Greenville County Technical Specification for:

WQ-05 BIORETENTION

1.0 Bioretention

1.1 Description

Bioretention areas are stormwater basins intended to provide water quality management by filtering stormwater runoff before release into a stormwater conveyance system or stabilized outlet. Bioretention may be used as a stand-alone practice or in series with other stormwater management practices as part of a treatment train. Use individual Bioretention areas for drainage areas up to 2 acres in size.

Stormwater runoff enters Bioretention areas and is temporarily stored in a shallow pond on top of a filter media layer. The ponded water then slowly filters down through the filter media and is absorbed by the plantings. As the excess water filters through the system it is temporarily stored and collected by an underdrain system that eventually discharges to a designed storm conveyance system or stabilized outlet.

Bioretention is applicable for small sites (up to 2 acres) where stormwater runoff rates are low and can be received into the Bioretention area as sheet flow. Because Bioretention areas are sensitive to fine sediments, do not install them on sites where the contributing area is not completely stabilized or is periodically being disturbed. Applicable sites include but are not limited to:

- Parking lot islands and additions,
- Cul-de-sacs,
- Common areas,
- Amenity areas,
- Individual residential home sites, and
- Small commercial facilities.

Bioretention areas are capable of removing metals, suspended solids, and oil and grease, and phosphorus but may perform poorly in the removal of nitrogen. In areas where nitrogen is a pollutant of concern, the Bioretention area underdrain system can be adapted to provide some denitrification.

1.2 Design

1.2.1 General Design Criteria

The required method to design an individual Bioretention area or to design a Bioretention area as part of a treatment train with other water quality BMPs is to use the Greenville County IDEAL Model to demonstrate overall site compliance with applicable County water quality standards. See County Design Manual for site-specific applicable water quality standards.

Bioretention areas work best when designed to treat the majority of runoff entering the cell. Divert excess runoff away from the Bioretention area or collect it with an overflow catch basin. Design a stable conveyance for bypass flows in compliance with Design Manual requirements for stormwater conveyances.

Design Bioretention areas to fit around natural topography and complement the surrounding landscape. Bioretention areas can be of any reasonable shape and can be fit around sensitive areas, natural vegetation, roads, driveways, and parking lots.

Typical Bioretention areas have a minimum width of 10 feet and a minimum flow length of 40 feet to establish a strong healthy stand of vegetation.

Where nitrogen is a concern, creating a 90 degree elbow in the underdrain system from the bottom of the Bioretention area to create an Internal Water Storage Zone will encourage the denitrification process.

A summary of the design characteristics for Bioretention areas is shown in Table 1.

Table 1. General Design Characteristics for Bioretention Areas

Infiltration Rate	Optimal range between 1 and 6 inches per hour for filter media.
Maximum Water Depth	Range from 6 to 12 inches, with a 9-inch standard.
Surface Area	Varies, but typically 3 to 8% of the contributing watershed, depending on the amount of impervious area.
Water Table	Vertical distance of 4 feet between bottom of Bioretention area and seasonally high ground water table.
Places to Avoid	Areas that regularly flood (at least once a year), areas within 10 feet of building foundations, and areas with shallow bedrock preventing excavation of Bioretention.
Mulch	A minimum of 2 inches is required while 3 to 4 inches is preferable. Use hardwood, not pine bark nuggets (float). Double-shredded hardwood works well.
Stone for Gravel Layer	Aggregate No. 57 or No. 5 stone is preferred. Separate the gravel from the filter media with a permeable geotextile.

Source: Urban Waterways / Urban Stormwater Structural Best Management Practices (BMPs), North Carolina Extension Service, June, 1999.

