4.2 Bioretention

Introduction

Bioretention areas, shallow depressional areas that are filled with an engineered soil media and are planted with trees, shrubs, and other herbaceous vegetation, are one of the most effective stormwater management practices that can be used in coastal South Carolina to reduce post-construction stormwater runoff rates, volumes, and pollutant loads. They also provide a number of other benefits, including improved aesthetics, wildlife habitat, urban heat island mitigation, and improved air quality. See Figures 4.2-1 – 4.2-3 for example designs.

They are designed to capture and temporarily store stormwater runoff in the engineered soil media, where it is subjected to the hydrologic processes of evaporation and transpiration, before being conveyed back into the storm drain system through an underdrain or allowed to infiltrate into the surrounding soils. The engineered soil media is comprised of sand, soil, and organic matter.

Typically, bioretention systems are not designed to provide stormwater detention of larger storms (e.g., 2-year, 10-year), but in some circumstances that may be possible. Bioretention practices should generally be combined with a separate facility to provide those controls.

Figure 4.2-1. Bioretention in Parking Lot (Photo: Center for Watershed Protection)

Figure 4.2-2. Bioretention in a Cul-de-sac (Photo: Center for Watershed Protection)

Figure 4.2-3. Bioretention in a Residential Setting (Photo: NEMO)

KEY CONSIDERATIONS: BIORETENTION

DESIGN CRITERIA:

- Bioretention areas should be designed to completely drain within 72 hours of the end of a rainfall event.
- A maximum ponding depth of 18 inches is recommended within bioretention areas to help prevent the formation of nuisance ponding conditions.
- Unless a shallow water table is found on the development site, bioretention area planting beds should be between 18 – 36 inches deep.
- The distance from the bottom of the practice to the top of the seasonal high water table should not be less than 0.5 feet.
- The infiltration rate of native soil needs to be included in most cases where no under drains are specified.

BENEFITS:

- Helps restore pre-development hydrology on development sites and reduces post-construction stormwater runoff rates, volumes, and pollutant loads.
- Can be integrated into development plans as attractive landscaping features.

LIMITATIONS:

- Can only be used to manage runoff from relatively small drainage areas of up to 5 acres in size.

SITE APPLICABILITY:

- Rural Use
- Suburban Use
- Urban Use
- Construction Cost: Medium
- Maintenance: Medium
- Area Required: Low

STORMWATER MANAGEMENT PRACTICE PERFORMANCE:

Runoff Reduction Credit Approach
(applies to Shellfish Bed, SMS4, and infiltration credit approaches)

- 100% credit for storage volume of infiltration or enhanced design.
- 60% credit for storage volume of standard design.

Coastal Zone Credit Approach

- 100% credit for storage volume of practice.

Statewide Water Quality Requirement Credit Approach

- Runoff Reduction credit applies to infiltration requirement.

Pollutant Removal[1]
80-90% - Total Suspended Solids
55-90% - Total Phosphorus
65-90% - Total Nitrogen
N/A - Metals
55-90% - Pathogens

[1] *expected annual pollutant load removal*

There are two different types of bioretention design configurations:

- **Standard Designs.** Practices with a standard underdrain design and less than 24 inches of filter media depth (see Figure 4.2-4). The particular design configuration to be implemented on a site is typically dependent on specific site conditions and the characteristics of the underlying soils. These criteria are further discussed below.
- **Enhanced Designs.** Practices that can infiltrate the design storm volume in 72 hours (see Figures 4.2-5 and 4.2-6) or practices with underdrains that contain at least 24 inches of filter media depth and an infiltration sump/storage layer (see Figure 4.2-5).

The particular design configuration to be implemented on a site is typically dependent on specific site conditions and the characteristics of the underlying soils. These criteria are further discussed below.

Bioretention Feasibility Criteria

Bioretention can be applied in most soils or topography, since runoff simply percolates through an engineered soil bed and is infiltrated or returned to the stormwater system via an underdrain. Key constraints with bioretention include the following:

Required Space. Planners and designers can assess the feasibility of using bioretention facilities based on a simple relationship between the contributing drainage area and the corresponding bioretention surface area. The surface area is recommended to be approximately 3 to 6% of the contributing drainage area (CDA), depending on the imperviousness of the CDA and the desired bioretention ponding depth.

Site Topography. Bioretention can be used for sites with a variety of topographic conditions, but is best applied when the grade of the area immediately adjacent to the bioretention practice (within approximately 15 to 20 feet) is greater than 1% and less than 5%.

Available Hydraulic Head. Bioretention is fundamentally constrained by the invert elevation of the existing conveyance system to which the practice discharges (i.e., the bottom elevation needed to tie the underdrain from the bioretention area into the storm drain system). In general, 4 to 5 feet of elevation above this invert is needed to accommodate the required ponding and filter media depths. If the practice does not include an underdrain or if an inverted or elevated underdrain design is used, less hydraulic head may be adequate.

Water Table. Bioretention must be separated from the water table to ensure that groundwater does not intersect the filter bed. Mixing can lead to possible groundwater contamination or failure of the bioretention facility. A separation distance of 0.5 feet is required between the bottom of the excavated bioretention area and the seasonally high groundwater table.

Tidal Impacts. For systems with an underdrain, the underdrain should be located above the tidal mean high water elevation. For entirely infiltration-based systems, the bottom of the stone reservoir should be located above the mean high water elevation. Where this is not possible, portions of the practice below the tidal mean high water elevation cannot be included in the volume calculations. Also, salt-tolerant vegetation may be necessary in these areas.

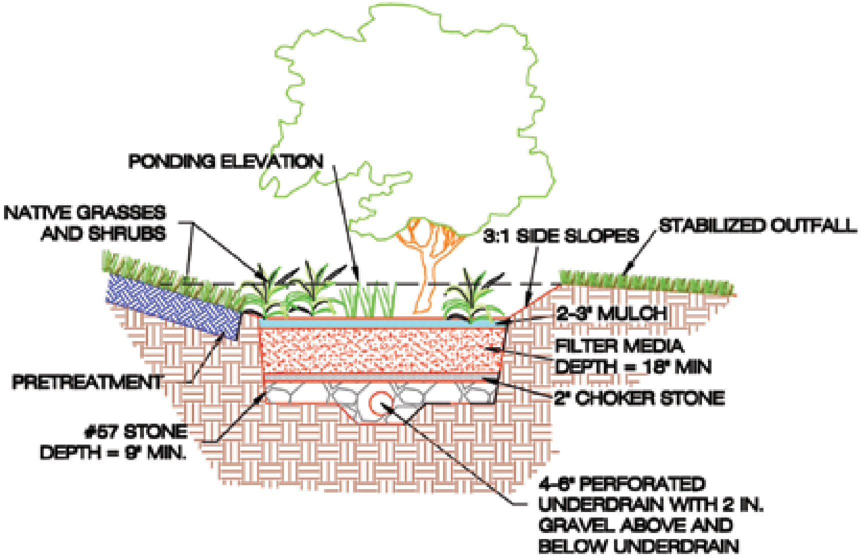

Figure 4.2-4. Bioretention Standard Design

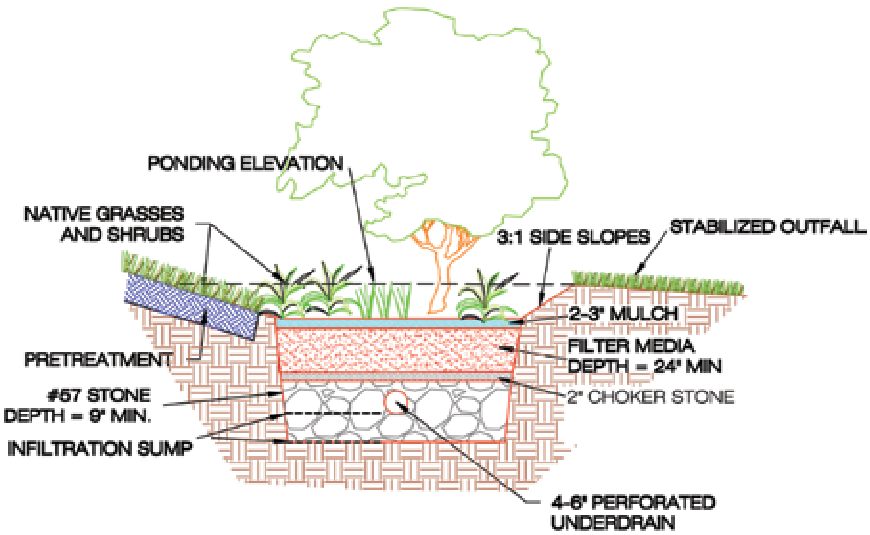

Figure 4.2-5. Bioretention enhanced design with an underdrain and infiltration sump/storage layer

