# Chapter 6 Post Construction Runoff Control

## 6.0 Introduction

This chapter outlines common permanent BMPs available to use in managing stormwater after construction is complete.

Design Approaches for post construction runoff control are listed with each of the design BMPs. The City will review proposed stormwater features on a case-by-case basis, considering all of the limiting site constraints. It is the intent of the City that Developers, Owners and Contractors utilize permanent BMP's that will provide post construction stormwater management to reduce pollutants from runoff to the Maximum Extent Practicable (MEP).

Several factors go into choosing what BMPs are best for each site. These factors should all be used in selecting BMPs that suit the conditions of the site to ensure optimum stormwater management while preventing additional design issues.

Each of the BMPs performance criteria are based on six major factors: feasibility, conveyance, pretreatment, treatment, landscaping, and maintenance.

Low Impact Development (LID), discussed in Chapter 3, should be considered when selecting BMPs during the design process when site situations are encountered, including:

1. **Watershed Factors**: Some watersheds have more issues with stormwater than others. This may include flooding, sediment or water quality problems. The City may require special controls within challenged watersheds.
2. **Terrain Factors**: Charleston has a wide range of terrain within the City limits. The BMPs chosen must be appropriate for the site topography.
3. **Stormwater Treatment**: The BMPs selected should be appropriate in scope and size to treat the quantity of water expected.
4. **Physical Feasibility**: Physical site constraints, such as soil characteristics and geotechnical conditions (i.e. landslide prone), at the project site must be a design consideration.
5. **Community Factors**: Consideration should be given to whether the selected BMPs can be installed without creating an "aesthetic nuisance." Security, safety, and aesthetics should all be a consideration.
6. **Location and Permitting**: The proximity to wetlands, floodplains, and infrastructure must be considered. The installation of permanent stormwater BMPs should not restrict floodplains, detrimentally impact existing utilities or create a net loss of native wetlands.

## 6.1 Storm Water Pollution Prevention Plan (SWPPP) for Post Construction

All completed developments over one (1) acre or any commercial or industrial project over one half (½) acre are required to maintain in perpetuity their installed post construction stormwater management facilities. It is the intent of the City that the SWPPP developed for construction can be utilized for post construction operation and maintenance of the permanent BMPs. A section of the SWPPP shall be dedicated to this function.

The post construction portion of the SWPPP will address requirements of the most current version of the City's MS4 General Permit.

The EPA provides a booklet for creating a SWPPP called, "Developing Your Stormwater Pollution Prevent Plan: A guide for Construction Sites" This booklet can be downloaded from the WVDEP website at: http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/guidance/Documents/Developing%20your%20SWPPP%20A%20Guide%20for%20Construction%20Sites.pdf

Key components of the post-construction section of a SWPPP developed for permanent installations within the City of Charleston shall include but are not limited to:

- Protection of downstream landowners from erosive discharge velocities, flooding, and/or upsets of the permanent control structure.
- Promote aesthetic appearance of finished BMP.
- Capture stormwater contaminants/pollutants to the MEP.
- Provide for routine maintenance of the facility and documentation of that maintenance.
- Provide for access by City personnel for inspection and equipment access for future maintenance.

It is the intent of this manual that the Developer/Owner of the property can utilize this required SWPPP document generated for the City permit to also meet the requirements of the WVDEP permit submittal.

Developers and Owners shall also realize that larger projects will require more effort in developing a SWPPP for post construction purposes. The generic version presented in this manual is based upon the typical historical project size of 10 acres or less. Large developments (e.g. box stores, commercial strip malls, etc.) will require a larger document to adequately describe and address the controls necessary to meet post construction stormwater management requirements.

The SWPPP must be submitted with the permit application to the City and once the permit is approved must be maintained on-site during construction at all times and available for review during normal work hours. After construction is complete the SWPPP shall be maintained by the Owner on site and available for review by the City during normal business hours or made available for review in the event of an upset or emergency.

The requirement for maintaining permanent post construction stormwater BMPs will be sustained in perpetuity after completion of construction. The Owner/Developer must execute a Stormwater Management Facilities Maintenance Agreement with the City prior to termination of the City Stormwater Permit. These requirements will remain in effect until modification of applicable codes by the City, demolition to original conditions or until a modification is proposed and approved by the City. The Owner/Developer shall request an inspection by the City and issuance of a post construction BMP Notice of Termination or Modification as applicable.

## 6.2 Stormwater Management Facilities Maintenance Agreement

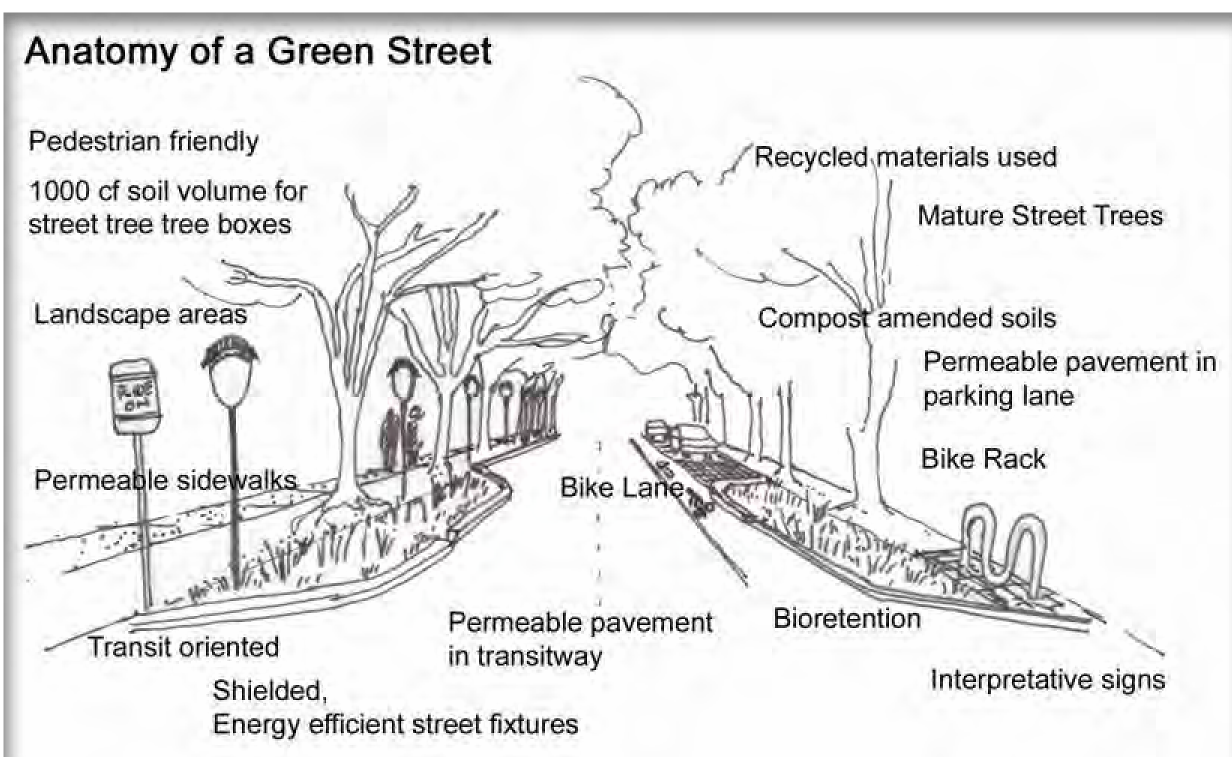
All new developments and redevelopments that include post construction stormwater BMPs will require the property owner to execute a Stormwater Management Facilities Maintenance Agreement including applicable right-of-entry provisions for inspection by the City. An easement shall be indicated for inspection and maintenance purposes on the stormwater management drawing or survey plat. Designers of post construction BMPs shall consider needed access when engineering the proposed features. Refer to Section 2.2.6 for information regarding permitting.

## 6.3 Post-Construction Measures and Alternative Measures

It is the intent of this manual to provide guidance for the more common methods of post-construction stormwater management. Starting with Section 6.4, commonly used BMPs are discussed and information regarding their construction and maintenance is provided. It is not the intent of this manual to limit the use of creative techniques. As such, introductions to various unique and innovative technologies are provided. There are several available technology options, in which the City will be proactive in considering alternative ideas, particularly with regard to achieving the goals of LID.

The user of this manual is referred to the following publications and organizations for supplemental information.

- The National Center for Watershed Protection - http://www.cwp.org/
- West Virginia Stormwater Management and Design Guidance Manual - http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/Pages/StormwaterManagementDesignandGuidanceManual.aspx
- Philadelphia Stormwater Management Guidance Manual - http://pwdplanreview.org/StormwaterManual.asp
- EPA - Post-Construction Stormwater Management in New Development & Redevelopment -http://water.epa.gov/polwaste/npdes/swbmp/PostConstruction-Stormwater-Management-in-New-Development-and-Redevelopment.cfm




*Courtesy of llowimpactdevelopment.org*

Swales

## 6.4 Swales

### 6.4.1 Device Description

Swales are open channels with a combination of grasses and/or other herbaceous plants, shrubs, and trees which act as both a stormwater conveyance and treatment system. Swales reduce peak flows by increasing travel time and friction. Depending on design, they can effectively improve water quality, reduce runoff volume and peak flow. Additionally, swales can be more aesthetically pleasing than a concrete or rock-lined drainage system and are generally less expensive to construct. Figure 6-4.1 provides an example of a vegetated swale.

Pollutant removal in swales is the result of filtration through channel and side slope vegetation, infiltration into the swale channel bottom, and microbial activity in the subsurface soils. Swales often collect sediments and other particulate material. While swales provide some infiltration and water quality treatment, these functions may be enhanced by adding check dams periodically along the length, see Figure 6-4.2. Swales planted with turf grass provide some of these functions, but turf grass is not as effective as deeper-rooted vegetation with respect to decreasing peak flows, allowing infiltration, and decreasing erosion.

Courtesy of Philadelphia Stormwater Manual v2.0

*Figure 6-4.1*
*Vegetated Swale*

### 6.4.2 Key Elements:

- Open channel design that balances storage, treatment, and infiltration with peak flow conveyance needs.
- Check dams are often used to increase storage, dissipate energy, and control erosion.
- Native vegetation increases friction and stabilizes soil.
- Designed to fit into many types of landscapes in an aesthetically pleasing manner.

*Figure 6-4.2*
*Vegetated Swale with Check Dams*

### 6.4.3 Device Uses and Applicability

Potential applications for swales:

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

Vegetated Swales address:

- Water Quality / Infiltration
- Volume reduction
- Channel Protection
- Peak Flow Management

Swales can be used with other treatment options to assist in stormwater treatment, such as filter strips and sediment forebays.

### 6.4.4 Swales in the Urban Landscape

Swales are landscaped channels that convey stormwater and reduce peak flows by increasing travel time and friction. Check dams increase these functions by providing ponding areas where settling and infiltration can occur. As the number of check dams increases, a swale may resemble a series of bioinfiltration/bioretention basins while still being designed to convey peak flows. The first ponding area may be designed as a sediment forebay and function as a pretreatment practice for the remainder of the swale or other stormwater management facilities.

Swales are applicable in many urban settings such as parking, commercial and industrial facilities, roads and highways, and residential developments. For instance, a swale is a practical replacement for roadway median strips and parking lot curb and gutter.

#### Commercial, Industrial, and Institutional Sites

These facilities often have landscaped or grassed areas that can also function as drainage pathways and infiltration areas.

#### Roads

Swales can be installed in some median strips and shoulders. In some cases, these systems may replace costly curb and gutter or storm sewer systems. (see Figure 6-4.3).

#### Residential Development

With approved property agreements, swales can be constructed parallel to the sidewalks and streets. Alternatively they can collect stormwater from multiple properties and convey it to a shared facility.

