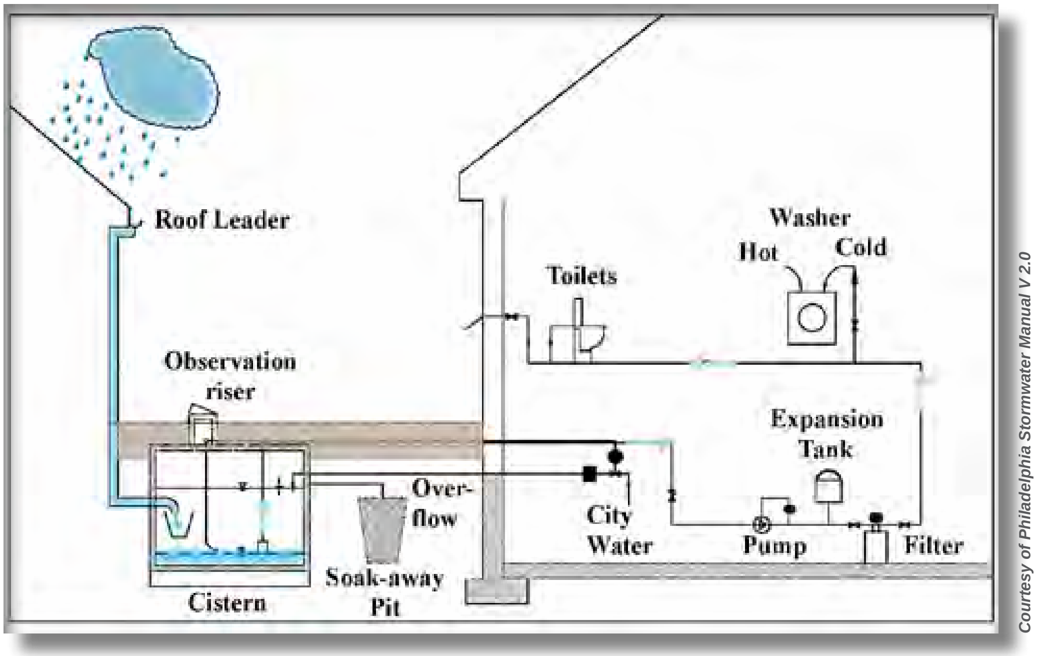
Figure 6-10.5
Fountain at Clay Center

Water Features in Public and Institutional Landscapes

Architectural designs have incorporated water storage into site design. Features such as water fountains and ponds capture stormwater from design storms to provide water sources for these landscape features. Figure 6-10.5 shows the water feature created at the Clay Center, which capture runoff and integrate it into the fountain.

Reusing Stormwater for Indoor Use

Roof runoff can be captured and stored for reuse in washing machines and for showering purposes if properly filtered, treated, and tested. Roof runoff used in toilets does not need to meet potable water standards. A rain barrel or cistern can be directly connected to the plumbing of a residential or commercial site; however, plumbing for non-potable rainwater reuse should be separate from potable plumbing.



Courtesy of Philadelphia Stormwater Manual V 2.0

Figure 6-10.6
Rainwater Reuse Detail

6.10.5 Recommended Design and Installation Procedures

Rainwater harvesting design is only limited by the complexity of the system one decides to use. There are many designs and techniques to consider. The following are some of the means for design and installation.

Rain Barrels

Rain barrels are used primarily in residential application and there are several sizes, shapes and types available. There are several sources to obtain information on rain barrels including but not limited to:

- Homeowner's Guide in Appendix A of this manual.
- The City's Stormwater Department offers classes on installation and maintenance of rain barrels.
- "How to Build and Install a Rain Barrel" West Virginia Department of Environmental Protection, http://www.dep.wv.gov/insidedep/Pages/rainbarrel.aspx
- "Rain Barrels" Prince George's County Department of Environmental Resources, http://www.princegeorgescountymd.gov/sites/StormwaterManagement/Resources/BMP/Documents/6_Guidelines%20for%20Rain%20Barrels.pdf
- "Rain Barrels and Cisterns" Low Impact Development Center. 2005. Website: http://www.lid-stormwater.net/index.html

Rainwater Harvesting for Large Applications

The West Virginia Department of Environmental Protection has collected extensive information on rainwater harvesting. The City has decided to refer to WVDEP materials for guidelines on rainwater harvesting. The West Virginia Stormwater Management and Design Guidance Manual provides details for a more efficient and effective rainwater collection system. The information can be located on the WVDEP website at - http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/Pages/StormwaterManagementDesignandGuidanceManual.aspx

6.10.6 Infiltration Credit

Post-Construction Stormwater Management, located in Section 2.3.4 requires the first one (1) inch of rainfall to be managed. See Table 6-10.1 for credit guidelines.

Table 6-10.1: Water Harvesting Credit

Credit	Description	Application
Design Volume credit up to 100% is possible if all water from storms with rainfall of 1 inch or less is used through demand, and the tank is sized such that no overflow from this size storm event occurs.	Standard Design -- • Year-round use of stored water and/or downstream secondary runoff reduction practice to manage drawdown and overflow from the tank. • System components as per the specification.	Usually sites with substantial rooftop areas and defined beneficial uses for the stored water. Small-scale (e.g., residential, small-scale commercial) applications are also possible if there are defined outdoor and/or indoor uses of the water.

6.10.7 Maintenance

As with other stormwater management practices (BMPs), these stormwater storage systems require regular maintenance to ensure a prolonged life. Table 6-10.2 describes the minimum maintenance requirements for rainwater harvesting.

Table 6-10.2: Rainwater Harvesting Maintenance Guidelines

Activity	Schedule
Occasional cleaning may be necessary to remove debris, such as leaves, coming off the drainage area. Flush cisterns to remove sediment. Brush the inside surfaces and thoroughly disinfect.	As needed
To avoid structural damage, the rain barrel should be drained prior to freezing weather.	Annually
Maintain records of all inspections and maintenance activity.	Ongoing

6.11 Permeable Pavement

6.11.1 Device Description

Permeable pavement is a porous surface with an underlying stone reservoir that temporarily stores surface runoff before infiltrating into the subsoil. This porous surface replaces traditional pavement, illustrated in Figure 6-11.1, allowing parking lot runoff to infiltrate directly into the soil and receive water quality treatment. There are several permeable pavement options, including interlocking pavers, asphalt, and concrete. Porous asphalt and pervious concrete appear the same as traditional pavement from the surface, but are manufactured without "fine" materials, and contain void spaces to allow infiltration. Pavers are concrete or clay interlocking blocks or synthetic fibrous grid systems with open areas designed to allow stormwater to permeate the void areas.

Figure 6-11.1
Permeable Pavers for Overflow Parking

Because permeable pavement systems are used to promote infiltration of stormwater runoff, this technique is very effective in removing pollutants and reducing the volume of stormwater entering a conventional stormwater management system. During a rain event, stormwater flows through the porous surface, drains into the crushed stone subbase beneath the pavement, and remains stored until stormwater can infiltrate into the soil.

Pavement disconnection (see impervious surface disconnection, Section 6-12) can be achieved by directing stormwater runoff to pervious areas allowing for infiltration thereby increasing the time of concentration. Pavement disconnection is appropriate for small or narrow pavement structures such as sidewalks, driveways, pathways and low-traffic alleys or side streets.