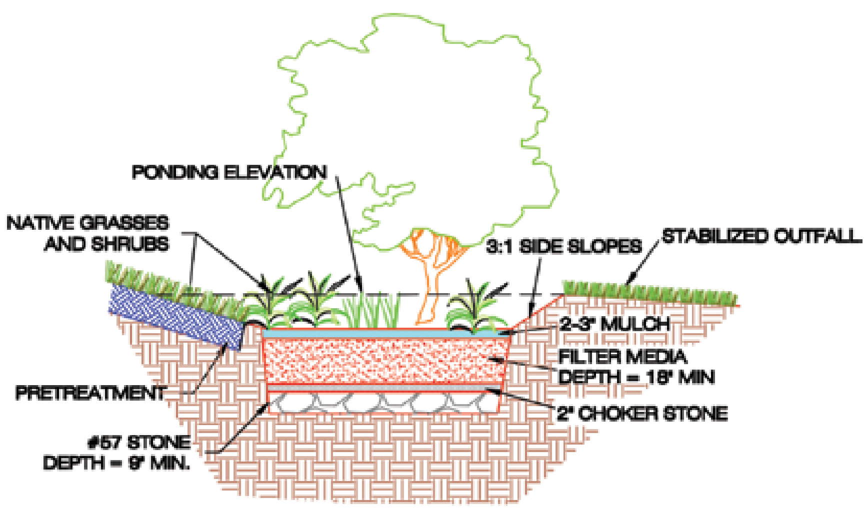

Figure 4.2-6. Bioretention enhanced design without an underdrain

Soils and Underdrains. Soil conditions do not typically constrain the use of bioretention, although they do determine whether an underdrain is needed. Underdrains are required if the measured permeability of the underlying soils is less than 0.3 in/hr. When designing an infiltration-based bioretention practice, designers must verify soil permeability by using the on-site soil investigation methods identified in *Appendix B*, or similar methods.

In fill soil locations, geotechnical investigations are required to determine if the use of an impermeable liner and underdrain are necessary.

Contributing Drainage Area. Bioretention cells work best with smaller contributing drainage areas, where it is easier to achieve flow distribution over the filter bed. The maximum recommended drainage area to a traditional bioretention area is 5 acres, and can consist of up to 100% impervious cover. However, if hydraulic considerations are adequately addressed to manage the potentially large peak inflow of larger drainage areas, such as off-line or low-flow diversions, or forebays, there may be case-by-case instances where the maximum drainage area can be adjusted.

Pollutant Hotspot Land Uses. Bioretention may not be an appropriate stormwater management practice for certain pollutant-generating sites. In areas where higher pollutant loading is likely (i.e. oils and greases from fueling stations or vehicle storage areas, sediment from un-stabilized pervious areas, or other pollutants from industrial processes), appropriate pretreatment, such as an oil-water separator or filtering device must be provided. These pretreatment facilities should be monitored and maintained frequently to avoid negative impacts to the bioretention area and subsequent water bodies.

On sites with existing contaminated soils, infiltration is not allowed. Bioretention areas must include an impermeable liner, and the Enhanced Design configuration cannot be used.

No Irrigation or Baseflow. The planned bioretention area should not receive baseflow, irrigation water, chlorinated wash-water, or other such non-stormwater flows. However, irrigation is allowed during the establishment period of the bioretention area to ensure plant survival. In addition, rain gardens or bioretention practices may be incorporated into the design of a Rainwater Harvesting System (See Rainwater Harvesting Specification).

Setbacks. To avoid the risk of seepage and to prevent damage to building foundations and contamination of groundwater aquifers, bioretention areas should be located at least:

- 10 feet from building foundations*
- 10 feet from property lines
- 150 feet from private water supply wells
- 50 feet from septic systems

*For building foundations, where the 10 foot setback is not possible, an impermeable liner may be used along the sides of the bioretention area (extending from the surface to the bottom of the practice) to prevent seepage or foundation damage.

Proximity to Utilities. Designers should ensure that future tree canopy growth in the bioretention area will not interfere with existing overhead utility lines. Interference with underground utilities should be avoided, if possible. When large site development is undertaken, the expectation of achieving avoidance will be high. Conflicts may be commonplace on smaller sites and in the public right-of-way. Where conflicts cannot be avoided, these guidelines shall be followed:

- ✧ Consult with each utility company on recommended offsets that will allow utility maintenance work with minimal disturbance to the stormwater Best Management Practice (BMP).
- ✧ Whenever possible, coordinate with utility companies to allow them to replace or relocate their aging infrastructure while BMPs are being implemented.
- ✧ BMP and utility conflicts will be a common occurrence in public right-of-way projects. However, the standard solution to utility conflict should be to allow the utility to be located below the BMP, but to ensure that sufficient soil coverage over the utility will be provided.
- ✧ Additionally, when accepting utility conflict into the BMP design, it is understood that the BMP will be temporarily impacted during utility maintenance but restored to its original condition.

Minimizing External Impacts. Urban bioretention practices may be subject to higher public visibility, greater trash loads, pedestrian traffic, vandalism, and even vehicular loads. These practices should be designed in ways that prevent, or at least minimize, such impacts. In addition, designers should recognize the need to perform frequent landscaping maintenance to remove trash, check for clogging, and maintain vigorous vegetation. The urban landscape context may feature naturalized landscaping or a more formal design. When urban bioretention is used in sidewalk areas of high foot traffic, designers should not impede pedestrian movement or create a safety hazard. Designers may also install low fences, grates, or other measures to prevent damage from pedestrian short-cutting across the practices.

Economic Considerations. Bioretention areas can be particularly cost effective when they are included in areas of the site already planned for landscaping.

Bioretention Conveyance Criteria

There are two basic design approaches for conveying runoff into, through, and around bioretention practices:

1. Off-line: Flow is split or diverted so that only the design storm or design flow enters the bioretention area. Larger flows by-pass the bioretention treatment.
2. On-line: All runoff from the drainage area flows into the practice. Flows that exceed the design capacity exit the practice via an overflow structure or weir.

If runoff is delivered by a storm drain pipe or is along the main conveyance system, the bioretention area should be designed off-line so that flows to do not overwhelm or damage the practice.

Off-line bioretention. Overflows are diverted from entering the bioretention cell. Optional diversion methods include the following:

- ✧ Create an alternate flow path at the inflow point into the structure such that when the maximum ponding depth is reached, the incoming flow is diverted past the facility. In this case, the higher flows do not pass over the filter bed and through the facility, and additional flow is able to enter as the ponding water filters through the soil media. With this design configuration, an overflow structure in the bioretention area is not required.

- ✧ Utilize a low-flow diversion or flow splitter at the inlet to allow only the design storm volume to enter the facility (calculations must be made to determine the peak flow from the design storm). This may be achieved with a weir, curb opening, or orifice for the target flow, in combination with a bypass channel or pipe. Using a weir or curb opening helps minimize clogging and reduces the maintenance frequency. With this design configuration, an overflow structure in the bioretention area is required (see on-line bioretention below).