*Courtesy of Philadelphia Stormwater Manual v2.0*

***Figure 6-4.3***
***Vegetated Swale Median***

### 6.4.5 Components of a Swale

Swale systems may include the following components:

- Inlet Control
- Pretreatment
- Excavated Channel
- Soil
- Stone (Optional)
- Vegetation
- Outlet Control
- Check Dams

- Inlet Control

  Runoff can enter the swale through a curb opening, pipe, weir, or other design. Runoff may flow off a curb-less parking lot or road and down a swale slope in a diffuse manner.

- Pretreatment

  Pretreatment is to dissipate energy, reduce runoff velocity and can extend the life of the design. Vegetated or stone filter strips are options for pretreatment. A sediment forebay may be constructed at the swale inlet, or the first swale segment and a check dam may be designed as a sediment forebay.

- Excavated Channel

  The channel itself provides the storage volume and conveyance capacity of the swale. Swale design balances needs for infiltration and treatment during small storms for conveyance during large storms.

- Soil

  The soil provides a growing medium for plants and allows infiltration. Growing medium may consist of amended native soils or imported soil.

- Check Dams

  It is recommended that swale designs include check dams. Ponding behind check dams provides storage, increases infiltration, increases travel time, reduces peaks, and helps prevent erosion by dissipating energy.

- Stone

  A crushed stone layer may be added beneath the soil to increase storage and promote infiltration. Stone will perform this function most effectively when placed in ponding areas.

- Vegetation

  Vegetation is included within a swale to impede the flow and prevent the erosive tendencies of stormwater along the swale channel. Additionally, vegetated swales can assist in dealing with excess stormwater through transpiration provided by plant life. Vegetated swales may consist of only turf grass or more elaborate planting schemes, illustrated in Figure 6-4.5 (page 6-8).

*Courtesy of Philadelphia Stormwater Manual v2.0*

***Figure 6-4.4***
***River Rock Swale With a Structural Check Dam and Weir System***

- Outlet Control

  A swale may have an outlet control to convey water to a sewer or receiving water.

### 6.4.6 Recommended Design Procedures

To ensure the vegetated swales are properly constructed and will provide sustained benefits to the area, the following criteria may be useful. (See Diagram 6-4.1, page 6-9).

1. Check the feasibility for the given site. Consider the available space, topography, soil conditions and contributing drainage area (maximum 5 acres per swale).
2. Create a Conceptual Site Plan for the entire site. Consider the site's natural topography in siting the swale and if possible, locate the swale along contours and natural drainage pathways with a maximum slope of four (4) percent, check dams may be used to reduce effect of slope. Use of swales on steeper slopes may be accomplished through the use of erosion control matting. It should be noted that vegetated swales effectiveness is reduced on steeper slopes.
3. Investigate the feasibility of infiltration according to conditions in the area proposed for the vegetated swale. If infiltration is feasible, determine the saturated vertical infiltration rate. If the proposed swale is for bioretention see Section 6.8.
4. Create a conceptual design for the vegetated swale using Table 6-4.1.

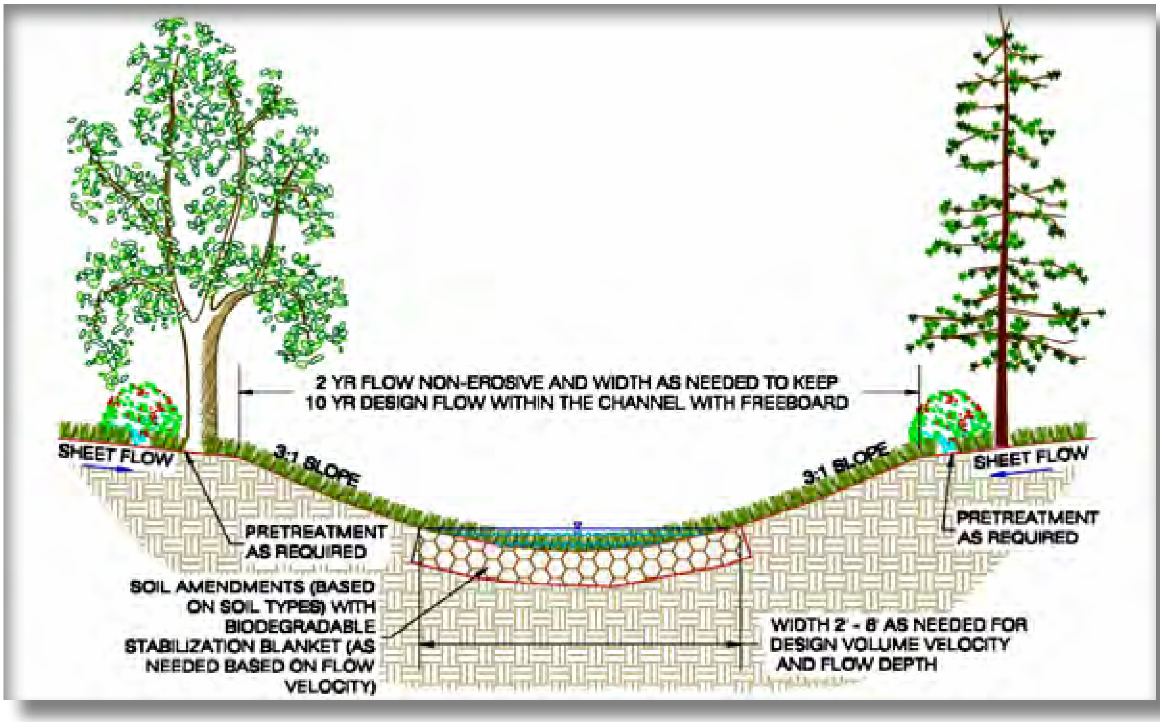
| Table 6-4.1: Suggested Swale Starting Design Values | |
|---|---|
| Bottom Width | 2-8 feet |
| Side Slopes | 3:1 or flatter* |
| Check Dams | Evenly spaced, 6-12 inches high** based on slope |
| *Swales may be trapezoidal or parabolic in shape. Recommended widths and slopes in this table may be used as a general guide for parabolic channels | |
| **Check dams are recommended for most applications to improve infiltration and water quality. They are strongly recommended for swales in which flow in combination with soil, slope, and vegetation may result in erosive conditions | |

Courtesy of Philadelphia Stormwater Manual v2.0

Courtesy of Philadelphia Stormwater Manual v2.0

*Figure 6-4.5*
*Vegetated swales with plantings*

5. Check the peak flow capacity of the swale. It is recommended that the swale convey the 10-year, 24-hour design storm with six (6) inches of freeboard and an average ponding depth of 12 inches or less. A maximum ponding depth of 18 inches may be allowable for some sites. The velocity shall be less than one (1) foot per second for a one (1) year storm. Flow over check dams may be estimated using a weir equation.




Courtesy of WVDEP

*Diagram 6-4.1*
*Vegetative swale*

6. Choose soil mix and swale vegetation. A minimum of six (6) inches of prepared soil is recommended for the channel bottom and slopes.
7. Check resistance of the swale to erosion. The swale shall convey the 2-year, 24-hour design storm without erosion  Adjust soil mix, vegetation, and temporary or permanent stabilization measures as needed.
8. Design inlet controls, outlet controls, and pretreatment as needed to protect swales from detrimental inflow impacts to reduce discharge to a non-erodible velocity.
9. Check that the design meets all requirements and adjust design as needed.
10. Complete construction plans and specifications.

### 6.4.7 Infiltration Credit

Post-Construction Stormwater Management, located in Section 2.3.4 requires the first one (1) inch of rainfall to be managed. Swales may be used to partially fmanage the first one inch. The credit are as follows:

- Type A & B soils a credit of 0.20 inches for the contributing drainage area
- Type C & D soils a credit of 0.10 inches for the contributing drainage area
- Swales with amended soils use 0.20 inches

Example: A swale with Type B soils is used to convey water from a parking lot that is required to manage 3,500 $ft^3$ to meet the 1-inch requirement. If the swale meets the minimum criteria the volume is reduced to (1-inch -0.20 inches) x 3,500 $ft^3$= 2,800 $ft^3$.



Minimum Swale Criteria

- Bottom width of 2-8 feet
- Channel side slopes of 3:1 or flatter
- Inflow energy dissipation & pretreatment must be installed
- Longitudinal slope is no greater than 4% (check dams may be used to reduce the effective slope)
- Flow velocity less than 1 ft/s during a 1-inch storm event
- Flow velocity non-erosive during the 2-year & 10-year storm event
- Swales must be able to convey a 10-year storm with a minimum of 6-inches of freeboard

### 6.4.8 Materials

Adherence to the following recommendations will allow for proper materials to be used in construction and design of vegetative swales.

Soil Amendment

- Soil amendment (also called soil restoration) is a technique applied after construction to deeply till compacted soils and restore their porosity by amending them with compost. Detail information on soil amendment can be located in the WVDEP's Stormwater Management and Design Guidance Manual located at: http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/Pages/StormwaterManagement-DesignandGuidanceManual.aspx

Vegetation

- It is critical that plant materials are appropriate for soil, hydrologic, light, and other site conditions. Select plants from the list of native species in the provided plant list in Appendix C. In addition, the ponding depth, drain time, sunlight, and salt tolerance shall be considered in the selection of plants. The use of turf grass is not recommended, however it may be acceptable provided clear evidence is presented to show all requirements are met.

Check Dams

- Check dams shall be constructed from natural wood, concrete, stone, boulders, earth, or other non erodible materials.
- Should a stone check dam be designed for overtopping, an appropriate selection of aggregate will ensure stability during flooding events. In general, one stone size for a dam is recommended for ease of construction, however, two or more stone sizes may be used, provided a larger stone is placed on the downstream side due to flows being concentrated at the exit channel of the weir. Several inches of smaller stone (e.g. AASHTO #57) can then be placed on the upstream side. Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

Stone Storage

- Stone used to provide additional storage shall be uniformly-graded, crushed, washed stone meeting the specifications of AASHTO No. 2 or AASHTO No. 4.
- Stone shall be separated from soil by a non-woven geotextile or similar as approved by the City.

Non-Woven Geotextile

- Geotextile shall consist of four (4) ounce needle punched non-woven polypropylene fibers and meet the following properties:
  - Grab Tensile Strength (ASTM-D4632) ≥ 120 lbs
  - Mullen Burst Strength (ASTM-D3786) ≥ 225 psi
  - Flow Rate (ASTM-D4491) ≥ 95 gal/min/ft2
  - UV Resistance after 500 hrs (ASTM-D4355) ≥ 70%
  - Heat-set or heat-calendared fabrics are not permitted

Pipe

- Pipe used for an underdrain shall be continuously perforated and provide a smooth interior with a minimum inside diameter of four (4) inches. High-density polyethylene (HDPE) pipe used in underdrains shall meet the specifications of AASHTO M252, Type S or AASHTO M294, Type S. Use of corrugated interior HDPE pipe is prohibited.

### 6.4.9 Construction Guidelines

The following is a typical construction sequence to properly install swales. Although steps may be modified to reflect different site conditions or design variations. Swales should be installed at a time of year that is best to establish turf cover without irrigation. Erosion and sediment control methods shall adhere to the WVDEP Stormwater Management and Design Guidance Manual located at: http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/Documents/Specification_4.2.5_Grass_Swales_WV-SW-Manual-11-2012.pdf

The timing of the installation of Swales is dependent on whether the swale is to be used as a conveyance during construction. It may be preferable to construct the swale prior to the contributing drainage area being directed to the swale in order to help establish vegetation in the swale bottom. If this is not feasible based on the construction sequencing of the site, then the contributing drainage area should be stabilized with vegetation before attempting to establish vegetation in the channel.