Pavement is considered disconnected if it meets the following criteria:

- The contributing flow path over impervious cover is no more than 75 feet
- The length of overland flow over pervious area is greater than or equal to the contributing length
- The soil is not designated as a hydrologic soil group D or equivalent
- The slope of the contributing impervious area is 5% or less

6.11.2 Key Elements

- Pervious structural surface with high infiltration rate.
- Porous surface and stone sub-base suitable for design traffic loads. Can be used on most travel surfaces with slopes less than 5%.
- Uncompacted, level sub-grade allows infiltration of stormwater.
- Open-graded aggregate sub-base provides storage.
- Additional storage and control structures can be incorporated to meet channel protection and flood control.
- Positive overflow prevents system flooding

6.11.3 Device Uses and Applicability

Potential applications for porous pavement include:

- Parking lots
- Sidewalks
- Driveways
- In low traffic alleys and side streets for infiltrating and controlling stormwater runoff

6.11.4 Permeable Pavement in the Urban Landscape

Permeable pavement systems are used to promote infiltration of stormwater runoff. This technique is very effective in removing pollutants and reducing the volume of stormwater entering a sewer system. During a rain event, stormwater flows through the porous surface, drains into the crushed stone subbase beneath the pavement, and remains stored until stormwater can infiltrate into the soil. Porous asphalt and concrete mixes are similar to their impervious counterparts, but do not include the finer grade particles. Interlocking pavers have openings that are filled with stone to create a porous surface.

Permeable pavement systems are suitable for most developments. They are especially well suited for parking lots, walkways, sidewalks, basketball courts, and playgrounds. Proper training of maintenance staff will help to prolong the life of the system.

Alternate for Paved Surfaces

Almost any surface that is traditionally paved with an impervious surface can be converted to a porous pavement system. Porous surfaces are particularly useful in high density areas where there is limited space for other stormwater management systems. Porous pavement can be used for parking lots, basketball courts, playgrounds, and plazas. Interlocking porous pavers can be used to provide an interesting aesthetic alternative to traditional paving. Porous pavement can be designed to meet the loading requirements for most parking lots and travel surfaces. However, for lots or loading areas that receive a high volume of heavy traffic, porous pavement can be used for parking stalls and conventional asphalt for travel lanes if the impervious surfaces are graded toward the porous surfaces.

Direct Connection of Roof Leaders and/or Inlets

The subbase storage of permeable pavement systems can be designed with extra capacity, and roof leaders and inlets from adjacent impervious areas can be tied into the subbase to capture additional runoff. These beds can be sized to accommodate runoff from rooftops via direct connection or to supplement other BMPs. Pretreatment may be necessary to prevent particulate materials from these surfaces from clogging the subbase of the porous pavement system. If roof leaders or inlets are connected into the bed, the porous asphalt cannot be considered disconnected and a positive overflow must be provided.

Direction of Impervious Runoff to Porous Pavement

Adjacent impervious surfaces can be graded so that the flow from the impervious area flows over the porous pavement and into the subbase storage below if sufficient capacity is created. If impervious runoff is directed onto porous pavement, it cannot be considered disconnected and a positive overflow must be provided.

6.11.5 Components of Permeable Pavement System

Different permeable surfaces are used for permeable pavement systems, but all rely on the same primary components:

- Inflow/Surfacing
  - Porous Concrete
  - Porous Asphalt
  - Permeable Pavers
  - Reinforced Turf
- Storage
- Positive Overflow
- Underdrain

- Inflow/Surfacing

There are many different types of structural surfaces that allow water to flow through void spaces in the surface. Any of these alternatives serve as a form of conveyance and filtration for the storage bed below. Several of the most commonly used porous structural surfaces are described below, but this does not represent a list of the porous surfaces appropriate for stormwater management applications.

- Porous Concrete

Porous concrete was developed by the Florida Concrete Association and has seen the most widespread application in Florida and other southern areas. Like porous asphalt, porous concrete is produced by substantially reducing the number fines in the mix in order to establish voids for drainage. Porous concrete has a coarser appearance than its conventional counterpart as shown in Figure 6-11.2.

Figure 6-11.2
Porous Concrete

- Porous Asphalt

Porous asphalt pavement was first developed in the 1970s and consists of standard bituminous asphalt in which the fines have been screened and reduced, allowing water to pass through very small voids. Recent research in open-graded mixes for highway application has led to additional improvements in porous asphalt through the use of additives and binders. Porous asphalt is very similar in appearance to conventional, impervious asphalt, as shown in Figure 6-11.3.

Courtesy of Philadelphia Stormwater Manual V 2.0

Figure 6-11.3
Porous Asphalt

- Permeable Pavers

Permeable pavers are interlocking units (often concrete) with openings that can be filled with a pervious material such as gravel. These units are often very attractive and are especially well suited to plazas, patios, small parking areas, etc. There are also plastic grids that can be filled with gravel to create a fully gravel surface that is not as susceptible to rutting and compaction as traditional gravel lots. Gravel used in interlocking concrete pavers or plastic grid systems must be well-graded to ensure permeability as shown in Figure 6-11.4.

- Reinforced Turf

  Reinforced turf consists of interlocking structural units with openings that can be filled with soil for the growth of turf grass and are suitable for traffic loads and parking as shown in Figure 6-11.5. They are often used in overflow or event parking. Reinforced turf grids are made of concrete or plastic and are underlain by a stone and/or a sand drainage system for stormwater management. While both plastic and concrete units perform well for stormwater management and traffic needs, plastic units may provide better turf establishment and longevity, largely because the plastic will not absorb water and diminish soil moisture conditions.

Figure 6-16.4
Permeable Pavers

Figure 6-16.5
Reinforced Turf

- Storage

  In addition to distributing mechanical loads, coarse aggregate laid beneath porous surfaces is designed to store stormwater prior to infiltration into soils. The aggregate is wrapped in a non-woven geotextile to prevent migration of soil into the storage bed and resultant clogging. The storage bed also has a choker course of smaller aggregate to separate the storage bed from the surface course. The storage bed can be designed to manage runoff from areas other than the porous surface above it, or can be designed with additional storage and control structures that meet the channel protection requirements and/or meet the flood control requirements.

- Positive Overflow

  Positive overflow must be provided for porous pavement systems that manage runoff from additional impervious surfaces. Positive overflow conveys runoff from larger storms out of the system and prevents flooding. A perforated pipe system can convey water from the storage bed to an outflow structure. The storage bed and outflow structure can be designed to control the channel protection and/or flood control requirement. Inlets can be used to provide positive overflow if additional rate control is not necessary.

- Underdrain

  An underdrain is a perforated pipe that collects water at the bottom of the system and conveys it to the system outlet. Underdrains eliminate most infiltration because they provide a preferential pathway for flow. A sand layer or gravel filter should surround the underdrain to filter sediment and facilitate flow to the underdrain. If a sand layer is used, the underdrain should be surrounded by a non-woven filter fabric to prevent clogging. If soil test determines that the water cannot infiltrate with 48 hours, an underdrain is necessary.