On-line bioretention. An overflow structure must be incorporated into on-line designs to safely convey larger storms through the bioretention area. The following criteria apply to overflow structures:

- ✧ An overflow must be provided within the practice to pass storms greater than the design storm storage to a stabilized water course. A portion of larger events may be managed by the bioretention area so long as the maximum depth of ponding in the bioretention cell does not exceed 18 inches.
- ✧ The overflow device must convey runoff to a storm sewer, stream, or the existing stormwater conveyance infrastructure, such as curb and gutter or an existing channel.
- ✧ Common overflow systems within bioretention practices consist of an inlet structure, where the top of the structure is placed at the maximum ponding depth of the bioretention area, which is typically 6 to 18 inches above the surface of the filter bed.
- ✧ The overflow device should be scaled to the application – this may be a landscape grate or yard inlet for small practices or a commercial-type structure for larger installations.
- ✧ At least 3–6 inches of freeboard must be provided between the top of the overflow device and the top of the bioretention area to ensure that nuisance flooding will not occur.
- ✧ The overflow associated with the 2-year and 10-year design storms must be controlled so that velocities are non-erosive at the outlet point (i.e., to prevent downstream erosion).

Bioretention Pretreatment Criteria

Pretreatment of runoff entering bioretention areas is necessary to trap coarse sediment particles before they reach and prematurely clog the filter bed. Pretreatment measures must be designed to evenly spread runoff across the entire width of the bioretention area. Several pretreatment measures are feasible, depending on the type of the bioretention practice and whether it receives sheet flow, shallow concentrated flow, or deeper concentrated flows. The following are appropriate pretreatment options:

- ✧ **Leaf Screens** (for small-scale residential applications) used as part of the gutter system serve to keep the heavy loading of organic debris from accumulating in the bioretention cell.
- ✧ **Grass Filter Strips** (sheet flow) that are perpendicular to incoming sheet flow extend from the edge of pavement (i.e., with a slight drop at the pavement edge) to the bottom of the bioretention basin at a 5:1 slope or flatter.

- ✧ **Stone Trenches** that are located at the edge of the pavement should be oriented perpendicular to the flow path to pre-treat lateral runoff, with a 2 to 4 inch drop from the pavement edge to the top of the stone. The stone should be sized according to the expected rate of discharge.
  - Note: stone trenches are not recommended for school settings.
- ✧ **Trash Racks** (for either sheet flow or concentrated flow) are placed between the pretreatment cell and the main filter bed or across curb cuts. These will allow trash to collect in specific locations and create easier maintenance.
- ✧ **Pretreatment Cells**, similar to a forebay, are located at piped inlets or curb cuts leading to the bioretention area, and consists of an energy dissipater sized for the expected rates of discharge. It has a storage volume equivalent to at least 15% of the total storage volume (inclusive) with a recommended 2:1 length-to-width ratio. The cell may be formed by a wooden or stone check dam or an earthen or rock berm. Pre-treatment cells do not need underlying engineered soil media, in contrast to the main bioretention cell. However, if the volume of the pretreatment cell will be included as part of the bioretention storage volume, the pretreatment cell must de-water between storm events. It cannot have a permanent ponded volume.
- ✧ **Filter Systems**, such as sand filters or proprietary filter designs also may be used for pretreatment.

Bioretention Design Criteria

Design Geometry. Incoming flow should be distributed as evenly as possible across the entire filter surface area.

Ponding Depth. The recommended surface ponding depth is 6 to 12 inches, although ponding depths can be as high as 18 inches. Higher ponding depths require more careful consideration of issues such as safety, fencing requirements, aesthetics, the viability and survival of plants, and erosion and scour of side slopes. This is especially true where bioretention areas are built next to sidewalks or other areas were pedestrians or bicyclists travel.

Side Slopes. Typical bioretention areas should be constructed with side slopes of 3:1 or flatter. In highly urbanized or space-constrained areas, a drop curb design or a precast structure can be used to create a stable, vertical side wall. These drop curb designs should not exceed a vertical drop of more than 12 inches, unless safety precautions, such as railings, walls, grates, etc. are included.

Filter Media. The filter media is the most important element of a bioretention facility in terms of long-term performance.

- ✧ <u>Particle Size Composition.</u> The bioretention soil mixture shall be classified as a loamy sand on the USDA Texture Triangle, with the following particle size composition:
  - 80–90% sand (at least 75% of which must be classified as coarse or very coarse sand)
  - 10–20% soil fines (silt and clay)
  - Maximum 10% clay
  - The particle size analysis must be conducted on the mineral fraction only or fol-

lowing appropriate treatments to remove organic matter before particle size analysis.

- ✧ Organic Matter. The filter media must contain 3 to 5% organic matter by conventional Walkley-Black soil organic matter determination method or similar analysis. Soil organic matter is expressed on a dry weight basis and does not include coarse particulate (visible) components.
- ✧ Available Soil Phosphorus (P). The filter media should contain sufficient plant available P to support initial plant establishment and plant growth, but not serve as a significant source of P for long term leaching. For the Mehlich I extraction procedure, a range of 5 to 15 mg/kg P is acceptable. For the Mehlich III procedure, a range of 18 to 40 mg/kg P is acceptable.

Figure 4.2-7. Bioretention with a Drop Curb (Photo: DC Green Infrastructure http://www.flickr.com/photos/dcgreeninfrastructure/)

- ✧ Cation Exchange Capacity (CEC). The relative ability of soils to hold and retain nutrient cations like Ca and K is referred to as cation exchange capacity or CEC, and is measured as the total amount of positively charged cations that a soil can hold per unit dry mass. CEC is also used as an index of overall soil reactivity and is commonly expressed in milliequivalents per 100 grams (meq/100g) of soil or cmol+/kg (equal values). A soil with a moderate to high CEC indicates a greater ability to capture and retain positively charged contaminants, which encourages conditions to remove phosphorus, assuming that soil fines (particularly fine silts and clays) are at least partially responsible for CEC. The minimum CEC of the filter media is 5.0 (meq/100 g or cmol+/kg). The filter media CEC should be determined by the Unbuffered Salt, Ammonium Acetate, Summation of Cations or Effective CEC techniques (Sumner and Miller, 1996) or similar methods that do not utilize strongly acidic extracting solutions.

The goal of the mixture as described above is to create a soil media that maintains long-term permeability while also providing enough nutrients to support plant growth. The initial permeability of the mixture will exceed the desired long-term permeability of 1 to 2 in/hr. The limited amount of topsoil and organic matter is considered adequate to help support initial plant growth, and it is anticipated that the gradual increase of organic material through natural processes will continue to support growth while gradually decreasing the permeability. Finally, the root structure of maturing plants and the biological activity of a self-sustaining organic content will maintain sufficient long term permeability as well as support plant growth without the need for fertilizer inputs.

The following is the recommended composition of the three media ingredients:

- ✧ Sand. Sand should consist of silica-based coarse aggregate, angular or round in shape, and meet the mixture grain size distribution below. No substitutions of alternate materials such as diabase, calcium carbonate, rock dust, or dolomitic sands are acceptable. In particular, mica can make up no more than 5% of the total sand fraction. The sand fraction may also contain a limited amount of particles greater than 2.0 millimeters and less than 9.5 millimeters per the table below, but the overall sand fraction must meet the specification of greater than 75% being coarse or very coarse sand.

Table 4.2-1. Sand Sizing Criteria

Sieve	Size (mm)	% Passing
3/8 in.	9.50	100
No. 4	4.75	95 to 100
No. 8	2.36	80 to 100
No. 16	1.18	45 to 85
No. 30	0.60	15 to 60
No. 50	0.30	3 to 15
No. 100	0.15	0 to 4
Note: Effective particle size (D10) > 0.3mm. Uniformity coefficient (D60/D10) < 4.0.		

- Topsoil. Topsoil is generally defined as the combination of the other ingredients referenced in the bioretention filter media: sand, fines (silt and clay), and any associated soil organic matter. Since the objective of the specification is to carefully establish the proper blend of these ingredients, the designer (or contractor or materials supplier) must carefully select the topsoil source material in order to not exceed the amount of any one ingredient. Generally, the use of a topsoil defined as a loamy sand, sandy loam, or loam (per the USDA Textural Triangle) will be an acceptable ingredient and in combination with the other ingredients meet the overall performance goal of the soil media.
- Organic Matter. Organic materials used in the soil media mix should consist of well-decomposed natural carbon-containing organic materials such as peat moss, humus, compost, pine bark fines or other organic soil conditioning material. However, per above, the combined filter media should contain 3 to 5% soil organic matter on dry weight basis (grams organic matter per 100 grams dry soil) by the Walkley-Black method or other similar analytical technique.