Steps for construction:

- Any accumulation of sediment that does occur within the channel must be removed during the final stages of grading or establishing vegetative cover in order to achieve the design cross-section.
- Grade the swale to the final dimensions shown on the plan. Excavators or backhoes should work from the sides to grade and excavate the swale to the appropriate design dimensions. Excavating equipment should have scoops with adequate reach so they do not have to sit inside the footprint of the open channel area. The final grading should rake or scarify the bottom as needed for seed preparation.
- Add Soil Amendments as needed. Till the bottom of the swale to a depth of one (1) foot and incorporate compost amendments.
- Install check dams, driveway culverts and internal pre-treatment features as shown on the plan. The top of each check dam should be constructed level at the design elevation.
- Seed or vegetate the bottom and banks of the open channel and peg in erosion control fabric or blanket where needed.
- Conduct the final construction inspection and develop a punchlist for facility acceptance.



### 6.4.10 Maintenance

Concurrent with the previous step, stabilize freshly seeded swales with appropriate temporary or permanent soil stabilization methods, such as erosion control matting or blanket. If runoff velocities are high, consider installing sod on the swale or diverting runoff until vegetation is fully established. Erosion and sediment control methods shall adhere to this manual and the WVDEP regulations.

Once the swale is sufficiently stabilized, remove temporary erosion and sediment controls. The importance of the swale being stabilized before receiving significant stormwater flow cannot be overstated.

Table 6-4.2 provides recommended guidelines for inspection and maintenance activities.

Table 6-4.2: Swale Maintenance Guidelines

| Activity | Schedule |
|---|---|
| ▪ Remulch void areas<br>▪ Treat or replace diseased trees and shrubs<br>▪ Keep overflow free and clear of leaves | As needed |
| ▪ Inspect soil and repair eroded areas<br>▪ Remove litter and debris<br>▪ Clear leaves and debris from overflow | Monthly |
| ▪ Inspect trees and shrubs to evaluate health | Biannually |
| ▪ Add additional mulch<br>▪ Inspect for sediment buildup, erosion, vegetative conditions, etc. | Annually |
| ▪ Maintain records of all inspections and maintenance activity | Ongoing |

## 6.5 Filter Strip

### 6.5.1 Device Description

Filter strips are densely vegetated areas that treat sheet flow stormwater from impervious areas (illustrated in Figure 6-5.1). Filter strips are effective at slowing stormwater runoff, providing water quality protection by reducing the amount of sediment, organic matter, nutrients and pesticides. Filter strips may infiltrate a portion of the runoff into the ground.

Filter strips are cost effective and relatively easy to install. They are an effective BMP in redevelopment of large impervious areas. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

Courtesy of spokanwastewater.org

*Figure 6-5.1*
*Filter Strip*

### 6.5.2 Key Elements

- Filter strips may provide pre-treatment for other BMP's.
- Sheet flow across the vegetated filter strip is necessary for proper filter strip function.
- Filter strip length is a function of slope, vegetation type, soil type, drainage area, and desired amount of pretreatment.
- Level spreading devices are recommended to provide uniform sheet flow conditions at the interface of the filter strip and adjacent land cover. The level spreader should be at minimum of 13 linear feet per one (1) cfs.
- The longest flow path to a filter strip, without the installation of energy dissipaters and/or flow spreaders, is 75 feet for impervious ground covers and 150 feet for pervious ground covers.
- Filter strip slope should never exceed 8%. Slopes less than 5% are generally preferred. The first 10 feet should be 2% or less.
- Maximum contributing drainage area slope is less than 5%, unless energy dissipation and/or flow spreaders are provided.
- Construction of filter strips should entail as little disturbance to existing vegetation at the site as possible.

### 6.5.3 Device Uses and Applicability

Potential applications for filter strips:

- Residential subdivision
- Commercial
- Industrial (limited)
- Urban (limited)
- Redevelopment
- Along roadways

Filter strips address:

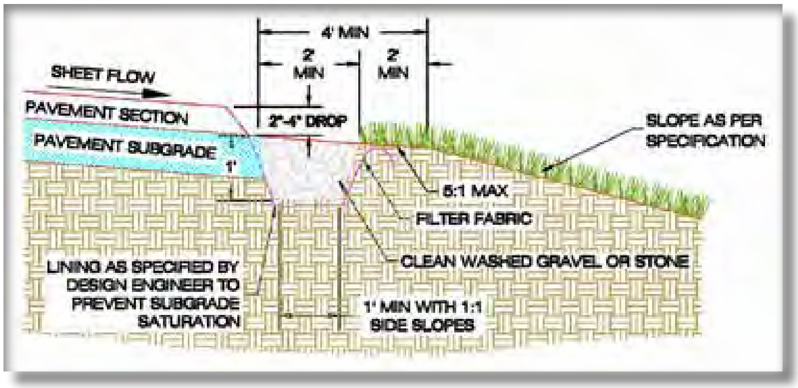
- Water Quality / Infiltration
- Volume reduction (no infiltration)
- Channel Protection
- Peak Flow Management

### 6.5.4 Filter Strips in the Urban Landscape

Filter strips are effective at slowing runoff velocities, removing pollutant loads, and promoting infiltration of runoff from by both impervious and pervious areas. Filter strips are suitable for many types of development projects. Filter strips can be used as pretreatment facilities for other BMPs in residential, commercial, and limited industrial development, roads and highways, and parking lots. Filter strips are recommended for use as a pretreatment component of other BMPs including but not limited to: bioretention, constructed wetlands, detention, filters, ponds/wet basins, porous pavement, and vegetated swales. The use of a properly maintained filter strip extends the life of the associated BMPs and decreases hydraulic residence time.  It also increases the amount of time before these structures need maintenance.

### 6.5.5 Components of a Filter Strip System

- Inlet Control
- Vegetation
- Permeable Berm




Courtesy of WVDEP

*Figure 6-5.2*
*Filter strip design example*

- Inlet Control

  Filter strips are typically combined with a level spreader or flow control device. A flow control device functions to lessen the flow energy of stormwater prior to entering the filter strip area. Concentrated flow rates can have an erosive effect that can damage the filter strip, rendering the strip ineffective. Curb openings combined with a gravel level spreader are a common type of flow control. Slotted or depressed curbs installed at the edge of the impervious area should ensure a well distributed flow to the filter strip. These slotted openings should be spaced along the length of the curb.

- Vegetation

  The vegetation for filter strips may be comprised of turf grasses, meadow grasses, shrubs, and native vegetation. It can include trees or indigenous areas of woods and vegetation. Vegetation adds aesthetic value as well as water quality benefits. The use of indigenous vegetated areas that have surface features that disperse runoff is encouraged, as the use of these areas will also reduce overall site disturbance and soil compaction. The use of turf grasses will increase the required length of the filter strip compared to other vegetation options  Filter strips should be seeded not sodded. Seeding allows for deep roots to be established.

- Permeable Berm

  Filter strip effectiveness may be enhanced by installing permeable berm perpendicular to the flow path. A permeable berm allows for a greater reduction in both runoff velocity and volume, thus improving pollutant removal capabilities by providing a temporary (very shallow) ponded area.

### 6.5.6 Recommended Design Procedures

To ensure the filter strips are properly applied throughout the project, the following may be useful:

1. Investigate the feasibility of infiltration according to soil and vegetative conditions in the area proposed for the filter strip. Determine the Hydrologic Soil Group and plan accordingly, see Table 6-5.1. If infiltration is feasible, determine the saturated vertical infiltration rate.

Table 6-5.1: Sheet Flow to Filter Strip

| Hydrologic Soil Group | Description | Application | Performance |
|---|---|---|---|
| A/B | Slope and width:<br>1% to 4% - minimum 35 ft. width<br>4% to 6% - minimum 50 ft. width<br>6% to 8% - minimum 65 ft. width<br>First 10 ft. must be ≤ 2% in all cases | Treat small areas of impervious cover (e.g., 5,000 sq. ft.); and/or<br><br>Moderate areas (10,000 sq. ft.) turf-intensive land uses (sports fields, golf courses) close to source | 6 $ft.^3$ of volume reduction for every 100 $ft.^2$ of Filter Strip |
| | Sheet Flow:<br>Pervious areas: max flow length ≤ 150 ft.;<br>Impervious areas: max flow length ≤75 ft.; | | |
| | Concentrated Flow:<br>Engineered Level Spreader lip = 13 lin. ft. per 1 cubic foot per second (cfs) | | |
| | Pre-Treatment:<br>Gravel Diaphragm at top of filter<br>Permeable Berm at bottom of filter | | |
| C/D | Standard Design –<br>Same as A/B soils | Same as A/B Soils | 3 $ft^3$ of volume reduction for every 100 $ft^2$ of Filter Strip |
| C/D | Soil Amendments<br>Same as A/B soils<br>Filter Strip soil amendments | Same as A/B Soils | 6 $ft.^3$ of volume reduction for every 100 $ft.^2$ of Filter Strip |

*Courtesy of WVDEP*

2. Examine size and slope of the drainage area, see Table 6-5.1 for guidelines. Determine the longest flow path length for the contributing drainage area.

3. If the slope of the filter strip parallel to the proposed flow path is greater than 8%, energy dissipaters and/or flow spreaders must be installed.

4. Design an inlet control to meet energy dissipation requirements.

   - A flow spreader which stretches the entire length (perpendicular to flow path) of the contributing drainage area should be designed in order to limit flow velocity to prevent erosion and to spread the flow equally across the filter strip. If necessary, a bypass shall be installed to prevent excessive, damaging flows.

5. Adjust filter strip design characteristics to provide desired amount of pretreatment. When considering retentive grading, use the infiltration area and the saturated vertical infiltration rate of the native soil to estimate how long the surface ponding will take to drain. The maximum drain down time for the ponded volume is 72 hours, however a drain down time of 24 to 48 hours is recommended. If ponded water does not drain in this time, adjust water surface depth, soil depth, and/or surface area and the design. An outlet pipe may be necessary to meet the volume and drainage time constraints.
6. All retentive grading techniques should encourage soil stabilization and erosion control with vegetative growth.
7. Choose plants and trees appropriate and compatible with the site conditions.
8. Filter strips may not be used in high use areas unless precautions are taken to minimize disturbance (i.e. signage, placement of sidewalks or paths to minimize disturbance of the filter strip).
9. Determine final contours of the filter strip.
10. Complete construction plans and specifications.

### 6.5.7 Infiltration Credit

Post-Construction Stormwater Management, located in Section 2.3.4 requires the first one (1) inch of rainfall to be managed. Filter strips may be used to partially manage the first one inch. The guidelines are as follows

- For Type A & B 6 $ft^3$ of volume reduction for every 100 $ft^2$ of filter strip.
- For Type C & D 3 $ft^3$ of volume reduction for every 100 $ft^2$ of filter strip.
- For filter strips with amended soils use 6 $ft^3$ of volume reduction.

Minimum filter strip Criteria:

- The slope of the filter strip must meet the requirements from Table 6-5.1 (page 6-15).

### 6.5.8 Materials

Adherence to the following recommendations will allow for proper materials to be used in construction and design of filter strips. Detailed information on materials may be located in the WVDEP's Stormwater Management and Design Guidance Manual located at: http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/Pages/StormwaterManagementDesignandGuidanceManual.aspx

- If existing topsoil is inadequate to support dense turf growth, imported top soil (loamy sand or sandy loam texture), with less than 5% clay content, corrected pH at 6 to 7, a soluble salt content not exceeding 500 parts per million, and an organic matter content of at least 2% shall be used. Topsoil shall be uniformly distributed and lightly compacted to a minimum depth of 6 to 8 inches.
- Select plants from the list of native species in the provided plant list in Appendix C that are appropriate for growth based on the project soils, hydrologic, light, and other relevant site conditions. In addition, the ponding depth, drain time, sunlight, and salt tolerance shall be considered in the selection of plants. The use of sod is not recommended.