6.11.6 Recommended Design Procedures

Design of permeable pavement systems is somewhat flexible as shown in Figure 6-11.6. The area and shape are dependent on the site design and selection of the surface material is dependent on intended site uses and desired appearance. The depth of the stone base can be adjusted depending on the management objectives, total drainage area, traffic load, and soil characteristics. The following design procedures are general guidelines to ensure proper design:

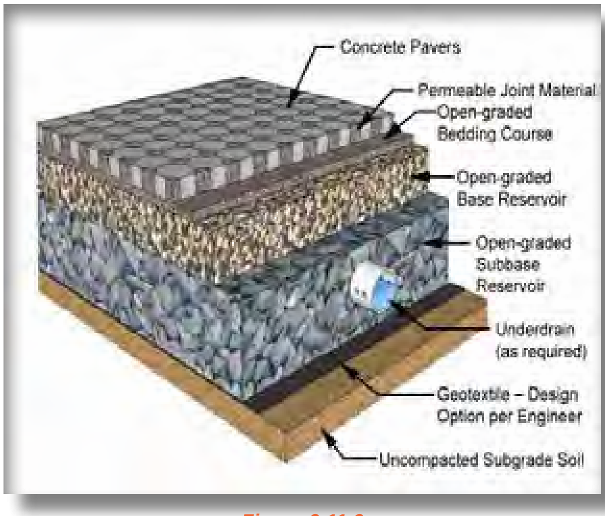


Figure 6-11.6
Design Cross-section of Permeable Pavers

1. Evaluate the site for infiltration design consideration, included in Section 4.2.4 of the WVDEP Stormwater Management and Design Guidance Manual. These considerations include available space, site topography, pavement section bottom slope, external drainage area, water table, soils, hotspots, high traffic or high pollutant loading conditions, high speed roads, floodplains, setbacks, proximity to utilities and community factors.

2. Geotechnical investigation is necessary to detect the soil infiltration rate. Infiltration testing must be within 25 feet of the infiltration footprint.

3. Infiltration practices should not be hydraulically connected to structure foundations in order to avoid harmful seepage. Setbacks to structures vary based on the contributing drainage area of the infiltration practice. The following can be used as guidelines:
   - 250 to 1,000 square feet = 5 feet if down-gradient from building; 25 feet if up-gradient.
   - 1,000 to 10,000 square feet = 10 feet if down-gradient from building; 50 feet if up-gradient.
   - More than 10,000 square feet = 25 feet if down-gradient from building; 100 feet if up-gradient

   In some cases, the use of an impermeable liner along the sides of the Permeable Pavement practice (extending from the surface to the bottom of the reservoir layer) may be used as an added precaution against seepage, and the setback requirements can be relaxed.

4. If the discharge is concentrated at one or more discrete points, no more than 1,000 sf may be discharged to any point. In addition, a gravel strip or other spreading device is required for concentrated discharges. For non-concentrated discharges along the entire edge of pavement, this requirement is waived; however, there must be provisions for the establishment of vegetation along the pavement edge and temporary stabilization of the area until vegetation becomes established.

5. Estimate the total storage volume and adjust area and/or depths as needed to provide required storage. Assume a porosity of 40% for AASHTO No 57 stone.

6. Design system with a level bottom; use a terraced system on slopes.

7. Using infiltration area and the saturated vertical infiltration rate of the native soil, estimate how long the surface ponding and soil storage will take to drain. The maximum drain down time for the entire storage volume is 48 hours. If storage does not drain in this time, adjust aggregate depth and/or surface area.

8. Consider an underdrain for systems that manage runoff from surrounding impervious areas:

9. Design distribution and overflow piping to minimize chance of clogging.

10. Check that any release rate requirements (including release through any underdrain) are met by the system as designed.

6.11.7 Infiltration Credit

Post-Construction Stormwater Management, located in Section 2.3.4 requires the first one (1) inch of rainfall to be managed. See Table 6-11.1 for credit guidelines.

Table 6-11.1: Permeable Pavement Credit

Credit	Description	Application
45% volume reduction for the Design Volume of the practice[1]	Basic Design - • Underdrain design • Depth of reservoir layer (above underdrain) • No infiltration sump below underdrain pipe(s)	• Sites with poor soils or constructed on fill material; • Constraints such as high bedrock or water table, stormwater hotspot, or other applications that require an impermeable liner.
100% volume reduction for the Design Volume of the practice[1]	Infiltration Design: • No underdrain • Depth of reservoir layer • Water infiltrates into the underlying soil within 48 hours	• Sites with permeable soils; confirmed infiltration rates ≥ 0.5 in./hr
• 100% volume reduction for the part of the Design Volume contained in the sump[1] • 45% volume reduction for the part of the Design Volume in the reservoir layer (above and including the underdrain)[1].	Infiltration Sump Design: • Underdrain • Depth of reservoir layer (above underdrain) • Sump below underdrain sized to drain within 48 hours (based on confirmed infiltration rate)	• Sites with marginal soils • Sites with permeable soils where an underdrain is preferred

[1] Design Volume includes storage within the stone reservoir below the pavement surface, including the volume of the infiltration sump, if used. The Design Volume can be 100% of that needed to meet the 1-inch performance standard for the contributing drainage area ("Target Treatment Volume") or some proportion of it when used in conjunction with other practices.

[2] Sump depth and volume based on ability to fully drain within 48 hours based on confirmed infiltration rate.

For information on qualifying design details look at the Section 4.2.4.- PP-2 Permeable Paver in the WVDEP Guidance Manual at; http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/Pages/StormwaterManagementDesignandGuidanceManual.aspx

6.11.7 Materials

The following materials in Table 6-11.2 will provide the project with efficient and effective infiltration.

Table: 6-11.2: Material Specifications

Material	Specification	Notes
Permeable Pavement Types		
Permeable Interlocking Concrete Pavers (PICP)	Surface open area: 5% to 15%. Thickness: 3.125 inches for vehicles. Compressive strength: 55 Mpa. Open void fill media: aggregate	This provides an attractive surface cover that can suppress weed growth.
Concrete Grid Pavers	Open void content: 20% to 50%. Thickness: 3.5 inches. Compressive strength: 35 Mpa. Open void fill media: aggregate, topsoil and grass, coarse sand.	Must conform to ASTM C1319 specifications. Reservoir layer required to support the structural load.
Plastic Reinforced Grid Pavers	Void content: depends on fill material. Compressive strength: varies, depending on fill material. Open void fill media: aggregate, topsoil and grass, coarse sand.	Reservoir layer required to support the structural load.
Pervious Concrete	Void content: 15% to 25 %. Thickness: typically 4 to 8 inches. Compressive strength: 2.8 to 28 Mpa.	May not require a reservoir layer to support the structural load, but a layer may be included to increase the storage or infiltration.
Porous Asphalt	Void content: 15% to 20 %. Thickness: typically 3 to 7 in. (depending on traffic load).	Reservoir layer required to support the structural load.
Material Specification for underneath the pavement surface		
Bedding Layer	2 in. depth of No. 8 stone over 3 to 4 inches of No. 57 stone 2 in. depth of No. 8 stone	ASTM D448 size No. 8 stone (e.g., 3/8 to 3/16 inch in size). Should be double-washed and clean and free of all fines.
Reservoir Layer	No. 2, 3, or 4 stone subbase No. 57 stone No. 2 stone	ASTM D448 size No. 57 stone (e.g. 1- 1/2 to 1/2 inch in size); No. 2 Stone (e.g. 3 inch to 3/4 inch in size). Depth is based on the pavement structural and hydraulic requirements. Should be double-washed and clean and free of all fines.
Underdrain	Use 4 to 6 inch diameter perforated PVC pipe (or equivalent corrugated HDPE may be used for smaller load-bearing applications), with 3/8-inch perforations at 6 inches on center. Perforated pipe installed for the full length of the Permeable Pavement cell, and non-perforated pipe, as needed, is used to connect with the storm drain system. Ts and Ys installed as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps at the Ts and Ys.	
Infiltration Sump (optional)	An aggregate storage layer below the underdrain invert. The depth of the reservoir layer above the invert of the underdrain must be at least 12 inches. The material specifications are the same as reservoir layer	
Non-woven Geotextile (optional)	AASHTO M288-06 Paving Fabrics Survivability Classes (1) and (2)	

Material	Specification	Notes
Non-woven Geotextile (optional)	Use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd. nonwoven geotextile. Note: This is used only in fill soils as determined by a geo-technical investigation	
Non-woven Geotextile (optional)	Use a perforated 4 to 6 inch vertical PVC pipe (AASHTO M 252) with a lockable cap, installed flush with the surface or just beneath PICP.	