1.2.2 Surface Area

To assist in the Bioretention design, the initial surface area may be estimated by the following equation from research by the North Carolina Extension Service, 1999:

$$\text{BSA} = \frac{(\text{DA})(R_v)}{D_{avg}}$$

Where:

BSA = Bioretention surface area (feet^2)
DA = Contributing drainage area of Bioretention area (feet^2)
R_v = Runoff volume (feet) 0.083-feet (1-inch) as a rule of thumb for estimation
D_{avg} = Average ponding water depth above ground (feet)

The initial Bioretention surface area may also be estimated by the following equation from research by Prince George's County, MD:

$$\text{BSA} = 0.1(R_v)(DA)$$

Where:

BSA = Bioretention surface area (feet^2)
0.1 = Empirical conversion factor
R_v = Runoff volume (inches) 1-inch as a rule of thumb for estimation
DA = Contributing drainage area of Bioretention area (feet^2)

1.2.3 Water Draw Down Time

Design Bioretention areas to fully de-water within a 24- to 72-hour period depending on the dimensions, filter media, and underdrain system. In order to allow for proper pollutant removal, design for the ponded runoff above the Bioretention area surface to drain in a maximum of 12 hours. Design for runoff within the filter media to drain to a depth of 2 feet below the Bioretention area surface within 48 hours.

Design the underdrain system to safely pass the peak draw down flow rate of the filter media. The general equation used to determine draw down time is Darcy's Equation:

$$Q = 2.3e^{-5}\ K\ A\frac{\Delta H}{\Delta L}$$

Where:

Q = Flow rate through bioretention (cfs)

K = Hydraulic conductivity of the filter media (in/hr) (Value varies based on actual filter media used)

A = Surface area of bioretention (feet^2)

ΔH = Maximum ponding depth above bottom of filter media (feet)

ΔL = Depth of filter media (feet)

Typical hydraulic conductivity (K) values for filter media are 1 to 6 inches per hour.

Determining the total draw down time is a three-step process.

1. Determine the time it takes to drain the ponded water.
   - Utilize Darcy's Equation to calculate the flow rate (cfs).
   - Calculate the total ponded water volume (feet^3) by multiplying the Bioretention area (feet^2) by the ponded water depth (feet).
   - Divide the total ponded water volume (feet^3) by the flow rate (cfs) to calculate the time to drain the ponded water (seconds)
2. Determine the time it takes to drain the saturated filter media.
   - Calculate the total volume of water contained in the filter media (feet^3) by multiplying the Bioretention area (feet^2) by the filter media depth (feet) by the porosity (dimensionless) of the filter media.
   - Divide the filter media water volume (feet^3) by the flow rate from Darcy's Equation (cfs) to calculate the time to drain the ponded water (seconds).
3. Add up the time to drain the ponded water with the time that it takes to drain the filter media to calculate the total Bioretention area draw down time.

1.3 Materials

Bioretention areas consist of an underdrain system, an internal water storage zone/denitrification zone (if desired), a filter media, an overflow system, plantings, a mulch layer and a pre-treatment system.

1.3.1 Underdrain System

Place an underdrain system beneath the filter media for **all** Bioretention areas as many of the native soils found in Greenville County do not allow for adequate infiltration. The perforated underdrain drain pipe must be connected to a stormwater conveyance system or discharge to a stabilized outlet that daylights (emerges from the ground and is open to the air).

In extreme situations where an underdrain is not feasible due to unique site constraints, infiltration rate must be a minimum 0.5 inches per hour, verified by site specific soil samples at the elevation of the bottom of the Bioretention area where infiltration will occur.

Provide an underdrain system that consists of continuous closed joint perforated plastic pipe underdrains with a minimum 4-inch diameter, an 8-inch minimum gravel filter layer, a non-woven geotextile filter fabric to wrap the perforated pipe and to separate the gravel from the native soils and the gravel from the filter media, and minimum 4-inch diameter non-perforated PVC outlet pipe and clean out wells.

The maximum spacing of pipe underdrains is 10 feet.

Design the underdrain system to safely pass the peak draw down rate calculated in Section 1.2.3.

Underdrain systems will be made of materials specified in Table 2.