In creating the filter media, it is recommended to start with an open-graded coarse sand material and proportionately mix in the topsoil materials to achieve the desired ratio of sand and fines. Sufficient suitable organic amendments can then be added to achieve the 3 to 5% soil organic matter target. The exact composition of organic matter and topsoil material will vary, making the exact particle size distribution of the final total soil media mixture difficult to define in advance of evaluating available materials. Table 4.2-2 summarizes the filter media requirements.

Table 4.2-2. Filter Media Criteria for Bioretention

Soil Media Criterion	Description	Standard(s)
General Composition	Soil media must have the proper proportions of sand, fines, and organic matter to promote plant growth, drain at the proper rate, and filter pollutants	♦ 80% to 90% sand (75% of which is coarse or very coarse); ♦ 10% to 20% soil fines ♦ Max. 10% clay; and ♦ 3% to 5% organic matter
Sand	Silica based coarse aggregate[1]	Sieve / Size / % Passing 3/8 in / 9.50 mm / 100 No. 4 / 4.75 mm / 95 to 100 No. 8 / 2.36 mm / 80 to 100 No. 16 / 1.18 mm / 45 to 85 No. 30 / 0.6 mm / 15 to 60 No. 50 / 0.3 mm / 3 to 15 No. 100 / 0.15 mm / 0 to 4 Effective Particle size (D10) > 0.3mm Uniformity Coefficient (D60/D10) < 4.0
Top Soil	Loamy Sand or Sandy Loam	USDA Textural Triangle
Organic Matter	Well aged, clean compost	Appendix C
P-Index or Phosphorus (P) content	Soil media with high P levels will export P through the media and potentially to downstream conveyances or receiving waters	P content = 5 to 15 mg/kg (Mehlich I) or 18 to 40 mg/kg (Mehlich III)
Cation Exchange Capacity (CEC)	The CEC is determined by the amount of soil fines and organic matter. Higher CEC will promote pollutant removal	CEC > 5 milliequivalents per 100 grams

[1] Many specifications for sand refer to ASTM C-33. The ASTM C-33 specification allows a particle size distribution that contains a large fraction of fines (silt and clay sized particles - < 0.05 mm). The smaller fines fill the voids between the larger sand sized particles, resulting in smaller and more convoluted pore spaces. While this condition provides a high degree of treatment, it also encourages clogging of the remaining void spaces with suspended solids and biological growth, resulting in a greater chance of a restrictive biomat forming. By limiting the fine particles allowed in the sand component, the combined media recipe of sand and the fines associated with the soil and organic material will be less prone to clogging, while also providing an adequate level of filtration and retention.

In cases where greater removal of specific pollutants is desired, additives with documented pollutant removal benefits, such as water treatment residuals, alum, iron, or other materials may be included in the filter media if accepted by the local agency.

- ✧ Filter Media Depth. The filter media bed depth must be a minimum of 24 inches, although this can be reduced to 18 inches for depth-constrained bioretention practices. Designers should note that the media depth must be 24 inches or greater to qualify for the enhanced design, unless an infiltration-based design is used. Turf, perennials, or shrubs should be used instead of trees to landscape shallower filter beds. See Tables 4.2-4 through 4.2-6 for a list of recommended native plants.

Surface Cover. Mulch is the recommended surface cover material, but other materials may be substituted, as described below:

- ✧ Mulch. A 2- to 3-inch layer of mulch on the surface of the filter bed enhances plant survival, suppresses weed growth, pretreats runoff before it reaches the filter media, and prevents rapid evaporation of rainwater. Shredded hardwood bark mulch, aged for at least 6 months, makes a very good surface cover, as it retains a significant amount of pollutants and typically will not float away. Avoid pine bark mulch, which will float during storms.
- ✧ Alternative to Mulch Cover. In some situations, designers may consider alternative surface covers, such as turf, native groundcover, erosion control matting (e.g., coir or jute matting), river stone, or pea gravel. The decision regarding the type of surface cover to use should be based on function, expected pedestrian traffic, cost, and maintenance. When alternative surface covers are used, methods to discourage pedestrian traffic should be considered. Stone or gravel are not recommended in parking lot applications, since they increase soil temperature and have low water-holding capacity.
- ✧ Media for Turf Cover. One adaptation suggested for use with turf cover is to design the filter media primarily as a sand filter with organic content only at the top. Compost tilled into the top layers will provide organic content for the vegetative cover. If grass is the only vegetation, the ratio of organic matter in the filter media composition may be reduced.

Choking Layer. A 2- to 4-inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Geotextile. If the available head is limited, or the depth of the practice is a concern, geotextile fabric may be used in place of the choking layer. An appropriate geotextile fabric that complies with AASHTO M-288 Class 2, latest edition, requirements, and has a permeability of at least an order of magnitude higher (10x) than the soil subgrade permeability must be used. Geotextile fabric may be used on the sides of bioretention areas as well.

Underdrains. Many bioretention designs will require an underdrain (see Bioretention Feasibility Criteria). The underdrain should be a 4- or 6-inch perforated schedule 40 PVC pipe, or equivalent corrugated HDPE for small bioretention practices, with $^{3}/_{8}$-inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, washed ASTM D448 No.57 stone. The underdrain must be sized so that the bioretention practice fully drains within 72 hours or less.

Multiple underdrains are recommended for bioretention areas wider than 40 feet, and each underdrain should be located no more than 20 feet from the next pipe.

All bioretention practices should include at least one observation well and/or cleanout pipe (minimum 4 inches in diameter). The observation wells should be tied into any of the Ts or Ys in the underdrain system and must extend upward above the surface of the bioretention area.

Upturned Elbow (optional). In cases where limited head is a site constraint and the bioretention must be designed to be relatively shallow (e.g., depth to groundwater, relatively flat sites, or other factors), or where increased nitrogen removal is desired, an upturned elbow underdrain design can be used. For more information on this design consult North Carolina Cooperative Extension publication entitled "Designing Bioretention with an Internal Water Storage (IWS) Layer" (Brown et al., 2009).

Underground Storage Layer (optional). An underground storage layer consisting of chambers, perforated pipe, stone, or other acceptable material can be incorporated below the filter media layer to increase the infiltration sump volume or the storage for larger storm events. To qualify for the Enhanced Design, this storage layer must be designed to infiltrate in 72 hours, at ½ the measured infiltration rate. The underground storage layer may also be designed to provide detention for the 2-year, or 10-year storms, as needed. The depth and volume of the storage layer will then depend on the target storage volumes needed to meet the applicable detention criteria.

Impermeable Liner: An impermeable liner is not typically required, although it may be utilized in fill applications where deemed necessary by a geotechnical investigation, on sites with contaminated soils, or on the sides of the practice to protect adjacent structures from seepage. Use a 30-milliliter (minimum) PVC geomembrane liner. (Follow manufacturer's instructions for installation.)

Material Specifications. Recommended material specifications for bioretention areas are shown in Table 4.2-3.

Table 4.2-3. Bioretention Material Specifications		
Material	**Specification**	**Notes**
Filter Media	Filter Media to contain: ♦ 70%–88% sand ♦ 8%–26% soil fines ♦ 1%–5% organic matter in the form of aged compost or wood chips	♦ Minimum depth of 24 inches (18 inches for small-scale practices) ♦ To account for settling/compaction, it is recommended that 110% of the plan volume be utilized
Filter Media Testing	♦ P-Index range = 10–30, OR ♦ Between 7 and 23 mg/kg of P in the soil media ♦ CECs greater than 10	
Mulch Layer	Use aged, shredded hardwood bark mulch	Lay a 2- to 3-inch layer on the surface of the filter bed.
Alternative Surface Cover	Use river stone or pea gravel, coir and jute matting, or turf cover.	Lay a 2- to 3-inch layer of to suppress weed growth.
Top Soil for Turf Cover	♦ Loamy sand or sandy loam texture, with less than 5% clay content ♦ pH corrected to between 6 and 7 ♦ organic matter content of at least 2%	3-inch tilled into surface layer.
Geotextile or Choking Layer	Lay a 2 to 4 inch layer of choker stone (e.g., typically No.8 or No.89 washed gravel) over the underdrain stone.	
	An appropriate geotextile fabric that complies with AASHTO M-288 Class 2, latest edition, requirements and has a permeability of at least an order of magnitude higher (10x) than the soil subgrade permeability must be used	♦ Can use in place of the choking layer where the depth of the practice is limited ♦ Geotextile fabric may be used on the sides of bioretention areas, as well
Underdrain Stone	1-inch diameter stone must be double-washed and clean and free of all fines (e.g., ASTM D448 No. 57 stone)	At least 9 inches deep
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)	Where appropriate, use a thirty mil (minimum) PVC Geomembrane liner	