Courtesy of WVDEP

6.11.9 Construction Guidelines

Given the diversity of extensive permeable pavement designs, there is no typical step-by-step construction sequence for proper installation. The following general construction considerations are noted:

Erosion and Sediment Controls

The following erosion and sediment control guidelines must be followed during construction:

Permeable pavement areas should be clearly marked on all construction documents and grading plans.

- Any area of the site intended ultimately to be a permeable pavement area should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment.
- If adjacent pervious (turf or landscaped areas) are designed to drain to permeable pavement, the permeable pavement areas should be fully protected from sediment intrusion by silt fence.
- During and immediately after construction of the permeable pavement, care should be taken to avoid tracking sediments onto any permeable pavement surface to avoid clogging.
- Any area of the site intended ultimately to be a permeable pavement area should generally not be used as the site of a temporary sediment basin. Where locating a sediment basin on an area intended for permeable pavement is unavoidable, the invert of the sediment basin must be a minimum of 2 feet above the final design elevation of the bottom of the aggregate reservoir course. All sediment deposits in the excavated area should be carefully removed prior to installing the sub-base, base and surface materials.

Permeable Pavement Installation

The following is a typical construction sequence to properly install permeable pavement, which may need to be modified depending on the specific variant of permeable pavement that is being installed.

Step 1. Construction of the permeable pavement shall only begin after the entire contributing drainage area has been stabilized. The proposed site should be checked for existing utilities prior to any excavation. Do not install the system in rain or snow, and do not install frozen aggregate materials.

Step 2. As noted above, temporary erosion and sediment controls are needed during installation to divert stormwater away from the permeable pavement area until it is completed. Special protection measures such as erosion control fabrics may be needed to protect vulnerable side slopes from erosion during the excavation process. The proposed permeable pavement area must be kept free from sediment during the entire construction process. Construction materials contaminated by sediments must be removed and replaced with clean materials.

Step 3. Where possible, excavators or backhoes should work from the sides to excavate the reservoir layer to its appropriate design depth and dimensions. For small pavement applications, excavating equipment should have arms with adequate extension so they do not have to work inside the footprint of the permeable pavement area (to avoid compaction). Contractors can utilize a cell construction approach, whereby the proposed permeable pavement area is split into 500 to 1000 sq. ft. temporary cells with a 10 to 15 foot earth bridge in between, so cells can be excavated from the side. Excavated material should be placed away from the open excavation so as to not jeopardize the stability of the side walls.

Step 4. The native soils along the bottom of the permeable pavement system should be scarified or tilled to a depth of 3 to 4 inches prior to the placement of stone. In large scale paving applications with weak soils, the soil subgrade may need to be compacted to 95% of the Standard Proctor Density to achieve the desired load-bearing capacity. (NOTE: This effectively eliminates the infiltration function of the installation, and it must be addressed during hydrologic design).

Step 5. Filter fabric should be placed as required by the design. This is typically only on the sides of the reservoir layer. Filter fabric should never be placed below the reservoir stone layer. In some cases, an impermeable layer. Impermeable liner material should be installed in accordance with the manufacturer's instructions with regard to seams, overlap, sides, etc.

Step 6. Provide a minimum of 2 inches of aggregate above and below the underdrains. The underdrains you should slope down toward the outlet at a grade of 0.5% or steeper. The up-gradient end of underdrains in the reservoir layer should be capped. Where an underdrain pipe is connected to a structure, there shall be no perforations within 1 foot of the structure. Ensure there are no perforations in clean-outs and observation wells within 1 foot of the surface.

Step 7. Moisten and spread 6-inch lifts of the appropriate clean, washed stone aggregate (usually No. 2 or No. 57 stone). Place at least 4 inches of additional aggregate above the underdrain, and then compact it using a vibratory roller in static mode until there is no visible movement of the aggregate. Do not crush the aggregate with the roller.

Step 8. Install the desired depth of the bedding layer, depending on the type of pavement, as follows:

- Pervious Concrete: No bedding layer is used.
- Porous Asphalt: The bedding layer for Porous Asphalt pavement consists of 1 to 2 inches of clean, washed ASTM D 448 No.57 stone.
- Permeable Interlocking Concrete Pavers: The bedding layer for open-jointed pavement blocks should consist of 2 inches of washed ASTM D 448 No.8 stone.

Step 9. Paving materials shall be installed in accordance with manufacturer or industry specifications for the particular type of pavement.

- **Installation of Interlocking Pavers.** The following installation method also applies to clay paving units. Contact manufacturers of composite units for installation specifications.
  - Moisten, place and level the No. 2 stone subbase and compact it in minimum 12 inch thick lifts with four passes of a 10-ton steel drum static roller until there is no visible movement. The first two passes are in vibratory mode with the final two passes in static mode. The filter aggregate should be moist to facilitate movement into the reservoir course.
  - Place edge restraints before the base layer, bedding and pavers are installed. Permeable interlocking pavement systems require edge restraints to prevent vehicle loads from moving the pavers. Edge restraints may be standard concrete curbs or curb and gutters.
  - Moisten, place and level the No. 57 base stone in a single lift (4 inches thick). Compact it into the reservoir course beneath with at least four (4) passes of a 10-ton steel drum static roller until there is no visible movement. The first two passes are in vibratory mode, with the final two passes in static mode.
  - Place and screed the bedding course material (typically No. 8 stone, 2 inches thick).
  - Pavers may be placed by hand or with mechanical installers.
  - Fill gaps at the edge of the paved areas with cut pavers or edge units. When cut pavers are needed, cut the pavers with a paver splitter or masonry saw. Cut pavers no smaller than one-third (1/3) of the full unit size if subject to tires.

- Fill the joints and openings with stone. Joint openings must be filled with No. 8, 89 or 9 stone per the paver manufacturer's recommendation. Sweep and remove excess stones from the paver surface.
- Compact and seat the pavers into the bedding course with a minimum low-amplitude 5,000 lbf, 75- to 95 Hz plate compactor. Do not compact within 6 feet of the unrestrained edges of the pavers.
- Thoroughly sweep the surface after construction to remove all excess aggregate.
- Inspect the area for settlement. Any paving units that settle must be reset and inspected.
- The contractor should return to the site within 6 months to top up the paver joints with stones.