- Where flow velocities dictate, use woven biodegradable erosion control fabric or mats that are durable enough to last at least two growing seasons, see specification 3.13 in WVDEP, 2006.
- Level Spreader lip should be concrete, timber, or other rigid material. Reinforced channel on upstream of lip.
- Geotextile should needled, non-woven, polypropylene geotextile meeting the following specifications:
  - Mullen Burst Strength (ASTM D3786): > 225 lbs./sq. in.
  - Grab Tensile Strength (ASTM D4632): > 120 lbs.
  - Flow Rate (ASTM D4491): > 125 gpm/sq. ft.
  - Apparent Opening Size (ASTM D4751): US #70 or #80 sieve
- Permeable Berm should consist of 40% excavated soil, 40% sand, and 20% pea gravel.
- Gravel Diaphragm should consist of Pea Gravel (AASHTO #8 or ASTM equivalent) or where steep (6% +) use clean bank-run AASHTO #57 or ASTM equivalent (1-inch maximum). Diaphragm should be 2 ft. wide, 1 ft. deep, and at least 3 in. below the edge of pavement.

### 6.5.9 Construction Guidelines

The following is a typical construction sequence to properly install a filter strip. Although steps may be modified to reflect different site conditions or design variations.

Filter strips can be within the limits of disturbance during construction. The following procedures should be followed during construction:

- Before site work begins, vegetated filter strip boundaries should be clearly marked.
- Only vehicular traffic used for filter strip construction should be allowed within 10 feet of the filter strip boundary.
- If existing topsoil is stripped during grading, it shall be stockpiled for later use.
- Construction runoff should be directed away from the proposed filter strip, using perimeter silt fence, or, preferably, a diversion dike.
- Construction of the gravel diaphragm or engineered level spreader shall not commence until the contributing drainage area has been stabilized and perimeter erosion and sediment controls have been removed and cleaned out.
- Vegetated filter strips 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 filter strip area, stabilized with vegetation, and protected by biodegradable erosion control matting or blankets.
- Stormwater should not be diverted into the filter strip until the turf cover is dense and well established.

### 6.5.10 Maintenance

All areas of the filter strip shall be inspected after significant storm events for ponding that exceeds maximum depth and duration guidelines. Corrective measures shall be taken immediately when excessive ponding occurs.

Table 6-5.2 provides recommended guidelines for inspection and maintenance activities.

Table 6-5.2: Filter Strips Maintenance Guidelines

| Activity | Schedule |
|---|---|
| ▪ Mowing and/or trimming of vegetation (not applicable to all filter strips). Filter strips that need mowing are to be cut to a height no less than 4 inches. Greater than 5 inches is preferred. | As needed |
| ▪ Inspect all vegetated strip components expected to receive and/or trap debris and sediment for clogging and excessive debris and sediment accumulation; remove sediment during dry periods. | Quarterly |
| ▪ Vegetated areas should be inspected for erosion, scour, and unwanted growth. This should be removed with minimum disruption to the planting soil bed and remaining vegetation. | Biannually |
| ▪ Inspect all level spreading devices for trapped sediment and flow spreading abilities. Remove sediment and correct grading and flow channels during dry periods. | |
| ▪ Maintain records of all inspections and maintenance activity. | Ongoing |

- When correcting grading of a flow spreading device, use proper erosion and sediment control precautions in the concentrated area of disturbance to ensure protection of the remaining portion of the filter.
- Disturbance to filter strips should be minimal during maintenance. At no time should any vehicle be driven on the filter strip. In addition, foot traffic should be kept to a minimum.
- If the filter strip is of the type that needs mowing (i.e., turf grass and possibly other native grasses), the lightest possible mowing equipment (i.e., push mowers, not riding mowers) should be used. The filter strip should be mowed perpendicular to the flow path (however not exactly the same path every mowing) to prevent any erosion and scour due to channeling of flow in the maintenance depressions.
- When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established.
- Bi-weekly inspections of erosion control and flow spreading devices should be performed until soil settlement and vegetative establishment has occurred

Filter strip design is not limited to the examples shown within this manual. Successful stormwater management plans will combine appropriate materials and designs specific to each site.

## 6.6 Bioretention

### 6.6.1 Device Description

Bioretention is the stormwater management practice in which stormwater runoff is conveyed to a shallow, vegetated depressed area where it is retained while awaiting infiltration. This method is very effective in removing pollutants and reducing the volume of stormwater runoff.

Bioretention is versatile and can be used in a variety of situations including large developments, high-density commercial property and smaller single-family residential sites, see Figure 6-6.1. It should be noticed that there are innumerable shapes and planting styles available. Bioretention concepts are included but not limited to:

- Water Quality Swale - linear and narrower applications, often with a longitudinal slope.
- Urban Bioretention – adaptations for highly impervious settings; includes engineered tree pits, median bioretention and stormwater planters.
- Residential Rain Garden – simplified version designed for residential yards and small-scale applications.

The designer is encouraged to be creative and innovative in their design.


***Figure 6-6.1***
***Rain Garden at Habitat for Humanity parking lot***

Bioretention areas are generally capable of handling stormwater from areas of up to about one (1) acre, but they can also be integrated throughout a site to manage larger areas. They are flexible and easy to incorporate in landscaped areas, and are ideal for placement in roadway median strips and parking lot islands. They can also provide water quality treatment from pervious areas.

### 6.6.2 Key Elements

- Preferred stormwater management design that replicates natural hydrologic processes.
- Flexible in size and configuration; can be used for a wide variety of applications.
- Water Quality volume that drains in no more than 48 hours.
- Amended soil that provides temporary stormwater storage and enhances plant growth.
- Native plantings that provide evapotranspiration of stormwater, remove pollutants, and enhance the landscape.
- Overflow structure.
- Maintenance of vegetation is required.
- Installation should not create other site engineering or construction liabilities.

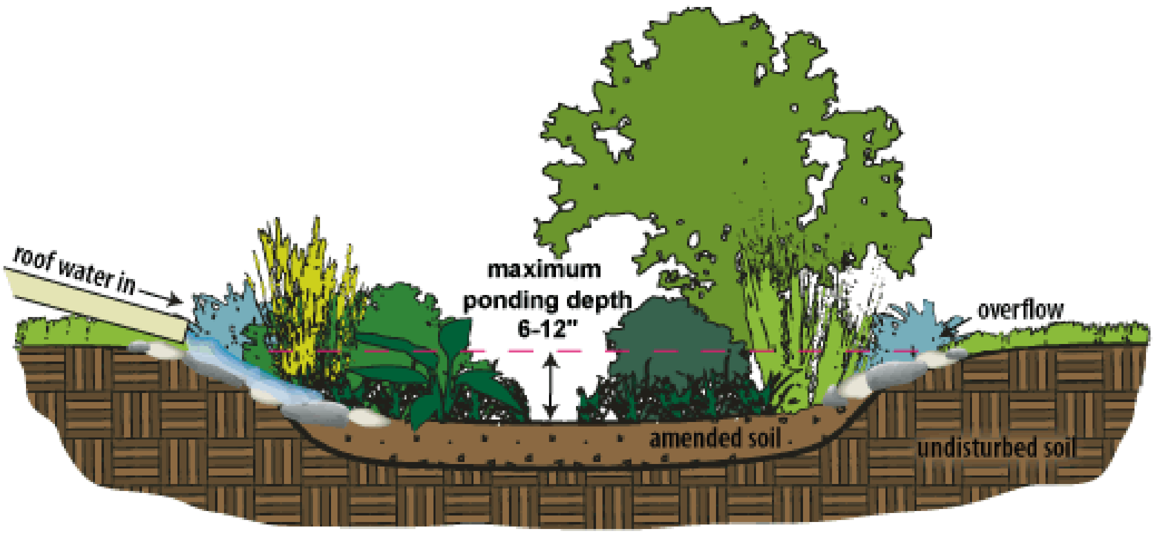



*Figure 6-6.2*
*Typical Rain Garden Cross-Section*

### 6.6.3 Device Uses and Applicability

Potential applications for Bioretention:

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

Bioretention addresses:

- Water Quality / Infiltration
- Volume reduction
- Channel Protection
- Peak Flow Management

### 6.6.4 Bioretention in the Urban Landscape

Bioretention areas are suitable for many types and sizes of development, from single-family residential to high-density commercial projects. Flexible and easy to incorporate in landscaped areas, bioretention facilities are ideal for placement in roadway median strips and parking lot islands, see Figure 6-6.2 for a typical cross-section.

In highly urbanized watersheds, bioretention is often one of the few retro-fit options that can be cost effectively employed by modifying existing landscaped areas, converting islands, under-used parking areas, and/or integrating into the resurfacing of a parking lot. Bioretention systems which can be applied in urban environments include planter boxes, residential applications, tree wells, parking lots, roadways, and industrial and commercial applications, which can capture both site and roof runoff. The application of bioretention systems is not limited to this list. Examples for each of these alternatives are provided below.

#### Planter Boxes

A flow-through planter box is designed with an impervious bottom or is placed on an impervious surface, see Figure 6-6.3 (Page 6-21). Pollutant reduction is achieved as the water filters through the soil. Flow control is obtained by storing the water in a reservoir above the soil and detaining it as it flows through the soil.

### Residential Applications

Landscaped garden areas can be designed with bioretention systems to create decorative features, habitat, and stormwater treatment at a residential site. The design can be as simple as incorporating a planting bed into the lowest point on a site.

### Tree Wells

Bioretention principles can be incorporated into a tree well design to create mini-treatment areas throughout a site. The design should ensure that the ponding area depth is appropriate to the tree size and species.

### Parking Lots

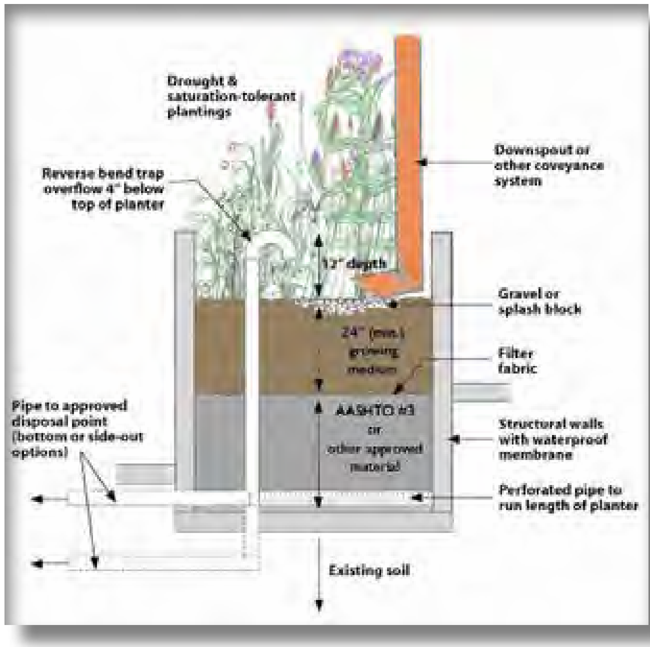
Parking lots are an ideal location for bioretention systems. Bioretention can be incorporated as an island, median, or along the perimeter of the parking area. Bioretention areas can enhance the aesthetics of a parking lot while managing stormwater from the site, see Figure 6-6.4. Site grading must not result in erosive velocities.

### Roads

Linear bioretention basins can be constructed alongside roads, in roadway medians, or in bump-outs that double as traffic calming devices. The system will manage runoff from the street and help to control automotive pollutants. In addition, these systems can help control roadway flooding.

### Commercial/Industrial/Institutional

At commercial, industrial, and institutional sites, areas for stormwater management and green space are often limited. At these sites, bioretention systems serve multiple purposes (i.e. stormwater management and landscaping). Bioretention areas can be used to manage runoff from impervious site areas such as parking lots, sidewalks, and rooftops.