Table 4.2-3. Bioretention Material Specifications		
Material	**Specification**	**Notes**
Underdrains, Cleanouts, and Observation Wells	Use 4- or 6-inch rigid schedule 40 PVC pipe, or equivalent corrugated HDPE for small bioretention practices, with 3/8-inch perforations at 6 inches on center. Multiple underdrains are necessary for bioretention areas wider than 40 feet, and each underdrain must 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 T's and Y's as needed, depending on the underdrain configuration ♦ Add cleanout pipes that extend to the surface (with caps) at the T's and Y's
Plant Materials	See Bioretention Landscaping Criteria	Establish plant materials as specified in the landscaping plan and the recommended plant list

Signage. Bioretention units in highly urbanized areas should be stenciled or otherwise permanently marked to designate it as a stormwater management facility. The stencil or plaque should indicate (1) its water quality purpose, (2) that it may pond briefly after a storm, and (3) that it is not to be disturbed except for required maintenance.

Specific Design Issues for Streetscape Bioretention. Streetscape bioretention is installed in the road right-of way, either in the sidewalk area or in the road itself. In many cases, streetscape bioretention areas can also serve as a traffic calming or street parking control devices. The basic design adaptation is to move the raised concrete curb closer to the street or in the street, and then create inlets or curb cuts that divert street runoff into depressed vegetated areas within the right-of-way. Designers should consult design standards pertaining to roadway drainage. It may be necessary to provide an impermeable liner on the road side of the bioretention area to keep water from saturating the road's sub-base.

Specific Design Issues for Engineered Tree Boxes. Engineered tree boxes are installed in the sidewalk zone near the street where urban street trees are normally installed. The soil volume for the tree pit is increased and used to capture and treat stormwater. Treatment is increased by using a series of connected tree planting areas together in a row. The surface of the enlarged planting area may be mulch, grates, or permeable pavers. The large and shared rooting space and a reliable water supply increase the growth and survival rates in this otherwise harsh planting environment.

When designing engineered tree boxes, the following criteria must be considered:

- ✧ The bottom of the soil layer must be a minimum of 4 inches below the root ball of plants to be installed.
- ✧ Engineered tree box designs sometimes cover portions of the filter media with pervi-

ous pavers or cantilevered sidewalks. In these situations, it is important that the filter media is connected beneath the surface so that stormwater and tree roots can share this space.

- Installing a grate over filter bed media is one possible solution to prevent pedestrian traffic and trash accumulation.
- Low, wrought iron fences can help restrict pedestrian traffic across the tree pit bed and serve as a protective barrier if there is a drop-off from the pavement to the micro-bioretention cell.
- Each tree should have a minimum rootable soil volume of 1,500 cubic feet.

Specific Design Issues for Stormwater Planters. Stormwater planters are a useful option to disconnect and treat rooftop runoff, particularly in ultra-urban areas. They consist of confined planters that store and/or infiltrate runoff in a soil bed to reduce runoff volumes and pollutant loads. Stormwater planters combine an aesthetic landscaping feature with a functional form of stormwater treatment. Stormwater planters generally receive runoff from adjacent rooftop downspouts and are landscaped with plants that are tolerant to periods of both drought and inundation.

A stormwater planter typically does not allow for infiltration. It is constructed with a watertight concrete shell or an impermeable liner on the bottom to prevent seepage (Figure 4.2-8). Since a stormwater planter is self-contained and does not infiltrate into the ground, it can be installed

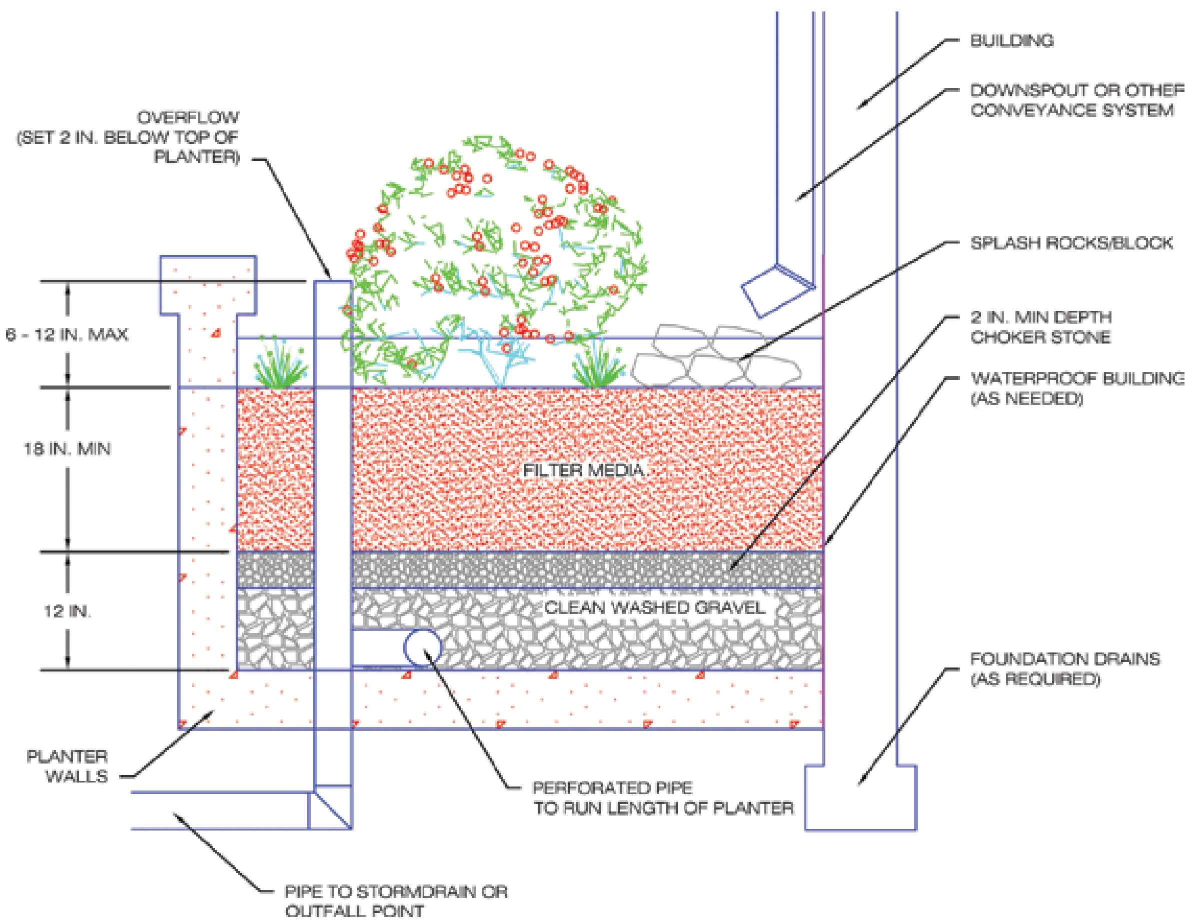

Figure 4.2-8. Stormwater Planter

right next to a building. The minimum filter media depth is 18 inches, with the shape and length determined by architectural considerations. Runoff is captured and temporarily ponded above the planter bed. Overflow pipes are installed to discharge runoff when maximum ponding depths are exceeded, to avoid water spilling over the side of the planter. In addition, an underdrain is used to carry runoff to the storm sewer system.

All planters should be placed at grade level or above ground. Plant materials must be capable of withstanding moist and seasonally dry conditions. The planter can be constructed of stone, concrete, brick, wood, or other durable material. If treated wood is used, care should be taken so that trace metals and creosote do not leach out of the planter.