- **Installation of Porous Asphalt.** The following has been excerpted from various documents, most notably Jackson (2007).
  - Install Porous Asphalt pavement similarly to regular asphalt pavement. The pavement should be laid in a single lift over the filter course. The laying temperature should be between 230ºF and 260ºF, with a minimum air temperature of 50ºF, to ensure the surface does not stiffen before compaction.
  - Complete compaction of the surface course when the surface is cool enough to resist a 10-ton roller. One or two passes of the roller are required for proper compaction. More rolling could cause a reduction in the porosity of the pavement.
  - The mixing plant must provide certification of the aggregate mix, abrasion loss factor, and asphalt content in the mix. Test the asphalt mix for its resistance to stripping by water using ASTM 1664. If the estimated coating area is not above 95%, additional anti-stripping agents must be added to the mix.
  - Transport the mix to the site in a clean vehicle with smooth dump beds sprayed with a non-petroleum release agent. The mix shall be covered during transportation to control cooling.
  - Test the full permeability of the pavement surface by application of clean water at a rate of at least five gallons per minute over the entire surface. All water must infiltrate directly, without puddle formation or surface runoff.
  - Inspect the facility 18 to 30 hours after a significant rainfall (greater than 1/2 inch) or artificial flooding, to determine the facility is draining properly.
- **Installation of Pervious Concrete.** The basic installation sequence for pervious concrete is outlined by the American Concrete Institute (2008). It is strongly recommended that concrete installers successfully complete a recognized Pervious Concrete installers training program, such as the Pervious Concrete Contractor Certification Program offered by the National Ready Mixed Concrete Association (NRMCA). The basic installation procedure is as follows:
  - Drive the concrete truck as close to the project site as possible.
  - Water the underlying aggregate (reservoir layer) before the concrete is placed, so the aggregate does not draw moisture from the freshly laid Pervious Concrete.
  - After the concrete is placed, approximately 3/8 to 1/2 inch is struck off, using a vibratory screed. This is to allow for compaction of the concrete pavement.
  - Compact the pavement with a steel pipe roller. Care should be taken to ensure over-compaction does not occur.
  - Cut joints for the concrete to a depth of 1/4 inch.
  - The curing process is very important for pervious concrete. Cover the pavement with plastic sheeting within 20 minutes of the strike-off, and keep it covered for at least seven (7) days. Do not allow traffic on the pavement during this time period.
  - Remove the plastic sheeting only after the proper curing time. Inspect the facility 18 to 30 hours after a significant rainfall (greater than 1/2 inch) or artificial flooding, to determine the facility is draining properly.

Construction Inspection

Inspections before, during and after construction are needed to ensure permeable pavement is built in accordance with these specifications. Use detailed inspection checklists that require sign-offs by qualified individuals at critical stages of construction, to ensure the contractor's interpretation of the plan is consistent with the designer's intent. Some common pitfalls can be avoided by careful construction supervision that focuses on the following key aspects of Permeable Pavement installation:

- Store materials in a protected area to keep them free from mud, dirt, and other foreign materials.
- The CDA should be stabilized prior to directing water to the permeable pavement area.
- Check the aggregate material to confirm it is clean and washed, meets specifications and is installed to the correct depth.
- Check elevations (e.g., the invert of the underdrain, inverts for the inflow and outflow points, etc.) and the surface slope.
- Make sure the Permeable Pavement surface is even, runoff evenly spreads across it, and the storage bed drains within 48 hours.
- Ensure caps are placed on the upstream (but not the downstream) ends of the underdrains.
- Inspect the pretreatment structures (if applicable) to make sure they are properly installed and working effectively.
- Once the final construction inspection has been completed, log the GPS coordinates for each facility and submit them for entry into the local BMP maintenance tracking database.

It may be advisable to divert the runoff from the first few runoff-producing storms away from larger permeable pavement applications, particularly when up-gradient conventional asphalt areas drain to the permeable pavement. This can help reduce the input of fine particles often produced shortly after conventional asphalt is laid down.

6.11.8 Maintenance

Maintenance is a crucial element to ensure the long-term performance of permeable pavement. The most frequently cited maintenance problem is surface clogging caused by organic matter and sediment. Periodic street sweeping will remove accumulated sediment and help prevent clogging; however, it is also critical to ensure that surrounding land areas remain stabilized.

The following tasks must be avoided on ALL permeable pavements:

It is difficult to prescribe the specific types or frequency of maintenance tasks that are needed to maintain the

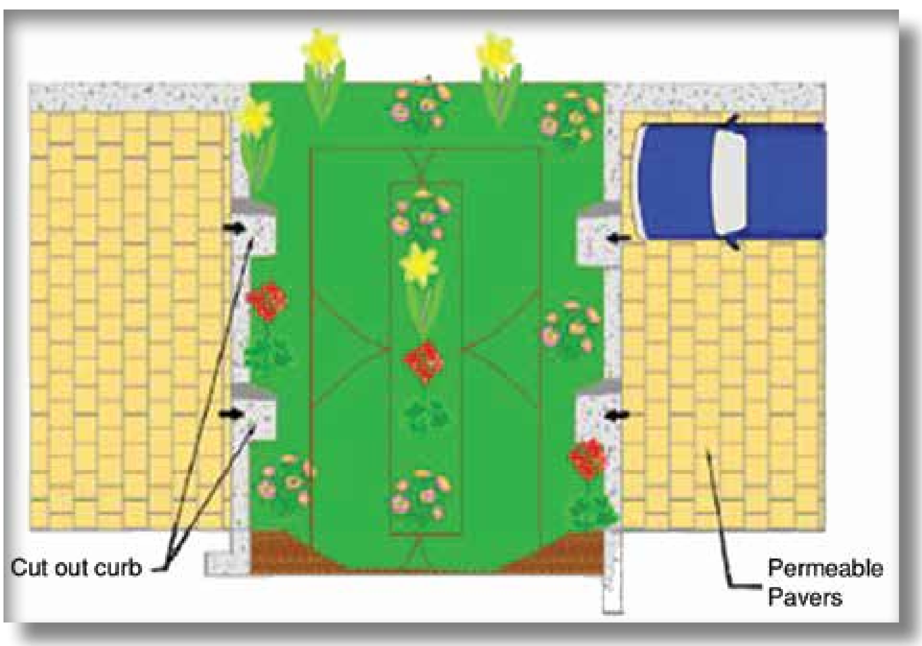
- sanding
- re-sealing
- re-surfacing
- power washing
- storage of snow piles containing sand
- storage of mulch or soil materials
- construction staging on unprotected pavement

hydrologic function of permeable pavement systems over time. The frequency of maintenance will depend largely on the pavement use, traffic loads, and the surrounding land use. One preventative maintenance task for large-scale applications involves vacuum sweeping on a frequency consistent with the use and loadings encountered in the parking lot. Many consider an annual, dry-weather sweeping in the spring months to be important. The contract for sweeping should specify that a vacuum sweeper be used that does not use water spray, since spraying may lead to subsurface clogging. As with most BMPs, porous pavement systems require regular maintenance to extend their life. Table 6-11.3 describes maintenance recommendations for porous pavement systems.

Table 6-11.3: Porous Pavement Maintenance Guidelines

Activity	Schedule
▪ For the first 6 months following construction, the practice and CDA should be inspected at least twice after storm events that exceed 1/2 inch of rainfall. Conduct any needed repairs or stabilization.	After installation
▪ Mow grass in grid paver applications, bag contents, no mulching mower. ▪ Stabilize the contributing drainage area to prevent erosion. ▪ Remove any soil or sediment deposited on pavement. ▪ Replace or repair any necessary pavement surface areas that are degenerating or spalling.	As Needed
▪ Vacuum porous asphalt or concrete surface with commercial cleaning unit. ▪ Clean out inlet structures within or draining to the subsurface bedding beneath porous surface.	2-4 times per year (depending on use)
▪ Maintain records of all inspections and maintenance activity. ▪ Spot weeding of grass applications	Annually
▪ Conduct maintenance using a regenerative street sweeper ▪ Replace any necessary joint material	If clogged
▪ Remove any accumulated sediment in pre-treatment cells and inflow points.	Once every 2 to 3 years

Design of porous pavement systems are not limited to the examples shown within this manual. Successful stormwater management plans will combine appropriate materials and designs specific to each site.