Table 2: Underdrain Material Specifications

Material	Specification
Aggregate	Use coarse Aggregate No. 57 or No. 5 consisting of crushed slag or gravel.
Pipe Underdrains	Use PVC perforated pipe (AASHTO M 252) underdrains with a minimum diameter of 4 inches.
Clean Out and Outlet Pipe	Use non-perforated PVC pipe with a minimum diameter of 4 inches.
Non-woven Geotextile Fabric	Use Class 2 Type C non-woven geotextile fabric.

1.3.2 Internal Water Storage Zone (Denitrification Zone)

If desired for enhanced nitrogen removal, provide an Internal Water Storage Zone below the outlet of the underdrain system. A non-woven geotextile fabric is not required between this zone and the underdrain system. Provide a non-woven geotextile fabric between the Internal Water Storage Zone and the underlying native soil. The Internal Water Storage Zone consists of the filter media and the stone used in the underdrain system. Adding a suitable carbon source like wood chips to the gravel in the Internal Water Storage Zone provides a nutrition source for anaerobic microbes and can enhance the denitrification process.

Provide a minimum of 12 inches of filter media above the max ponding height of the Internal Water Storage Zone. Install a valve as specified in Section 1.4.2.3 for dewatering the Internal Water Storage Zone if prolonged standing water occurs.

1.3.3 Filter Media

The filter media provides a medium for physical filtration for the stormwater runoff with enough organic matter content to support growth and provide water and nutrients for plant life.

Ensure the filter media of the Bioretention area is level to allow uniform ponding over the entire area. The maximum ponding depth above the filter media is 12 inches to allow the Bioretention area to drain within a reasonable time and to prevent long periods of plant submergence. Provide a filter media with a minimum infiltration rate of 1 inch per hour (optimal range is 1 to 6 inches per hour). The filter media is to be furnished, and on-site soils are not acceptable. The filter media shall be a uniform mix of sand and organic material meeting the following criteria.

Sand

- 75% to 85% composition by weight
- Medium to coarse washed sand

- Washed river sand and concrete/masonry sand are acceptable
- Do not use lime stone screenings

Organic Material

- 15% to 25% composition by weight
- Compost material that is well decomposed, stable, and weed free
- Derived from leaves, yard debris, wood waste, food waste, or other organic materials
- Does not include manure or biosolids
- Do not use manure-based mushroom compost
- US Composting Council Seal of Testing Assurance (STA) compost is preferred

Acidity/Alkalinity (pH)

- Between 5.2 and 8.0 with an optimal range of 6.0 to 7.5
- Tested prior to installation with documentation to be provided to County
- Utilizing Clemson Extension Agricultural Service Laboratory is recommended. For more information, visit their website at https://www.clemson.edu/public/regulatory/ag-srvc-lab/soil-testing/index.html.

Should the filter media pH fall outside of the acceptable range, modify with pelletized lime (to raise pH) or iron sulfate plus sulfur (to lower pH). Uniformly mix lime or iron sulfate into the filter media prior to use in Bioretention areas.

The Engineer will submit the source and makeup of the filter media and the pH test results to the County prior to the start of construction of Bioretention area. Do not add material to a stockpile of filter media once a stockpile has been sampled. Allow sufficient time for filter media preparation and testing. It is recommended that the Engineer or Contractor consult the County regarding the list of landscape suppliers with the acceptable material that are capable of providing pre-mixed filter media in order to reduce testing and mobilization time and construction delays.

Use a filter media that is uniform, free of stones, stumps, roots or other similar objects larger than 2 inches excluding mulch. Do not mix or dump materials or substances within the Bioretention area that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations.

A filter media that fails to meet the minimum requirements must be amended or replaced. The recommended depth of the filter media is shown in Table 3.