Practice Sizing. Bioretention is typically sized to capture the water quality volume or larger design storm volumes in the surface ponding area, soil media, and gravel reservoir layers of the practice.

Total storage volume, *Sv*, is calculated using Equation 4.2-1.

Equation 4.2-1. Bioretention Storage Volume

$$Sv = SA_{bottom} \times [(d_{media} \times \eta_{media}) + (d_{gravel} \times \eta_{gravel})] + (SA_{average} \times d_{ponding})$$

where:

Sv	=	total storage volume of practice (ft^3)
SA_{bottom}	=	bottom surface area of practice (ft^2)
d_{media}	=	depth of the filter media (ft)
η_{media}	=	effective porosity of the filter media (typically 0.25)
d_{gravel}	=	depth of the underdrain and underground storage gravel layer (ft)
η_{gravel}	=	effective porosity of the gravel layer (typically 0.4)
$SA_{average}$	=	average surface area of practice (ft^2) (typically = ½ × [top area + SA_{bottom}])
$d_{ponding}$	=	maximum ponding depth of practice (ft)

Equation 4.2-1 can be modified if the storage depths of the soil media, gravel layer, or ponded water vary in the actual design or with the addition of any surface or subsurface storage components (e.g., additional area of surface ponding, subsurface storage chambers, etc.). The maximum depth of ponding in the bioretention must not exceed 18 inches.

In the LID Compliance Calculator spreadsheet, the Sv for infiltration and enhanced designs is given a 100% runoff reduction credit; the Sv for standard designs is given a 60% runoff reduction credit, since much of the water stored quickly exits the underdrain. For projects in the Coastal Zone, the Sv for all design types is given a 100% credit toward the storage requirement.

Bioretention can also be designed to address, in whole or in part, the detention requirements. The *Sv* can be counted as part of the 2-year or 10-year runoff volumes to satisfy the required detention volumes.

Note: In order to increase the storage volume of a bioretention area, the ponding surface area may be increased beyond the filter media surface area. However, the top surface area of the practice (i.e., at the top of the ponding elevation) may not be more than twice the size of the surface area of the filter media (SA_{bottom}).

Bioretention Landscaping Criteria

Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan must be provided for bioretention areas.

Minimum plan elements include the proposed bioretention template to be used, delineation of planting areas, and the planting plan including the following:

- Common and botanical names of the plants used
- Size of planted materials
- Mature size of the plants
- Light requirements
- Maintenance requirements
- Source of planting stock
- Planting sequence

It is recommended that the planting plan be prepared by a qualified landscape professional (e.g., licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions.

Native plant species are preferred over non-native species, but some ornamental species may be used for landscaping effect if they are not aggressive or invasive. Some popular native species that work well in bioretention areas and are commercially available can be found in Tables 4.2-4 through 4.2-6 (based on CUCES, 2000; MDE, 2000; Carolina Clear, 2009; Lady Bird Johnson Wildflower Center, 2013; and USDA-NRCS, 2013).

The degree of landscape maintenance that can be provided will determine some of the planting choices for bioretention areas. Plant selection differs if the area will be frequently mowed, pruned, and weeded, in contrast to a site which will receive minimum annual maintenance. In areas where less maintenance will be provided and where trash accumulation in shrubbery or herbaceous plants is a concern, consider a “turf and trees” landscaping model where the turf is mowed along with other turf areas on the site. Spaces for herbaceous flowering plants can be included.

Table 4.2-4 Perennials and Grasses Appropriate for Bioretention				
Scientific Name	**Common Name**	**Indicator[1]**	**Inundation**	**Salt Tolerance**
Aletris farinosa	White Colicroot	FAC	Moist soil	None
Andropogon gerardii	Big Bluestem	FAC	No	Moderate
Aquilegia canadensis	Wild Columbine	FACU	No	None
Asclepias incarnata	Swamp Milkweed	OBL	Saturated	None
Asclepias lanceolata	Red Milkweed	OBL	Wet soils	Moderate/ brackish
Aster novae-angliae	New England Aster	FACW	Moist soils, yes	Yes
Athyrium filix-femina	Lady Fern	FAC	Moist to wet soils	None
Canna glauca	Water Canna	OBL	Moist to wet soils	None
Canna flaccida	Golden Canna	OBL	Moist to wet soils	None
Carex stricta	Tussock Sedge	OBL	Saturated, 0-6”	None
Chasmanthium latifolium	River Oats	FAC	Moist soils	None
Chelone glabra	White Turtlehead	OBL	Moist to wet soils	
Conoclinium coelestinum	Blue Mistflower	FAC	Moist to Wet soils	
Crinum americanum	Southern Swamp Lily	OBL	Saturated	
Dulichium arundinaceum	Threeway Sedge	OBL	Saturated, shallow	None
Echinodorus cordifolius	Creeping Burhead	OBL	Saturated, shallow	
Equisetum hyemale	Scouring Rush	FACW	Saturated, shallow	
Eupatorium fistulosum	Joe Pye Weed	FACW	Moist to Wet Soils	
Geranium maculatum	Spotted Geranium	FACU	Moist Soils	
Helianthus angustifolius	Swamp Sunflower Narrowleaf Sunflower	FACW	Wet Soils	
Hibiscus coccineus	Scarlet Swamp Hibiscus	OBL	Saturated, shallow	
Hibiscus moscheutos	Rose Mallow Hibiscus	OBL	Saturated, shallow	Low
Hymenocallis caoliniana	Spider Lily	OBL	Saturated, shallow	None
Iris versicolor	Virginia Iris	OBL	Shallow	None
Juncus effuses	Common Rush	OBL	Shallow <6”	Low

Table 4.2-4 Perennials and Grasses Appropriate for Bioretention				
Scientific Name	**Common Name**	**Indicator[1]**	**Inundation**	**Salt Tolerance**
Liatris spicata	Gayfeather Blazing Star	FAC	Moist Soils	Low
Lobelia cardinalis	Cardinal Flower	FACW	Moist to Wet Soils	None
Lobelia siphilitica	Blue Lobelia	OBL	Moist to wet soils	
Lysimachia ciliata	Fringed Loosestrife	FACW	Moist to wet soils, seasonal flooding	
Mimulus ringens	Allegheny monkeyflower	OBL	Saturated, shallow	
Onoclea sensibilis	Sensitive Fern	FACW	Moist to wet soils	
Osmunda cinnamomea	Cinnamon Fern	FACW	Moist to wet soils	Low
Osmunda spectabilis	Royal Fern	OBL	Moist to wet soils	None
Orontium aquaticum	Golden Club	OBL	Up to 10”	
Panicum virgatum	Switch Grass	FAC	Moist soil	Moderate
Peltandra virginica	Green Arrow Arum	OBL	Shallow < 1’	Low (< 2 ppt)
Pontederia cordata	Pickerelweed	OBL	Shallow < 1’	Low (< 3 ppt)
Physostegia virginiana	Obedient Plant	FACW	Moist soil	
Polygonatum biflorum	Great Solomon’s Seal	FACU	Moist soil	
Rhynchospora colorata	Starrush Whitetop	FACW	Saturated	
Rudbeckia laciniata	Cutleaf Coneflower	FACW	Moist soil	None
Sagittaria latifolia	Common Arrowhead, Duck Potato	OBL	Up to 2.0’	None
Saururus cernuus	Lizard’s Tail	OBL	Shallow < 4”	None
Schizachyrium scoparium	Little Bluestem	FACU	Moist soil	None
Schoenoplectus tabernaemontani	Softstem Bulrush	OBL	Wet soil to standing water	Fresh or Brackish
Solidago sempervirens	Seaside Goldenrod	FACW	Yes	High
Sorghastrum nutans	Indiangrass	FACU	Moist soil	Moderate
Spartina alterniflora	Saltmarsh Cordgrass	OBL	Yes	High

Table 4.2-4 Perennials and Grasses Appropriate for Bioretention

Scientific Name	Common Name	Indicator[1]	Inundation	Salt Tolerance
Spartina bakeri	Sand cordgrass	FACW	Moist to wet soils	Fresh - Saline
Spartina patens	Saltmeadow Cordgrass	FACW	Wet soils	High
Thalia dealbata	Powdery Alligator-flag	OBL	up to 1.5’	Yes
Tradescantia virginiana	Virginia Spiderwort	FAC	Moist soils	None
Vernonia noveboracensis	Ironweed	FACW	Moist soils	None