Permeable Paver with Bioretention

6.12 Impervious Surface Disconnection

6.12.1 Device Description

Impervious Surface Disconnection involves managing runoff close to its source by intercepting, infiltrating, filtering, treating or reusing it as it moves from the impervious surface to the drainage system. These impervious surfaces are defined as connected if the impervious area drains directly to the storm sewer drainage system and disconnected if the impervious area first drains onto a lawn or other pervious area where infiltration can occur. Disconnection practices can be used to reduce the volume of runoff that enters the combined or separate sewer systems.

Courtesy of Philadelphia Stormwater Manual V 2.0

Figure 6-12.1
Roof Drain Disconnect

6.12.2 Key Elements

Impervious Surface Disconnection can be used to:

- Partially manage the first one-inch of rainfall from impervious cover on-site when applying Simple Disconnection in all Hydrologic Soil Groups with or without Soil Amendments.
- Reduce pollutant loads to meet water quality targets (total maximum daily loads or TMDLs).
- Retrofit existing developed areas.

The contributing area of rooftop to each disconnected discharge is 1000 square feet or less. The overland flow path has a positive slope of 5% or less.

Courtesy of tcstormwater.org

Figure 6-12.2
Disconnection of Roof onto Turf Pavers

6.12.3 Device Uses and Applicability

Potential applications for Impervious surface disconnect:

- Residential
- Commercial
- Urban
- Industrial
- Redevelopment

Impervious surface disconnect addresses:

- Volume reduction
- Storm event peak discharge

6.12.4 Impervious Surface Disconnection in the Urban Landscape

Runoff from urban catchments depends largely on the amount of impervious surface and the connectivity of these surfaces to the storm sewer drainage system. In residential areas, pervious lawns and turf pavers, see Figure 6-12.2, can be used to help manage stormwater runoff by intercepting and infiltrating runoff from impervious surfaces.

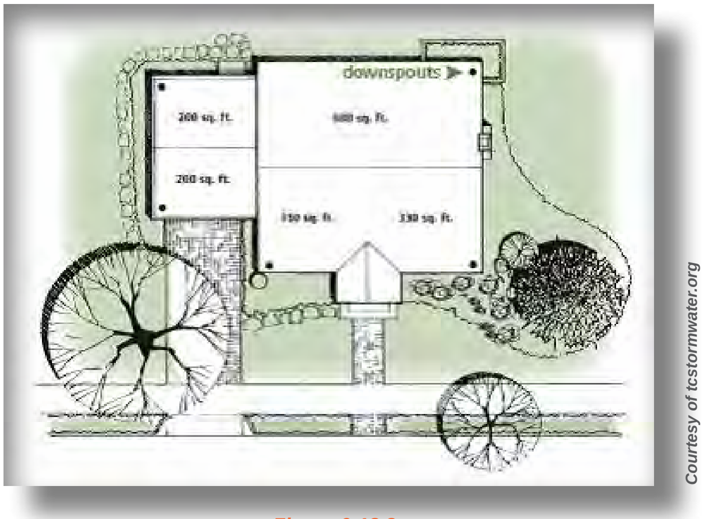
Simple Disconnection

Impervious surface disconnection whereby rooftops and/or on-lot residential impervious surfaces are directed to pervious areas or conservation areas, on lots/parcels that are generally 6,000 square feet or more (depending on local conditions), see Figure 6-12.3 and Figure 6-10.4.

Disconnection with Compensatory Practices

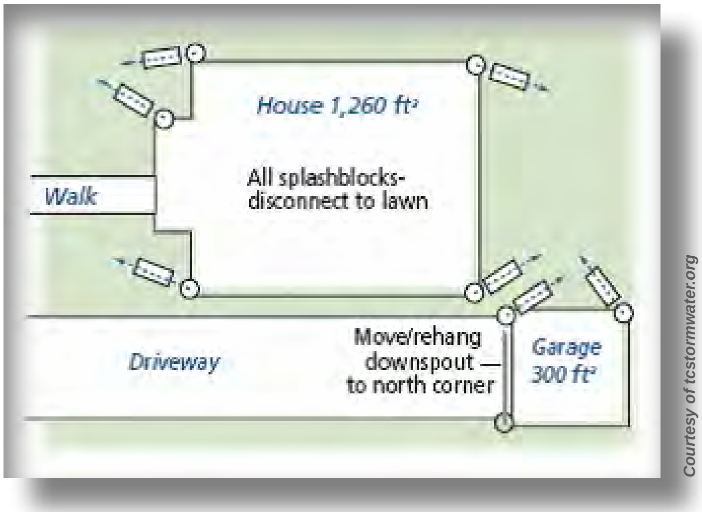
Impervious surface disconnect where adequate space for simple disconnection is not available, or a higher volume reduction credit is desired. Compensatory (micro-scale) runoff reduction practice(s) can be applied immediately adjacent to the rooftop downspout or impervious surface, see Figure 6-12.5. Compensatory practices can use less space than simple disconnection and can enhance runoff reduction rates. These practices include:

- Infiltration by small infiltration practices (dry wells or french drains, see Section 6-8 Infiltration Systems.
- Filtration or extended filtration by rain gardens or stormwater planters, see Section 6-6 Bioretention.
- Storage and reuse with a cistern or other vessel (rainwater harvesting), see Section 6-10 Rainwater Harvesting.



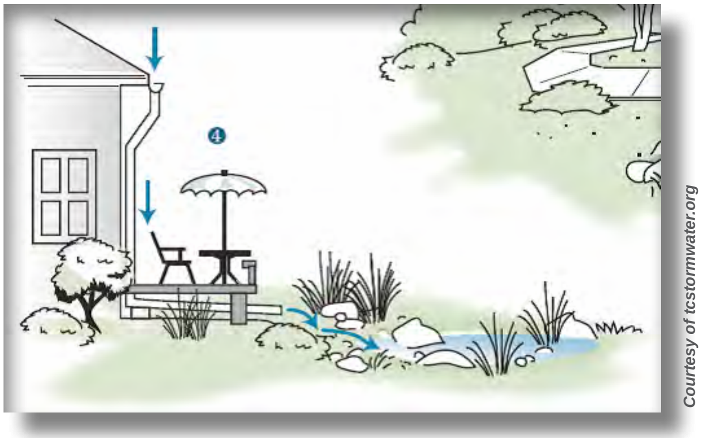
Courtesy of tcstormwater.org

Figure 6-12.3
Residential Site Plan



Courtesy of tcstormwater.org

Figure 6-12.4
Impervious Surface Disconnection



Courtesy of tcstormwater.org

Figure 6-12.5
Roof Drain Disconnect into a Rain Garden

6.12.5 Recommended Design and Installation Procedures

Evaluate the site for impervious surface disconnection consideration, included in Section 4.2.2 of the WVDEP Stormwater Management and Design Guidance Manual. These considerations include available space, site topography, soils and underdrains, contributing drainage area, hotspot land uses, floodplains, setbacks, proximity to utilities and community factors. The following are general guidelines to ensure proper design.