Courtesy of Philadelphia Stormwater Manual v2.0

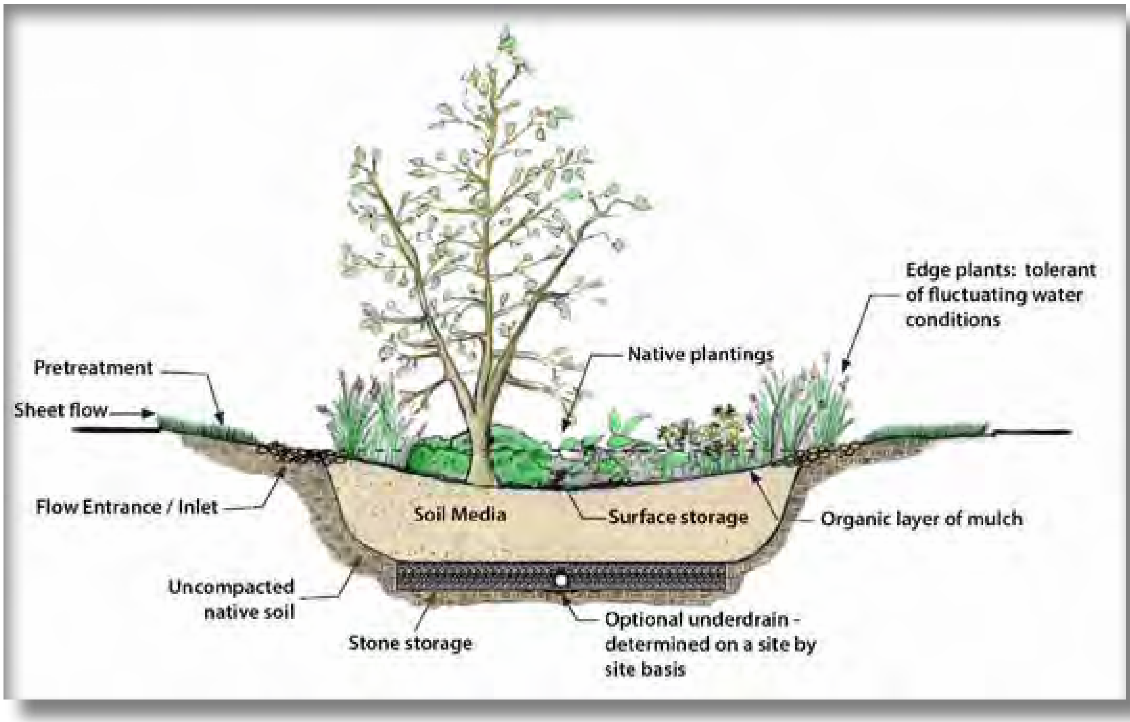
*Figure 6-6.3*
*Profile of flow-through planter box*

*Figure 6-6.4*
*Bioretention off parking area*

### 6.6.5 Components of a Bioretention System

Bioretention systems can be designed to infiltrate all or some of the flow that they treat, see Figure 6-6.5. The primary components of a bioretention system are:

- Pretreatment
- Flow entrance / inlet
- Surface storage (ponding area)
- Organic layer or mulch
- Native plantings
- Soil Media
- Choker Stone Layer
- Stone storage (if required)
- Underdrain (if required)
- Overflow Structure
- Impermeable Liner (specific design practices)




*Modified from Philadelphia Stormwater Manual v2.0*

*Figure 6-6.5*
*Components of a Bioretention*

- Pretreatment

  Pretreatment is recommended for bioretention systems. Additional pretreatment may prolong the life of the system by reducing sediment and other pollutant loads. Pretreatment options may include a grass strip, pretreatment cells, stone energy dissipaters, etc.

- Flow Entrance / Inlet

  It is recommended that runoff is conveyed to a curbless bioretention area via sheet flow over a grass or gravel filter strip. This is not always possible due to site constraints or space limitations. On sites where curb removal is not an option or where flow is concentrated by the time it reaches the bioretention area, curb openings coupled with energy dissipaters provide an alternative runoff inlet, see Figure 6-6.6 (page 6-23).

Roof leaders that flow into bioretention areas also require energy dissipaters to prevent erosion in the bed.

- Surface Storage (ponding area)

  Surface storage provides temporary storage of stormwater runoff before infiltration, evaporation, and uptake can occur within the bioretention system. Ponding time provides water quality benefits by allowing larger debris and sediment to settle out of the water. Ponding design depths reduce hydraulic loading of underlying soils, minimize facility drainage time, and prevent standing water.

- Organic Layer or Mulch

  The organic layer or mulch provides a medium for biological growth, decomposition of organic material, adsorption, and binding of heavy metals. The mulch layer can also serve as a sponge that absorbs water during storms and retains water for plant growth during dry periods.

*Figure 6-6.6*
*Flow Entrance*

- Native Plantings

  The plant material in a bioretention system removes nutrients and stormwater pollutants through vegetative uptake, evaporate water through evapotranspiration, and creates pathways for infiltration through root development and plant growth. A varied plant community is recommended to avoid susceptibility to insect and disease infestation and to ensure viability. A mixture of groundcover, grasses, shrubs, and trees is recommended to create a microclimate that can ameliorate urban stresses as well as discourage weed growth and reduce maintenance.

- Soil Media

  The soil media acts as a filter between the surface storage and the native soil. The prepared planting soil provides additional storage while the water infiltrates into the native soil. Storage is a function of both soil depth and bioretention surface area. The planting soil also provides a medium suitable for plant growth.

- Choker Stone Layer

  The choking layer is installed on top of the underdrain layer and below the soil media layer. This consists of a layer of choker stone (typically ASTM D448 No.8 or No.89 washed gravel). The depth of the choker layer should be 1 inch of choker stone for every 1 foot of soil media. For instance, 3 feet of soil media depth would have 3 inches of choker stone.

  In lieu of the choking layer, designers have the option of using a needle-punched, non-woven geotextile fabric with a flow rate of > 110 gal./min./sq. ft. placed between the underdrain and the soil media layers. This may be a desirable option if available head or depth to water table or bedrock are site constraints. However, this option should only be used when the choking layer cannot fit into the practice.

- Storage Layer (if required)

  In addition to surface and soil storage, a storage layer can be included to provide additional storage. To increase storage for larger storm events; chambers, perforated pipe, stone, or other acceptable material can be incorporated below the filter media layer.

- Underdrain (if required)

  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 a soil test determines that the water cannot infiltrate with 48 hours, an underdrain is necessary.

*Figure 6-6.6*
*Bioretention with Overflow*

- Overflow Structure

  An overflow structure may be provided at the maximum ponding depth. When runoff exceeds system storage capacity, the excess flow leaves the system through the overflow. If additional stormwater controls are required on the site, the overflow can connect to a system that will provide channel protection or peak rate control. If no additional stormwater controls are required, the overflow can be connected to a storm sewer, combined sewer, or receiving water, as appropriate for the site.

- Impermeable Liner (specific design practices)

  This material should be used only for appropriate hotspot or slip prone areas, small-scale practices that are located near building foundations, or in appropriate fill applications where deemed necessary by a geotechnical investigation. Designers should use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd. non-woven geotextile.

### 6.6.6 Recommended Design Procedures

Design of bioretention systems are somewhat flexible. The area, depth, and shape of the system can be varied to accommodate site conditions and constraints. The following are general guidelines to ensure proper design:

1. Investigate the feasibility of infiltration in the area proposed for bioretention. If infiltration is not feasible, consider amended soils, an underdrained bioretention system or an alternate location for the bioretention area. The underlying soil must infiltrate within 48 hours. If water does not infiltrate within 48 hours than the system should be designed as an extended filtration system.

2. Estimate the total storage volume and adjust area and/or depths as needed to provide required storage. Use Table 6-6.1 (page 6-25) as a starting point in designing a bioretention basin.

| Table 6-6.1: Suggested Starting Design Values for Areas and Depths | |
|---|---|
| Typical Ponding Depth* | 6 – 12 inches |
| Soil Depth | 18 – 24 inches |
| Mulch Layer Depth | 2 – 3 inches |
| Side Slope | 3:1 or flatter |
| Choker Stone Layer | 1 inch per 1 foot of soil media |
| *Note pond depth may not exceed 18 inches | |

3. Estimate how long the surface ponding and soil storage will take to drain based on the infiltration area and the saturated vertical infiltration rate of the native soil. The maximum drain time for the entire storage volume (surface, planting soil, and gravel if used) is 48 hours. If storage does not drain in this time, adjust the surface depth, soil depth, surface area, and/or the design until the volume, drainage time, and site constraints are met.
4. Determine the choker layer thickness. The depth of the choker layer should be 1 inch of choker stone for every 1 foot of soil media. For instance, 3 feet of soil media depth would have 3 inches of choker stone.
5. In areas where infiltration might threaten existing or proposed structures, such as a hotspot or slip prone soil, an impervious liner may be specified.
6. Check that any release rate requirements (including release through any underdrain) are met by the system as designed.
7. Choose plants, trees, and either mulch or seeding appropriate to the site. See Appendix C for suggested plantings.
8. Choose a soil mix and depth appropriate for plant growth. Soil depth shall be the larger of what is needed for storage or healthy plant growth. For information on soil media requirements see the bioretention section 4.2.3 of the West Virginia DEP Stormwater Management and Design Guidance Manual.
9. Design an inlet control for energy dissipation including pretreatment area.
10. Design a overflow for large storms capable of safely passing the 10-year 24 hour storm event. A bioretention system should not be located in areas where failure of the structure will result in flooding.

### 6.6.7 Infiltration Credit

Post-Construction Stormwater Management, located in Section 2.3.4 requires the first one (1) inch of rainfall to be managed. Bioretention may be used to manage the first one inch. Guidelines in Table 6-6.2.

Table 6-6.2: Bioretention Infiltration Credit

| Credit | Description | Application |
|---|---|---|
| 60% Volume Reduction | Basic Design<br>• Underdrain<br>• At least 1.5 ft. of soil media depth, but less than 2.0 ft.<br>• No infiltration sump below underdrain pipe(s). | Sites with vertical constraints such as high bedrock or water table, stormwater hotspot, slip prone, or other applications that require an impermeable liner. |
| 100% Volume Reduction | Infiltration Design<br>• No underdrain<br>• Water infiltrates into the underlying soil within 48 hours.<br>OR<br>Extended Filtration Design<br>• Underdrain<br>• At least 2.0 ft. of soil media depth,<br>OR<br>• At least 1.5 ft. of soil media depth with stone sump below underdrain designed to drain Design Volume within 48 hours on suitable soils (e.g., limited on fill) or upturned elbow underdrain design. | Generally most sites that have good to marginal infiltration rates -- HSG A, B, and C and do not require an impermeable liner.<br><br>Use the Infiltration Design for tested infiltration rates > 0.5 in. per hr., and the Extended Filtration Design for other sites. |

*Courtesy of WVDEP*

### 6.6.8 Materials

The following materials in Table 6-6.3 may be used to ensure the bioretention systems are efficient and effective.