[1] Wetland Indicator Status (USACE, 2010):

- *OBL (Obligate) almost always is a hydrophyte, rarely found in uplands (occurs in wetlands >99% of the time)*
- *FACW (Facultative Wetland) usually a hydrophyte, but occasionally found in uplands (occurs in wetlands 67-99% of the time)*
- *FAC (Facultative) commonly occurs either as a hydrophyte or a non-hydrophyte (occus in wetlands 33-67% of the time)*
- *FACU (Facultative Upland) occasionally is a hydrophyte, but usually occurs in uplands (occurs in wetlands 1-33% of the time)*

Table 4.2-5. Shrubs Appropriate for Bioretention

Scientific Name	Common Name	Indicator[1]	Inundation	Salt Tolerance
Baccharis halimifolia	Groundsel Tree Salt Myrtle	FAC	Wet soils	High
Callicarpa americana	Beautyberry	FACU	Moist soils	None
Cephalanthus occidentalis	Button Bush	OBL	Up to 3 ft	Low
Clethra alnifolia	Summersweet Sweet Pepperbush	FACW	Moist to wet soils	None
Cyrilla racemiflora	Swamp Titi	FACW	Moist to wet soils	Low
Hamamelis virginiana	Witch Hazel	FACU	Moist to wet soils	None
Hypericum prolificum	Shrubby St. John's Wort	FAC	Moist soils, flood tolerant	None
Ilex glabra	Inkberry	FACW	Wet soils, flood tolerant	Moderate
Ilex verticillata	Winterberry Holly	FACW	Moist to wet soils	None
Ilex vomitoria	Yaupon Holly	FAC	Moist soils	Moderate
Itea virginica	Virginia Sweetspire	FACW	Moist to wet soils	None
Kosteletzkya virginica	Seashore Mallow	OBL	Moist to wet soils	Moderate
Lindera benzoin	Spicebush	FACW	Seasonal inundation	None
Myrica cerifera	Wax Myrtle	FAC	Moist to wet soils	Moderate
Photinia pyrifolia	Red Chokeberry	FACW	Moist soils	Low
Rhododendron canescens	Dwarf Azalea	FACW	Moist soils	None
Rhododendron viscosum	Swamp Azalea	OBL	Wet soil	None
Rosa carolina	Carolina Rose	FACU	Moist to wet soils	Moderate
Sabal minor	Dwarf Palmetto	FACW	Moist to wet soils	None

Table 4.2-5. Shrubs Appropriate for Bioretention

Scientific Name	Common Name	Indicator[1]	Inundation	Salt Tolerance
Sambucus canadensis	Elderberry	FACW	Moist to wet soils	None
Serenoa repens	Saw Palmetto	FACU	Occasionally wet	None
Vaccinium corymbosum	Highbush Blueberry	FACW	Wet soil	High
Viburnum dentatum	Arrowwood	FAC	Moist to wet	None

[1] *Wetland Indicator Status (USACE, 2010):*

- *OBL (Obligate) almost always is a hydrophyte, rarely found in uplands (occurs in wetlands >99% of the time)*
- *FACW (Facultative Wetland) usually a hydrophyte, but occasionally found in uplands (occurs in wetlands 67-99% of the time)*
- *FAC (Facultative) commonly occurs either as a hydrophyte or a non-hydrophyte (occus in wetlands 33-67% of the time)*
- *FACU (Facultative Upland) occasionally is a hydrophyte, but usually occurs in uplands (occurs in wetlands 1-33% of the time)*

Table 4.2-6. Trees Appropriate for Bioretention[1]				
Scientific Name	**Common Name**	**Indicator[2]**	**Inundation**	**Salt Tolerance**
Acer rubrum	Red Maple	FAC	Seasonal inundation	None
Amelanchier canadensis	Serviceberry	FAC	Moist to wet soils	Moderate
Betula nigra	River Birch	FACW	Moist soils	None
Carpinus caroliniana	American Hornbeam	FAC	Periodic flooding	None
Celtis occidentalis	Hackberry	FACU	Moist soils	Low
Chamaecyparis thyoides	Atlantic White Cedar	OBL	Wet soils	None
Chionanthus virginicus	Fringetree	FACU	Moist soils	None
Cornus florida	Flowering Dogwood	FACU	Moist soils	None
Crataegus aestivalis	Mayhaw May Hawthorn	OBL	Wet soils	None
Diospyros virginiana	Persimmon	FAC	Variable moisture	Low
Gordonia lasianthus	Loblolly Bay	FACW	Moist soils	None
Ilex cassine	Dahoon Holly	FACW	Moist soils	Low
Ilex opaca	American Holly	FAC	Wet soils	Moderate
Juniperus virginiana	Eastern Red Cedar	FACU	Moist soils	Low
Liquidambar styraciflua	Sweetgum	FAC	Moist soils	None
Liriodendron tulipifera	Tulip Tree	FAC	Moist soils	Low
Magnolia virginiana	Sweetbay Magnolia	FACW	Moist soils	None
Nyssa aquatica	Water Tupelo	OBL	Wet soils	None
Nyssa biflora	Ogeechee Tupelo	OBL	Moist to wet soils	None
Nyssa sylvatica	Black Gum, Black Tupelo	FAC	Moist soils; seasonal flooding	Moderate
Ostrya virginiana	Hop Hornbeam, Ironwood	FACU	Moist soils	None

Table 4.2-6. Trees Appropriate for Bioretention[1]

Scientific Name	Common Name	Indicator[2]	Inundation	Salt Tolerance
Platanus occidentalis	American Sycamore	FACW	Saturated soils; seasonal flooding	None
Quercus bicolor	Swamp White Oak	FACW	Moist to wet soils	None
Quercus lyrata	Overcup Oak	OBL	Yes	None
Quercus michauxii	Swamp Chestnut Oak	FACW	Moist soils	None
Quercus nuttallii	Nuttall Oak	FACW	Extended flooding	None
Quercus pagoda	Cherrybark Oak	FACW		None
Quercus palustris	Pin Oak	FACW	Moist to wet soils	Low
Quercus phellos	Willow Oak	FACW	Moist soils	None
Quercus shumardii	Shumard Oak	FAC	Short-term flooding	None
Sassafras albidum	Sassafrass	FACU	Moist soils	None
Taxodium ascendens	Pond Cypress	OBL	Moist soils	High
Taxodium distichum	Bald Cypress	OBL	Wet soils; standing water	High
Ulmus americana	American Elm	FAC	Moist soils	Low

[1] *Consider characteristics of trees – such as mature height & spread, aggressive root structures, knee development, etc. – in order to select the species most appropriate for the site. All these species will tolerate some degree of flooding; however, make sure that other site constraints (outfall structures, berms, utilities, hardscapes, etc.) will not be negatively impacted as a specimen grows and matures.*

[2] *Wetland Indicator Status (USACE, 2010):*

- *OBL (Obligate) almost always is a hydrophyte, rarely found in uplands (occurs in wetlands >99% of the time)*
- *FACW (Facultative Wetland) usually a hydrophyte, but occasionally found in uplands (occurs in wetlands 67-99% of the time)*
- *FAC (Facultative) commonly occurs either as a hydrophyte or a non-hydrophyte (occus in wetlands 33-67% of the time)*
- *FACU (Facultative Upland) occasionally is a hydrophyte, but usually occurs in uplands (occurs in wetlands 1-33% of the time)*

Planting recommendations for bioretention facilities are as follows:

- ✧ The primary objective of the planting plan is to cover as much of the surface area of the filter bed as quickly as possible. Herbaceous or ground cover layers are as important or more important than more widely spaced trees and shrubs.
- ✧ Native plant species should be specified over non-native species.
- ✧ Plants should be selected based on a specified zone of hydric tolerance and must be capable of surviving both wet and dry conditions ("Wet footed" species should be planted near the center, whereas upland species do better planted near the edge).
- ✧ Woody vegetation should not be located at points of inflow; trees should not be planted directly above underdrains but should be located closer to the perimeter.
- ✧ Shrubs and herbaceous vegetation should generally be planted in clusters and at higher densities (i.e., 10 feet on-center and 1 to 1.5 feet on-center, respectively).
- ✧ If trees are part of the planting plan, a tree density of approximately one tree per 250 square feet (i.e., 15 feet on-center) is recommended.
- ✧ Plant trees using the guidelines provided in the Clemson University Cooperative Extension document entitled, "Planting Trees Correctly" (Polomski et al., 2004). In particular, dig holes deep enough that the topmost roots in the root ball are level with the ground (soil media) surface, and place 2 to 3 inches of mulch above these roots. Also, dig the hole two to five times wider than the root ball to allow for root growth.
- ✧ Tree species should be those that are known to survive well in the compacted soils and the polluted air and water of an urban landscape.
- ✧ If trees are used, plant shade-tolerant ground covers within the drip line. Note that the planting plan should account for succession, where shade tolerant plants may be planted to cover a greater area as the tree canopy grows.