1. Simple Disconnection design criteria see Table 6-12.1:

Table 6-12.1: Simple Disconnect Recommendations

Design Factor	Design Criteria
Impervious Area Treated	• 1,000 sq. ft. per rooftop disconnection • Non-rooftop impervious areas: longest contributing impervious area flow path ≤75 ft.
Sizing/Geometry	• Pervious disconnection area width: ≥ 15 ft. and ≤ 25 ft. • Pervious disconnection area length: 40 ft.
Grade	• ≤ 2% • ≤ 5% with turf reinforcing • Receiving areas must be graded away from any building foundations
Inflow	• Sheet flow with level spreader for the entire width of the pervious area
Minimum Soil Infiltration Rate	• 0.5 inches/hour for Simple Disconnection (or use Compensatory Practice)
Building Setbacks	• 5 ft. away from building if the grade of the receiving area is less than 1%

Courtesy of WVDEP

2. Disconnection with compensatory practice: Infiltration design criteria see Table 6-12.2:

Table 6-12.2: Disconnection with Compensatory Practice: Infiltration

Design Factor	Infiltration Design
Roof Area Treated	• 250 to 2,500 sq. ft.
Typical Practices	• Dry well and french drain
Recommended Maximum Depth	• 3 feet
Minimum Soil Infiltration Rate	• Field verified ≥ 0.5 in./hr.
Pretreatment	• External (leaf screens, grass strip, etc.)
Required Soil Test	• One per practice
Building Setbacks	• 5 ft. down-gradient[1], 25 ft. up-gradient

Courtesy of WVDEP

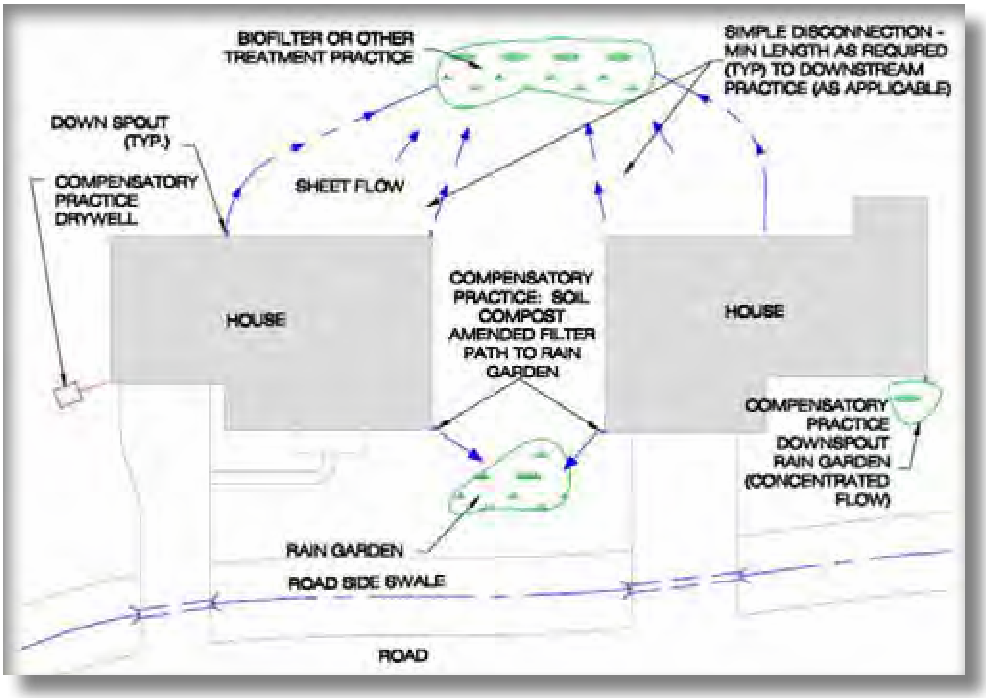
[1] Note that the building setback of 5 ft. is intended for simple foundations. The use of a dry well or french drain adjacent to an in-ground basement or finished floor area should be carefully designed and coordinated with the design of the structure's waterproofing system (foundation drains, etc.), or avoided altogether.

3. Disconnection to a rain garden design criteria see Table 6-12.3:

Table 6-12.3: Disconnect to a Rain Garden Recommendations	
Design Factor	Infiltration Design
Impervious Area Treated	• Up to 2,500 sq. ft.
Type of Inflow	• Sheet flow; Concentrated flow with level spreader or energy dissipater
Minimum Soil Infiltration Rate	• 0.5 in./hr. (or use underdrain)
Pretreatment	• Energy dissipater, forebay, grass filter
Underdrain	• Optional per soils (see Section 6-6: Bioretention)
Gravel Layer	• 12 inches
Minimum Filter Media Depth	• 18 inches
Media Source	• Can be mixed on-site
Impermeable Liner	• For hotspot or adjacent to foundations
Sizing	• See Section 6-6: Bioretention
Building Setbacks	• 5 ft. down-gradient, 25 ft. up-gradient (or use an impermeable liner for planters)

Courtesy of WVDEP

Disconnection to Rain Gardens should include provisions to bypass flows around the practice when the rain event exceeds the design volume. The adjacent pervious areas should be designed to safely convey design and large storm events away from the practice and to a receiving area without causing erosion. Since the rooftop drainage systems (roof leaders) typically limit the flow, there are generally no detailed conveyance criteria related to a design storm or peak flow rate.



Courtesy of WVDEP

Figure 6-12.6
Plan View of Impervious Disconnect Options

6.12.6 Infiltration Credit

Post-Construction Stormwater Management, located in Section 2.3.4 requires the first one (1) inch of rainfall to be managed. See Table 6-12.4 for credit guidelines.

Table 6-12.4: Impervious Surface Disconnection Credit

Credit	Description	Application
4 cu. ft. of volume reduction for every 100 sq. ft. of pervious receiving area.	A/B Soil Group Simple Disconnection • Max. 1,000 sq. ft. rooftop area to each disconnection point. • Non-rooftop impervious area longest flow path ≤ 75 ft. • Disconnection area width: ≥15 ft. / ≤ 25 ft. • Disconnection area length: = 40 ft. • Grade of receiving pervious area ≤ 2% or ≤ 5% with turf reinforcement.	• Residential or small commercial rooftops and/or other small areas of on-lot impervious cover; • Lot sizes ≥ 6,000 sq. ft. (this is a recommended lot size for Simple Disconnection; local governments may determine a locally-appropriate size. Smaller lots can still disconnect to Compensatory Practice).
2 cu. ft. of volume reduction for every 100 sq. ft. of pervious receiving area.	C/D Soil Group Simple Disconnection • Same design criteria as above.	• See above
4 cu. ft. of volume reduction for every 100 sq. ft. of pervious receiving area.	C/D Soil Group Soil Amendments- (see Soil Amendments Appendix D of WVDEP Design Manual). • Same design criteria as above. • Soils of pervious receiving area amended as per specifications.	• Residential or small commercial rooftops and/or other small areas of on-lot impervious cover.
The runoff reduction performance credits for the Compensatory Practices vary by design and site conditions.	Compensatory Practices: • Infiltration • Rain Garden • Rainwater Harvesting	• Residential or small commercial rooftops or on-lot impervious cover. • Lot sizes may vary

Courtesy of WVDEP

6.12.7 Construction Guidelines

For simple disconnection, the receiving pervious area can be within the limits of disturbance during construction. The following procedures should be followed during construction:

- Before site work begins, the receiving pervious disconnection area boundaries should be clearly marked.
- Construction traffic in the disconnection area should be limited to avoid compaction. The material stockpile area shall not be located in the disconnection area.
- Construction runoff should be directed away from the proposed disconnection area, using perimeter silt fence, or, preferably, a diversion dike.

- If existing topsoil is stripped during grading, it shall be stockpiled for later use.
- The disconnection area may require light grading to achieve desired elevations and slopes. This should be done with tracked vehicles to prevent compaction.
- Topsoil and/or compost amendments should be incorporated evenly across the disconnection area, stabilized with seed, and protected by biodegradable erosion control matting or blankets.
- Stormwater should not be diverted into any compost amended areas until the turf cover is dense and well established.