Table: 6-6.3: Material Specifications

| Material | Specification | Notes |
|---|---|---|
| Filter Media | 70%-88% sand<br>• 8%-26% top soil<br>• 3%-5% organic matter in the form of leaf compost. | Minimum depth of 24 in.; 36 in. recommended; (18 in. if an infiltration sump is used ) The volume of filter media used should be based on 110% of the plan volume, to account for settling or compaction. |
| Mulch Layer | Use aged, shredded hardwood bark mulch. | Lay a 2 to 3 in. layer on the surface of the filter bed. |
| Plant Materials | See Appendix C | Establish plant materials as specified in the landscaping plan and the recommended plant list. |
| Alternative Surface Cover | Use river stone or pea gravel, coir and jute matting, or turf cover. | Lay a 2 to 3 in. layer to suppress weed growth. |
| Filter Fabric (optional) | Woven monofilament fabric or non-woven geotextile as per AASHTO M-288 (do not use siltfence). | Apply only to the side slopes and, optionally, in a 2 ft. wide strip directly above the underdrain pipes. |
| Choking Layer | Layer of choker stone (typically No.8 or No.89 washed gravel), which is laid over the underdrain stone at a depth of 1 in. of choker stone for every 1 ft. of overlying soil media. An alternative is needle-punched, non-woven geotextile with the flow rate of > 110 gal./ min./sq. ft. (ONLY if stone choking layer cannot fit into the practice). | |
| Underdrain Stone | Between 7 and 21 mg./kg. of P in the soil media. CECs greater than 10. | 12 in. depth |
| Infiltration Sump (As Needed) | 1-in. diameter stone should be double-washed and clean and free of all fines (e.g., ASTM D448 No. 57 stone). | Designed to drain the sump design volume (gravel layer below underdrain or with an upturned elbow) within 48 hours; can use standard 12 in. depth below the underdrain invert if soil at the infiltration sump elevation has a verified infiltration rate ≥ 0.25 in./hr. |
| Storage Layer (optional) | To increase storage for larger storm events, chambers, perforated pipe, stone, or other acceptable material can be incorporated below the filter media layer. | |
| Impermeable Liner (optional) | Use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd. non-woven geotextile.<br>Note: This is used only for stormwater hotspots, and small practices near building foundations, or in fill soils as determined by a geotechnical investigation. | |
| Underdrains, Cleanouts, and Observation Wells | Use 4- or 6-in. rigid PVC pipe (or equivalent corrugated HDPE for small Bioretention practices), with 3/8-in. perforations at 6 in. on center; each underdrain should be located no more than 20 feet from the next pipe. | Lay the perforated pipe under the length of the Bioretention cell, and install non-perforated pipe as needed to connect with the storm drain system or to daylight in a stabilized conveyance. Install Ts and Ys as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface with vented caps at the Ts and Ys. |

*Courtesy of WVDEP*

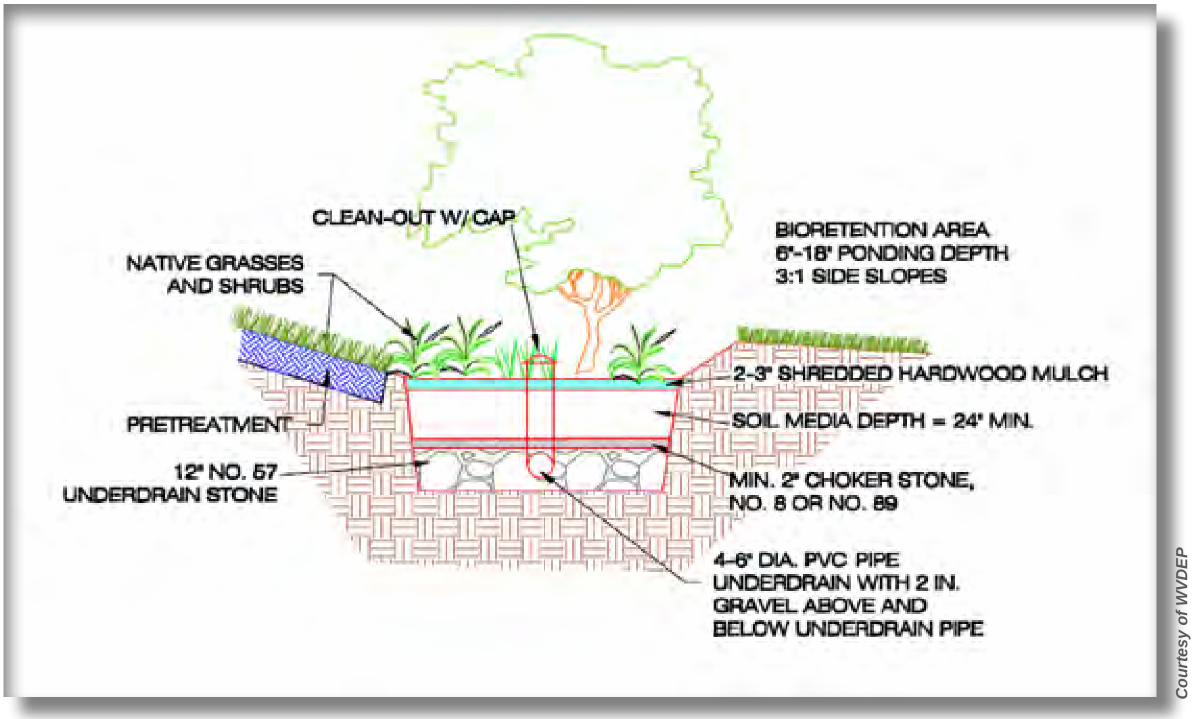



*Figure 6-6.7*
*Bioretention construction example*

### 6.6.9 Construction Guidelines

The following is a typical construction sequence to properly install a Bioretention basin, see Figure 6-6.7. The construction sequence for Residential Rain Gardens is more simplified. These steps may be modified to reflect different Bioretention applications or expected site conditions:

- Step 1. Construction of the Bioretention area may only begin after the entire contributing drainage area has been stabilized with vegetation. It may be necessary to block certain curb or other inlets while the Bioretention area is being constructed. The proposed site should be checked for existing utilities prior to any excavation.
- Step 2. The designer and the installer should have a preconstruction meeting, checking the boundaries of the contributing drainage area and the actual inlet elevations to ensure they conform to original design. Since other contractors may be responsible for constructing portions of the site, it is quite common to find subtle differences in site grading, drainage and paving elevations that can produce hydraulically important differences for the proposed Bioretention area. The designer should clearly communicate, in writing, any project changes determined during the preconstruction meeting to the installer and the City.
- Step 3. Temporary approved erosion and sediment controls are needed during construction of the Bioretention area to divert stormwater away from the Bioretention 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 construction process.
- Step 4. Any pre-treatment cells should be excavated first and then sealed to trap sediments.
- Step 5. Excavators or backhoes should work from the sides to excavate the Bioretention area to its ap-

propriate design depth and dimensions. Excavating equipment should have scoops with adequate reach so they do not have to sit inside the footprint of the Bioretention area. Contractors should use a cell construction approach in larger Bioretention basins, whereby the basin is split into 500 to 1,000 sq. ft. temporary cells with a 10-15 foot earth bridge in between, so that cells can be excavated from the side.

- Step 6. It may be necessary to rip the bottom soils to a depth of 6 to 12 inches to promote greater infiltration.
- Step 7. If using a filter fabric, place the fabric on the sides of the Bioretention area with a 6-inch overlap on the sides. If an underdrain stone storage layer will be used, place the appropriate depth of No.57 stone on the bottom, install the perforated underdrain pipe, then pack No.57 stone to 3 inches above the underdrain pipe. On top of the No.57 stone, add 2 inches of choker stone (No.8 or No.89 stone) and then 2 to 4 inches of construction sand as a filter between the underdrain and the soil media layer. If no stone storage layer is used, start with 6 inches of No.57 stone on the bottom, and proceed with the layering as described above.
- Step 8. Deliver the soil media and store it on an adjacent impervious area or plastic sheeting. Apply the media in 12-inch lifts until the desired top elevation of the Bioretention area is achieved. Wait a few days to check for settlement, and add additional media, as needed, to achieve the design elevation.
- Step 9. Prepare planting holes for any trees and shrubs, install the vegetation, and water accordingly. Install any temporary irrigation.
- Step 10. Place the surface cover (mulch, river stone or turf), depending on the design. If coir or jute matting will be used in lieu of mulch, the matting will need to be installed prior to planting (Step 9), and holes or slits will have to be cut in the matting to install the plants.
- Step 11. Install the plant materials as shown in the landscaping plan, and water them during weeks of no rain for the first two months.
- Step 12. If curb cuts or inlets are blocked during Bioretention installation, unblock these after the drainage area and side slopes have good vegetative cover. If the drainage area includes newly installed asphalt, it is recommended that unblocking curb cuts and inlets take place after two to three storm events since new asphalt tends to produce a lot of fines and grit during the first several storms.
- Step 13. Conduct the final construction inspection (see below), then log the GPS coordinates for each Bioretention facility and submit to the City's Stormwater Department.



### 6.6.10 Maintenance

Properly designed and installed bioretention systems require little maintenance. During periods of extended drought, bioretention systems may require watering approximately every 10 days. Table 6-6.4 provides recommended guidelines for inspection and maintenance activities.

Table 6-6.4: Bioinfiltration / Bioretention Maintenance Guidelines

| Activity | Schedule |
|---|---|
| ▪ Water vegetation at the end of each day for two weeks after planting is completed.<br>▪ Water vegetation regularly to ensure successful establishment. | First year after installation |
| ▪ Re-mulch void areas.<br>▪ Treat diseased trees and shrubs.<br>▪ Keep overflow free and clear of leaves. | As needed |
| ▪ Inspect soil and repair eroded areas.<br>▪ Remove litter and debris.<br>▪ Clear leaves and debris from overflow. | Monthly |
| ▪ Inspect trees and shrubs to evaluate health, replace if necessary.<br>▪ Inspect underdrain cleanout.<br>▪ Verify drained out time of system. | Biannually |
| ▪ Add additional mulch.<br>▪ Inspect for sediment buildup, erosion, vegetative conditions, etc. | Annually |
| ▪ Maintain records of all inspections and maintenance activity. | Ongoing |

Design of bioretention systems is not limited to the examples shown within this manual. For more examples please refer to the biorention section of the West Virginia DEP Stormwater Management and Design Guidance Manual at http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/Documents/Specification_4.2.3_Bioretention_WV-SW-Manual-11-2012.pdf

Successful stormwater management plans will combine appropriate materials and designs specific to each site.

Filters

## 6.7 Filters

### 6.7.1 Device Description

Filters are used to reduce pollutant levels in stormwater runoff by filtering out sediment, metals, and other pollutants and the filtered stormwater can then be infiltrated or discharged. Filters are structures in excavated areas containing a layer of sand, organic material, or other filter media. These can be designed to provide a specific detention time and may be combined with other BMP practices. Figure 6-7.1 provides a schematic of a filter.

A filtration practice is differentiated from a bioretention practice by the use of sand as filter media and a lack of a vegetated layer.

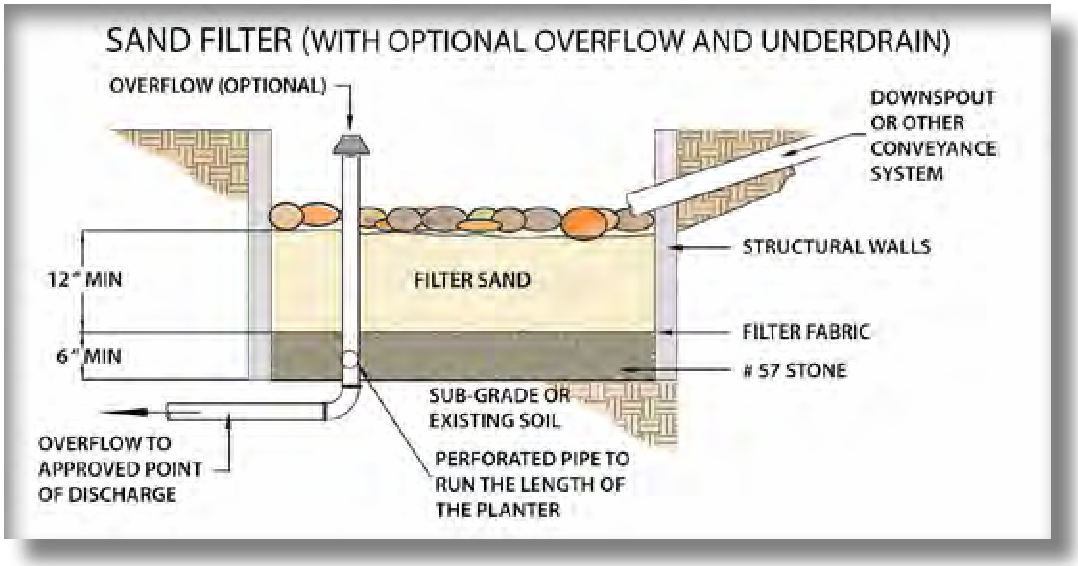



*Figure 6-7.1*
*Filter cross-section*

There is a multitude of available manufactured filters in addition to innumerable site specific designs. Filters may provide necessary water quality treatment when infiltration cannot be achieved or where contaminant levels may preclude untreated infiltration.