Bioretention Construction Sequence

Erosion and Sediment Controls: Bioretention areas should be fully protected by silt fence or construction fencing. Bioretention areas must remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. Where this is unavoidable, the impacted area must not be excavated below 2 feet above the final design elevation of the bottom of the practice until further compaction by heavy equipment can be avoided. Once the area is excavated to grade, the impacted area must be tilled to a depth of 12 inches below the bottom of the practice. Large bioretention applications may be used as sediment traps or basins during construction. However, these must be accompanied by notes and graphic details on the erosion and sediment control plan specifying that (1) the maximum excavation depth of the trap or basin at the construction stage must be at least 1 foot higher than the post-construction (final) invert (bottom of the facility), and (2) the facility must contain an underdrain. The plan must also show the proper procedures for converting the temporary sediment control practice to a permanent bioretention facility, including dewatering, cleanout, and stabilization.

Bioretention Installation: The following is a typical construction sequence to properly install a bioretention basin. 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, or designed with a temporary bypass. 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, the installer, and the local agency inspector 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 inspector. Material certifications for aggregate, soil media, and any geotextiles should be submitted for approval to the inspector at the preconstruction meeting.

Step 3: Temporary erosion and sediment controls (e.g., diversion dikes, reinforced silt fences) 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 pretreatment 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 appropriate 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-square foot temporary cells with a 10- to 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 geotextile fabric, place the fabric on the sides of the bioretention area with a 6-inch overlap on the sides. Place the appropriate depth of No. 57 stone on the bottom, install the perforated underdrain pipe, place No. 57 stone to 3 inches above the underdrain pipe, and add the choking layer or appropriate geotextile layer as a filter between the underdrain and the soil media layer.

Step 8: Apply the soil 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. Note: The batch receipt confirming the source of the soil media must be submitted to the local agency inspector.

Step 9: Prepare planting holes for any trees and shrubs, install the vegetation, and water accordingly. Install any temporary irrigation.

Step 10: Install the plant materials as shown in the landscaping plan, and water them as needed.

Step 11: Place the surface cover (i.e., mulch, river stone, or turf). If coir or jute matting will be used in lieu of mulch, the matting will need to be installed prior to planting (Step 10), and holes or slits will have to be cut in the matting to install the plants.

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. It is recommended that unblocking curb cuts and inlets take place after two to three storm events if the drainage area includes newly installed asphalt, since new asphalt tends to produce a lot of fines and grit during the first several storms.

Step 13: Conduct the final construction inspection using a qualified professional, providing the local agency with an as-built, then log the GPS coordinates for each bioretention facility, and submit them for entry into the maintenance tracking database.

Construction Supervision. Supervision during construction is recommended to ensure that the bioretention area is built in accordance with the approved design and this specification. Qualified individuals should use detailed inspection checklists that include sign-offs at critical stages of construction, to ensure that the contractor's interpretation of the plan is consistent with the designer's intentions.

Bioretention Maintenance Criteria

When bioretention practices are installed, it is the owner's responsibility to ensure they, or those managing the practice, (1) be educated about their routine maintenance needs, (2) understand the long-term maintenance plan, and (3) be subject to a maintenance covenant or agreement, as required by the locality.

Maintenance of bioretention areas should be integrated into routine landscape maintenance tasks. If landscaping contractors will be expected to perform maintenance, their contracts should contain specifics on unique bioretention landscaping needs, such as maintaining elevation differences needed for ponding, proper mulching, sediment and trash removal, and limited use of fertilizers and pesticides.

Maintenance tasks and frequency will vary depending on the size and location of the bioretention, the landscaping template chosen, and the type of surface cover in the practice. A generalized summary of common maintenance tasks and their frequency is provided in Table 4.2-7.

Table 4.2-7. Typical Maintenance Tasks for Bioretention Practices	
Frequency	**Maintenance Tasks**
Upon establishment	♦ For the first 6 months following construction, the practice and CDA should be inspected at least twice after storm events that exceed ½ inch of rainfall. Conduct any needed repairs or stabilization. ♦ Inspectors should look for bare or eroding areas in the contributing drainage area or around the bioretention area, and make sure they are immediately stabilized with grass cover. ♦ One-time, spot fertilization may be needed for initial plantings, depending on soil test results. ♦ Water to achieve approximately 1 inch of total water (irrigation plus rainfall) per week or to prevent wilting during the first growing season (March- November). Long periods of deep watering are preferred to frequent, shallow watering. ♦ Remove and replace dead plants. Up to 10% of the plant stock may die off in the first year, so construction contracts should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction.
At least 4 times per year	♦ Mow grass filter strips and bioretention with turf cover. ♦ Check curb cuts and inlets for accumulated grit, leaves, and debris that may block inflow.
Twice during growing season	♦ Spot weed, remove trash, and rake the mulch.
Annually	♦ Conduct a maintenance inspection. ♦ Supplement mulch in devoid areas to maintain a 3-inch layer. ♦ Remove sediment in pretreatment cells and inflow points.
Once every 2–3 years	♦ Remove and replace the mulch layer.
As needed	♦ Add reinforcement planting to maintain desired vegetation density. ♦ Remove invasive plants using recommended control methods. ♦ Remove any dead or diseased plants. ♦ Stabilize the contributing drainage area to prevent erosion. ♦ Prune trees and shrubs.

The most common non-routine maintenance problem involves standing water. If water remains on the surface for more than 72 hours after a storm, adjustments to the grading may be needed or underdrain repairs may be needed. The surface of the filter bed should also be checked for accumulated sediment or a fine crust that builds up after the first several storm events. There are several methods that can be used to rehabilitate the filter. These are listed below, starting with the simplest approach and ranging to more involved procedures (i.e., if the simpler actions do not solve the problem):

- ✧ Open the underdrain observation well or cleanout and pour in water to verify that the underdrains are functioning and not clogged or otherwise in need of repair. The purpose of this check is to see if there is standing water all the way down through the soil. If there is standing water on top, but not in the underdrain, then there is a clogged soil layer. If the underdrain and stand pipe indicates standing water, then the underdrain must be clogged and will need to be cleaned out.
- ✧ Remove accumulated sediment and till 2 to 3 inches of sand into the upper 6 to 12 inches of soil.
- ✧ Install sand wicks from 3 inches below the surface to the underdrain layer. This reduces the average concentration of fines in the media bed and promotes quicker drawdown times. Sand wicks can be installed by excavating or auguring (i.e., using a tree auger or similar tool) down to the top of the underdrain layer to create vertical columns which are then filled with a clean open-graded coarse sand material (e.g., ASTM C-33 concrete sand or similar approved sand mix for bioretention media). A sufficient number of wick drains of sufficient dimension should be installed to meet the design dewatering time for the facility.
- ✧ Remove and replace some or all of the soil media.

It is recommended that a qualified professional conduct a spring maintenance inspection and clean-up at each bioretention area. Maintenance inspections should include information about the inlets, the actual bioretention facility (sediment buildup, outlet conditions, etc.), and the state of vegetation (water stressed, dead, etc.) and are intended to highlight any issues that need or may need attention to maintain stormwater management functionality.

An example maintenance checklist for bioretention areas is included in *Appendix F*.

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