6.12.8 Maintenance

As with other stormwater management practices (BMPs), these require regular maintenance to ensure a prolonged life. Table 6-12.5 describes the minimum maintenance requirements for Impervious Surface Disconnection.

Table 6-12.5: Impervious Surface Disconnection Maintenance Guidelines

Activity	Schedule
Occasional cleaning of discharge area may be necessary to remove debris, such as leaves, coming off the drainage area. Check to ensure that the drainage path is flowing away from structure. Maintain bioretention systems, rainwater harvesting systems, and permeable pavers as directed in this chapter.	As needed
If disconnection is tied into a rainwater harvesting system , to avoid structural damage, the rain barrel should be drained prior to freezing weather.	Annually
Maintain records of all inspections and maintenance activity.	Ongoing

Courtesy of WVDEP

6.13 Detention Basins

6.13.1 Device Description

Detention basins (dry ponds, extended detention basins, detention ponds, extended detention ponds) are basins whose outlets have been designed to detain stormwater runoff for some minimum time (e.g., 48 hours) to allow particles and associated pollutants to settle. Unlike wet ponds, these facilities do not have a large permanent pool of water. However, they are often designed with small pools at the inlet and outlet of the basin. They are typically used for peak flow control by including additional detention storage see Figure 6-13.1.

Detention basins have traditionally been one of the most widely used stormwater best management practices. In some instances, these ponds may be the most appropriate best management practice. However, they should not be used as a one size fits all solution.

Courtesy of susdrain.com

Figure 6-13.1
Detention Basin

Detention basins offer several challenges with design, construction and maintenance. Therefore, the City has decided to cite these following publications as guidelines for detention basins.

EPA Post-Construction Stormwater Management in New Development & Redevelopment Retention / Detention at http://water.epa.gov/polwaste/npdes/swbmp/PostConstruction-Stormwater-Management-in-New-Development-and-Redevelopment.cfm

West Virginia Erosion and Sediment Control Best Management Practice Manual (2006 – sediment basins and stormwater management ponds) at https://apps.dep.wv.gov/dwwm/stormwater/BMP/index.html

Maryland Stormwater Design Manual (2000; revised 2009) at http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.aspx

Virginia Stormwater BMP Clearinghouse (updated 2011) http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html

Pennsylvania Stormwater Best Management Practices Manual Chapter 6.6 at http://www.elibrary.dep.state.pa.us/dsweb/View/Collection-8305

Detention basin design is not limited to the as for mentioned publications. Detention basins will be review and approved on a case by case basis.

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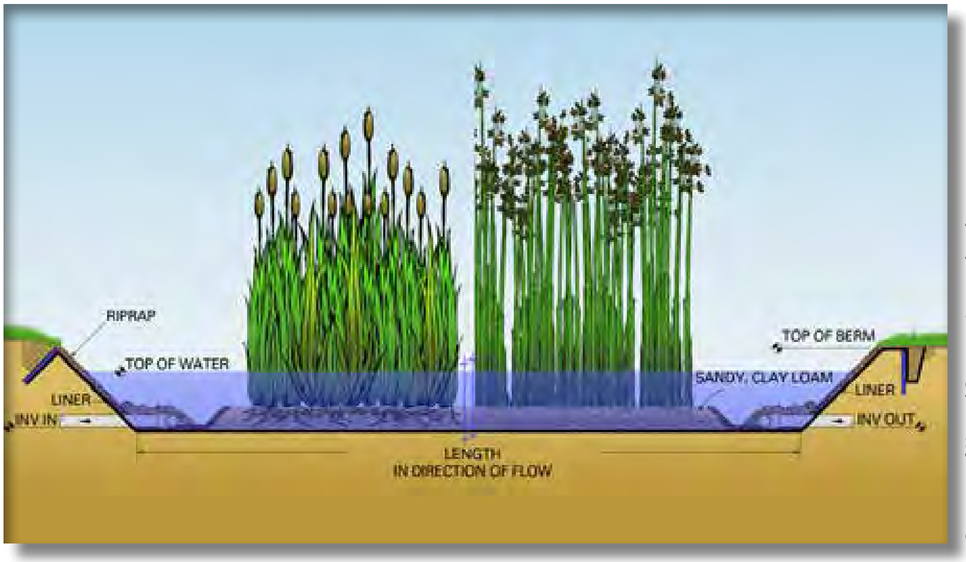
6.14 Stormwater Wetlands

6.14.1 Device Description

Stormwater wetlands sometime called constructed wetlands are shallow marsh systems that are designed to treat stormwater runoff. Wetlands are one of the best BMPs for pollutant removal, they can also mitigate peak rates and reduce runoff volume. They also can provide considerable aesthetic and wildlife benefits. As water flows through a wetland, many of the suspended solids become trapped by vegetation and settle out. Other pollutants are transformed to less soluble forms and are taken up by plants or become inactive. Wetland plants also provide the necessary conditions for microorganisms to live. Through a series of complex processes, these microorganisms also transform and remove pollutants from the water. Figure 6-13.1 provides a schematic of such a system.



Courtesy of Natural Systems International

Figure 6-14.1
Surface Flow Constructed Wetland

Constructed wetlands offer several challenges with design, construction and maintenance. Therefore, the City has decided to cite these following publications as guidelines for constructed wetlands.

EPA Post-Construction Stormwater Management in New Development & Redevelopment Retention / Detention at http://water.epa.gov/polwaste/npdes/swbmp/PostConstruction-Stormwater-Management-in-New-Development-and-Redevelopment.cfm

Section 4.2.11 of the West Virginia Department of Environmental Protection Stormwater Management and Design Guidance Manual. at http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/Documents/Specification_4.2.11_Stormwater_Wetlands_WV-SW-Manual-11-2012.pdf

Maryland Stormwater Design Manual (2000; revised 2009) at http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/MarylandStormwaterDesignManual/Pages/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.aspx

Constructed wetland design is not limited to the as for mentioned publications. Constructed wetlands will be review and approved on a case by case basis.

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6.15 Subsurface Vaults

6.15.1 Device Description

Subsurface vaults sometime called in-line storage are designed to retain stormwater runoff during a rain event thereby decreasing peak flow. They are constructed underground as pipe, concrete structures or special designed plastic structures and are designed to sustain the load of traffic and overlying soils see Figure 6-15.1. Subsurface vaults are ideal for a variety of settings including commercial properties and re-development locations, because they can be designed in limited space. Pretreatment systems can be installed at the inlet to treat stormwater runoff and remove debris.

Courtesy of StormTech.com

Figure 6-15.1
Subsurface Storage with Infiltration

Subsurface vaults are not effective entirely on their own. They work in conjunction with other stormwater management techniques, such as filters. Subsurface vaults minimize interference with the intended land use at the surface of a site.

Subsurface vaults offer several challenges with design, construction and maintenance. Therefore, the City has decided to cite these following publications as guidelines for subsurface vaults.

EPA Post-Construction Stormwater Management in New Development & Redevelopment Retention / Detention at http://water.epa.gov/polwaste/npdes/swbmp/PostConstruction-Stormwater-Management-in-New-Development-and-Redevelopment.cfm

“More Than Just Storage” Below ground detention systems offer water-quality benefits and opportunities for reuse. by Janet Aird at Stormwater: The journal for surface water quality professionals. at http://www.stormh2o.com/SW/Articles/More_Than_Just_Storage_16283.aspx

City of Philadelphia Stormwater Management Guidance Manual, Chapter , Subsurface Vaults at http://www.pwdplanreview.org/StormwaterManual.aspx

Subsurface vaults design is not limited to the as for mentioned publications. Subsurface vaults will be review and approved on a case by case basis.

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