### 6.7.2 Key Elements

- Acceptable technique on sites where vegetated systems are impractical.
- Surface ponding that drains down in no more than 48 hours.
- Filter medium (typically sand, peat, or a mixture) removes pollutants and increases travel time.
- Underdrain allowed on sites where infiltration is not feasible, or where a filter is used in combination with other practices.
- Flow splitter or overflow bypasses large storms.
- Maintenance is required to preserve capacity of system.

### 6.7.3 Device Uses and Applicability

Potential applications for filters:

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

Filters Address:

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

### 6.7.4 Stormwater Filters in the Urban Landscape

Stormwater filters may be suitable for sites without sufficient surface area available for vegetated bioretention basins. Filters are designed to either infiltrate or to treat and convey runoff to a disposal point. The only difference between a filter and a bioretention basin, as defined in this manual, is surface vegetation. Vegetated basins often include a filtering layer that may be designed according to the guidelines in this section. Filters are recommended as a viable BMP for use in:

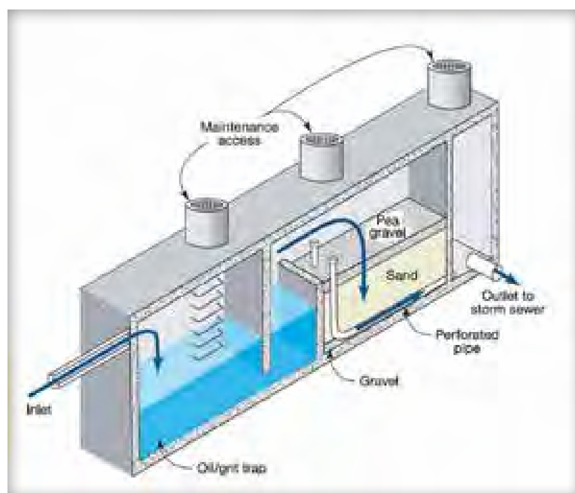
- Parking lots
- Roadways
- Industrial sites
- Marina areas
- Transportation facilities
- Fast food and shopping areas
- Waste Transfer Stations
- Urban Streetscapes

Filters may be visible from the surface, as seen in Figure 6-7.2, or completely subsurface. They may be designed as a single large chamber (often with a smaller chamber for pretreatment) or as a long, narrow trench at the perimeter of a parking lot see Figure 6-7.4 (page 6-33).

Manufactured filters, illustrated in Figure 6-7.3, or oil/water separators capable of removing oils and grease and other contaminants of concern from stormwater are required for commercial or industrial facilities having a high potential for stormwater contamination. This includes fueling stations, maintenance facilities and other locations which typically require some type of State environmental permitting or registration.

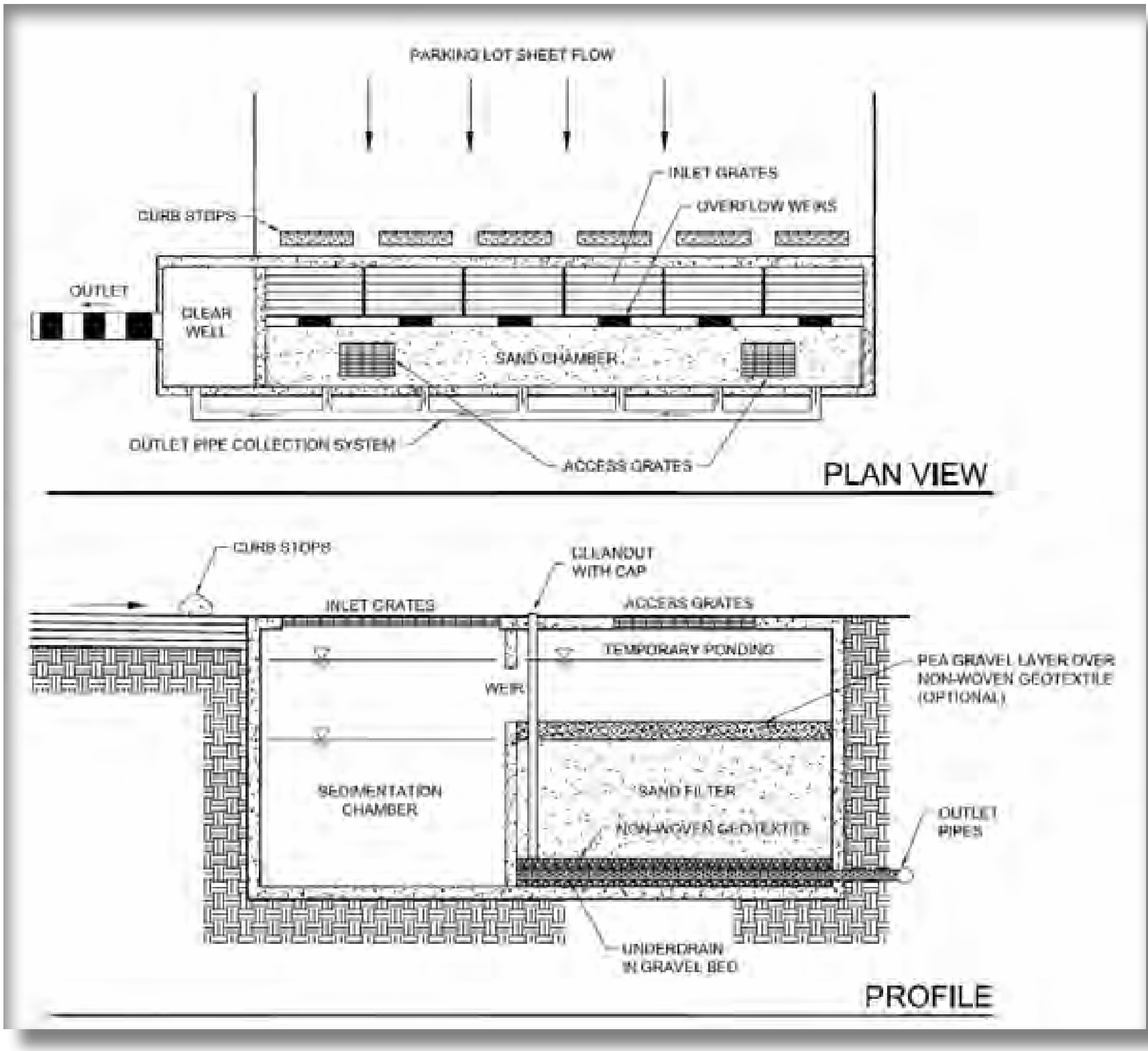
Courtesy of Montgomerycountymd.gov

***Figure 6-7.2***
***Stormwater Filter***




Courtesy of Philadelphia Stormwater Manual V 2.0

***Figure 6-7.3***
***Underground Sediment Trap and Oil Removal Device.***




*Courtesy of WVDEP*

***Figure 6-7.4***
***Cross-section of a parking lot Filter***

## 6.7.5 Components of a Stormwater Filter System

Stormwater filters can be designed to infiltrate all or some of the flow. Components of a stormwater filter system include:

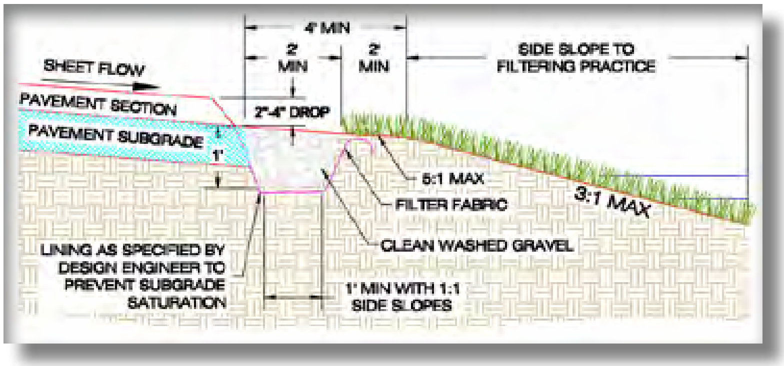
- Excavation or Container
- Pretreatment
- Flow Entrance/Inlet
- Surface Storage (ponding area)
- Filter Media
- Underdrain (if required)
- Overflow Structure

- Excavation or Container

  The filter media may be contained in a simple trench lined with a geotextile, or in a more structural facility such as concrete. In either case, the container may be designed either to allow infiltration or to collect flow in an underdrain system.

- Pretreatment

  Adequate pre-treatment is needed to prevent premature filter clogging and ensure filter longevity, see Figure 6-7.5. Incorporating baffles, submerged orifices, and other techniques into the pre-treatment / sedimentation chamber will improve performance longevity and therefore reduce maintenance costs. An effective method of increasing the functional longevity of the filter is to limit the drainage area to impervious cover only. This helps to minimize the sources of sediment and organic material that combine to clog the surface of filtering practices. Acceptable forms of pretreatment for filters are filter strips, appropriate prefabricated and proprietary designs, swales, sediment forebays, bioretention, and planter boxes.




*Courtesy of WVDEP*

***Figure 6-7.5***
***Detail of pretreatment of pavement edge***

- Flow Entrance/Inlet

  Flow may be introduced to a filter through a number of controls. Stormwater should enter as sheet flow, if not a flow spreader is required.

- Surface Storage (ponding area):

  The filter may allow water to pond during intense storms as water flows slowly through the filter media.

- Filter Media

  Stormwater flows onto filter media where sediments and other pollutants are separated from the stormwater. Filter materials such as sand, peat, granular activated carbon (GAC), leaf compost, pea gravel and others are used for water quality treatment. Coarser materials allow faster transmission, but finer media filters particles of a smaller size. Sand has been found to be a good balance between these two criteria (Urbonas, 1999), but different types of media remove different pollutants. While sand is a reliable material to remove TSS, (Debusk and Langston, 1997) peat removes slightly more TP, Cu, Cd, nd Ni than sand. Depending on the characteristics of the stormwater runoff, a combination of these filter materials will provide the best quality results. In addition to determining the degree of filtration, media particle size determines travel time in the filter and plays a role in meeting release rate requirements. The minimum recommended depth is 12 inches, (18 to 24 inches recommended).

- Underdrain (if required)

  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.

### 6.7.6 Recommended Design Procedures

The following are general guidelines to ensure proper design:

1. Investigate the feasibility of infiltration in the area proposed for the stormwater filter.

   *It should be noted: Facilities with a high potential for stormwater contamination cannot infiltrate into an un-contaminated area or natural soil without specific approval from the City.*

2. The filter area may be estimated initially using Darcy's Law, assuming the soil media is saturated. Darcy's Law equation is:

$$SA_{filter} = \frac{(Dv)(d_f)}{[(k)(h_{avg} + d_f)(t_f)]}$$

Where:

| | | |
|---|---|---|
| $SA_{filter}$ | = | area of the filter surface (ft2) |
| Dv | = | Design Volume (ft3) |
| df | = | filter media depth (thickness, ft) = minimum 1 ft above underdrains |
| k | = | Coefficient of permeability (partially clogged sand) = 3.5 ft/day |
| hf | = | Average height of water above filter surface bed (ft) = maximum 5 ft |
| tf | = | Design drawdown time (days) = 40 hours = 1.67 days |

*Courtesy of WVDEP*

3. A filter designed for infiltration, estimate the total storage volume and adjust the area and/or depth as needed to provide required storage per Table 6-7.1.

| Table 6-7.1: Suggested Starting Design Values for Ponding and Media Depths | |
|---|---|
| Average Ponding Depth | 3 – 6 inches |
| Filler Media Depth | 18 – 30 inches |

4. Using the stormwater filter area and the saturated vertical infiltration rate of the filter media, estimate the drainage time for ponded surface water. The saturated vertical infiltration rate may be based on the estimated saturated hydraulic conductivity of the proposed filter materials. The maximum drain down time for the entire storage volume is 48 hours. If storage does not drain in this time, adjust pretreatment depth, filter media depth, surface area and the design until the volume and drainage time constraints are met.

5. Design underdrains to minimize the chances of clogging. Underdrains shall be provided with cleanouts to facilitate maintenance.

6. In areas where infiltration might threaten existing or proposed structures, such as a hotspot or slip prone soil, an impervious liner may be specified. Check that any release rate requirements (including release through any underdrain) are met by the system.

7. Design a pretreatment facility.

8. Design an inlet control for the filter media chamber to meet energy dissipation requirements.

9. Design a bypass or control structure for larger storms.

10. Design any structural components required.



### 6.7.7 Infiltration Credit

Post-Construction Stormwater Management, located in Section 2.3.4 requires the first one (1) inch of rainfall to be managed. Filters may be used to manage the first one inch. Guidelines in Table 6-6.2.

Table 6-6.2: Filter Infiltration Credit

| Credit | Description | Application |
|---|---|---|
| 60%<br>Volume<br>Reduction | Underlying soil will not allow water to infiltrate within 48 hours:<br>• One cell design<br>• Sand Media used | Hydrologic Soil group D, Hotspots, high bedrock or water table, or sites that require an impermeable liner. |
| 100%<br>Volume<br>Reduction | Water infiltrates into the underlying soil within 48 hours.<br>OR<br>Underdrain<br>• Sand media with an organic layer (12 inches minimum). | Sites with Hydrologic soil groups A, B, or C. |

Proprietary filters will be reviewed on a case by case basis.

### 6.7.8 Materials

The following materials in Table 6-7.2 may be used to ensure the filter is efficient and effective.

Table: 6-7.2: Material Specifications

| Materials | Specification |
|---|---|
| Surface Cover | Surface sand filters: 3-inch layer of topsoil on top of a non-woven geotextile above the sand layer.<br>Underground sand filters: Optional - Pea gravel layer on top of a coarse non-woven geotextile laid over the sand layer. |
| Sand | Clean AASHTO M-6/ASTM C-33 medium aggregate concrete sand with a particle size range of 0.02 to 0.04 inch in diameter. |
| Underdrain | The underdrain should consist of High Density Polyethylene smooth or corrugated flexible wall pipe. Pipes must comply with ASHTO M252 and ASTM F405.<br><br>Underdrains meeting ASTM F758 should be perforated with slots that have a maximum width of 3/8 inch and provide a minimum inlet area of 1.76 square inches per linear foot of pipe.<br><br>Underdrains meeting ASTM F949 should be perforated with slots with a maximum width of 1/8 inch that provide a minimum inlet area of 1.5 square inches per linear foot of pipe.<br><br>Underdrain pipe supplied with precision-machined slots provides greater intake capacity and superior clog-resistant drainage of fluids, as compared to standard round-hole perforated pipe. Slotted underdrain reduces entrance velocity into the pipe, thereby reducing the possibility that solids will be carried into the system. Slot rows can generally be positioned symmetrically or asymmetrically around the pipe circumference, depending upon the application. |

| Materials | Specification |
|---|---|
| Non-woven Geotextile | Use needled, non-woven, polypropylene geotextile meeting the following specifications:<br>Grab Tensile Strength (ASTM D4632) ≥ 120 lbs<br>Mullen Burst Strength (ASTM D3786) ≥ 225 lbs/sq. in.<br>Flow Rate (ASTM D4491) ≥125 gpm/sq. ft.<br>Apparent Opening Size (ASTM D4751) = US #70 or #80 sieve<br>NOTE: Heat-set or heat-calendared fabrics are not recommended. |
| Underdrain Stone | Use #57 stone or the ASTM equivalent (1 inch maximum). |
| Impermeable Liner | Use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd. nonwoven geotextile. |

*Courtesy of WVDEP*

### 6.7.9 Construction Guidelines

No runoff shall be allowed to enter the filter prior to completion of all construction activities, including revegetation and final site stabilization. Construction runoff shall be treated in separate sedimentation basins and routed to bypass the filtration system. Should construction runoff enter the system prior to final site stabilization, all contaminated materials must be removed and replaced with new clean filter materials before a regulatory inspector approves its completion. The approved erosion and sediment control plans shall include specific measures to provide for the protection of the filter before the final stabilization of the site.

The following is the typical construction sequence to properly install a structural sand filter. This sequence can be modified to reflect different filter designs, site conditions, and the size, complexity and configuration of the proposed Filtration application:

- Step 1. Filter should only be constructed after the contributing drainage area to the facility is completely stabilized, so sediment from the contributing drainage area does not flow into and clog the filter. If the proposed Filtration area is used as a sediment trap or basin during the construction phase, the construction notes should clearly specify that, after site construction is complete, the sediment control facility will be dewatered, dredged and re-graded to design dimensions for the post-construction filter.
- Step 2. Stormwater should be diverted around filter as it is being constructed. This is usually not difficult to accomplish for off-line filter. It is extremely important to keep runoff and eroded sediments away from the filter throughout the construction process. Silt fence or other sediment controls should be installed around the perimeter of the filter, and erosion control fabric may be needed during construction on exposed side-slopes with gradients exceeding 4H:1V. Exposed soils in the vicinity of the Filtration practice should be rapidly stabilized by hydro-seed, sod, mulch, or other method.
- Step 3: Assemble construction materials on-site, make sure they meet design specifications, and prepare any staging areas.
- Step 4: Clear and strip the project area to the desired subgrade.
- Step 5: Excavate/grade until the appropriate elevation and desired contours are achieved for the bottom and side slopes of the filter.
- Step 6: Install the filter structure and check all design elevations (concrete vaults for surface, underground and perimeter sand filters). Upon completion of the filter structure shell, inlets and outlets should be temporarily plugged and the structure filled with water to the brim to demonstrate water tightness.

Maximum allowable leakage is 5% of the water volume in a 24-hour period. If the structure fails the test, repairs must be performed to make the structure watertight before any sand is placed into it.

- Step 7: Install the gravel, underdrains, and choker layer of the filter.
- Step 8: Spread sand across the filter bed in 1 foot lifts up to the design elevation. Backhoes or other equipment can deliver the sand from outside the filter structure. Sand should be manually raked. Clean water is then added until the sedimentation chamber and filter bed are completely full. The facility is then allowed to drain, hydraulically compacting the sand layers. After 48 hours of drying, refill the structure to the final top elevation of the filter bed.
- Step 9 (Surface Sand Filters Only): Install the permeable filter fabric over the sand, add a 3-inch topsoil layer and pea gravel inlets, and immediately seed with the permanent grass species. The grass should be watered, and the facility should not be switched on-line until a vigorous grass cover has become established.
- Step 10: Stabilize exposed soils on the perimeter of the structure with temporary seed mixtures appropriate for a buffer. All areas above the normal pool should be permanently stabilized by hydroseed, sod, or seeding and mulch.
- Step 11: Conduct the final construction inspection, then log the GPS coordinates for each filter facility and submit them to the City's Stormwater Department. Multiple construction inspections are critical to ensure that filter is properly constructed. Inspections are recommended during the following stages of construction:
  - Pre-construction meeting
  - Initial site preparation (including installation of project erosion and sediment controls)
  - Excavation/grading to design dimensions and elevations
  - Installation of the filter structure, including the water tightness test
  - Installation of the underdrain and filter bed
  - Check that turf cover is vigorous enough to switch the facility on-line
  - Final inspection (after a rainfall event to ensure that it drains properly and all pipe connections are watertight)

### 6.7.10 Maintenance

For filters located entirely underground, unobstructed access must be provided over the entire sand filter, including inlet and outlet pipe structures, by either doors or removable panels. Ladder access is required for vault heights greater than 4 feet.

In areas where the potential exists for the discharge and accumulation of toxic pollutants (such as metals), filter media removed from filters must be handled and disposed of in accordance with all state and federal regulations.

In West Virginia, temperatures may dip below freezing for several months, and surface filtration may not be as effective in the winter. Peat and compost may hold water, freeze, and become impervious on the surface. Design options that allow direct sub-surface discharge into the filter media during cold weather may help overcome this condition.

Table 6-7.3 provides recommended guidelines for inspection and maintenance activities for filters.

| Table 6-7.3: Filter Maintenance Guidelines | |
|---|---|
| Activity | Schedule |
| ▪ Rake filter media surface for the removal of trash and debris from control openings.<br>▪ Repair leaks from the sedimentation chamber or deterioration of structural components.<br>▪ Remove the top few inches of filter media and cultivation of the surface when filter bed is clogged. | As needed |
| ▪ Inspect filter for standing water (filter drainage is not optimal) and discoloration (organics or debris have clogged filter surface). | Quarterly |
| ▪ Inspect Filter Media<br>▪ Clean out accumulated sediment from filter bed chamber.<br>▪ Clean out accumulated sediment from sedimentation chamber. | Annually |
| ▪ Maintain records of all inspections and maintenance activity. | Ongoing |

### 6.7.11 Manufactured Filters

Design of stormwater filters are not limited to the examples shown within this manual. Successful stormwater management plans will combine appropriate materials and designs specific to each site. Manufactured Filter come in all shapes and sizes and can be used in various combinations in the overall design of filtration systems, see Figure 6-7.6.

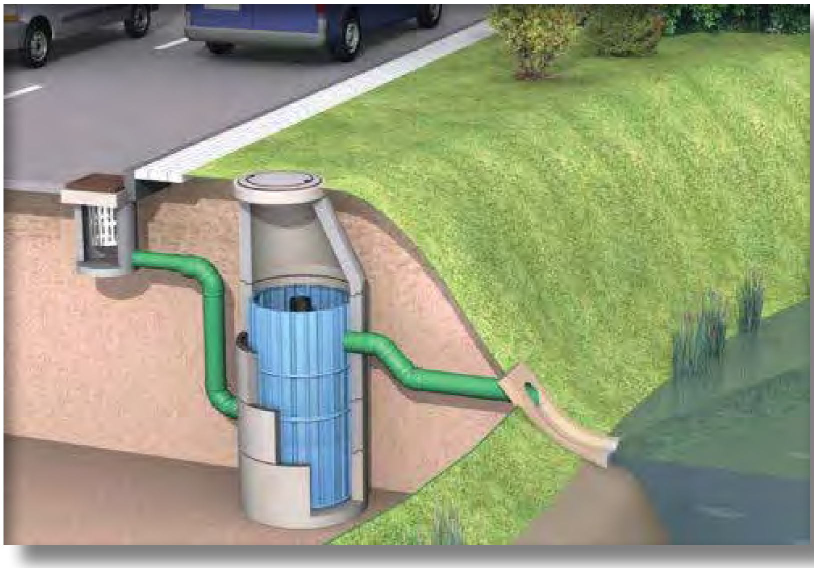


*Figure 6-7.6*
*Example of manufactured filter*

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