Table 3: Filter Media Depth

Vegetation	Filter Media Depth (ft)
Turf Grass Only	2.0
Native Grasses or Shrubs	3.0
Small Trees	4.0

1.3.4 Overflow System

Design an overflow system to pass runoff away from the Bioretention area. Place an outflow structure at the elevation of the maximum 9-inch to 12-inch ponding depth above the Bioretention area surface to carry excess runoff to a stormwater conveyance system or stabilized outlet.

1.3.5 Plantings

Use plantings that conform to the standards of the current edition of *American Standard for Nursery Stock* as approved by the American Standards Institute, Inc.

For Bioretention applications near roadways, consider site distances and other safety concerns when selecting plant heights. Consider human activities which may damage the plantings, cause soil compaction or otherwise damage the function of the Bioretention area when selecting plant species.

Use plant materials that have normal, well developed stems or branches and a vigorous root system. Only use plantings that are healthy, free from physical defects, plant diseases, and insect pests. Symmetrically balance shade and flowering trees. Ensure major branches do not have V shaped crotches capable of causing structural weakness. Ensure trunks are free of unhealed branch removal wounds greater than a 1-inch diameter.

Use plant species that are tolerant of wide fluctuations in soil moisture content. Use plantings capable of tolerating saturated soil conditions for the length of time anticipated for drawdown, as well as anticipated runoff constituents. See Table 4 below for guidance on acceptable plant types.

Acceptable Bioretention area plantings include:

- Turf Grass only,
- Native Grasses and Perennials,
- Shrubs, and
- Trees.

1.3.5.1 Turf Grass Only

Use turfgrass species with a thick dense cover, slow growing, applicable to the expected moisture conditions (dry or wet), do not require frequent mowing, and have low nutrient requirements. The preferred method of establishing turf grass is sodding. Use temporary erosion control blankets to provide temporary cover when establishing turf grass by seeding.

1.3.5.2 Native Grasses and Perennials

Create a low maintenance native grass or wildflower meadow with native grasses and native perennial species. Temporary erosion control blankets may be used in lieu of a hardwood mulch layer. Plant native grasses and perennials of the same species in clusters 1.0 to 1.5 feet on-center.

1.3.5.3 Shrubs

Provide shrubs a minimum of 2 feet in height. Do not plant shrubs near the inflow and outflow points of the Bioretention area. Plant shrubs of the same species in clusters 10 feet on-center.

1.3.5.4 Trees

Provide trees with a minimum 1-inch caliper. Plant trees near the perimeter of the Bioretention area. Do not plant trees near the inflow and outflow points of the Bioretention area. Do not plant trees directly above Underdrains. Plant trees at a density of one tree per 250 square feet.

1.3.5.5 Planting Plan

A Bioretention area landscape plan includes all planting types, total number of each species, and the location of each species used. The plan includes a description of the contractor's responsibilities including a planting schedule, installation specifications, initial maintenance, a warranty period, and expectations of plant survival. A planting plan includes long-term inspection and maintenance guidelines. Use planting plans prepared by a qualified landscape architect, botanist or qualified extension agent. Use native plant species over non-native species. Ornamental species may be used for landscaping effect if they are not aggressive or invasive. Typical plantings are shown in Table 4 below, but this list is not necessarily exhaustive and other plants may be utilized as appropriate.

Table 4: Bioretention Plant Species

Botanical Name	Common Name	Height	Zone*	Light	Description
Trees					
Aesculus pavia	Red Buckeye	10-15 ft.	2	Sun/shade	Spring flowers, prefers part shade, may defoliate early in season.
Amelanchier canadensis	Serviceberry	12-20 ft.	2	Sun/ part shade	Moist to average soils; Tolerates part shade; Multi-stem grey bark, early spring white flowers, early purple berries, red in fall; high wildlife value, fruits for birds.
Betula nigra	River Birch	50 ft.		Sun	Deciduous; Multi-stem upright.
Carpinus caroliniana	Ironwood/ American Hornbeam	30 ft.	1,3	Sun /shade	Shade tolerant, handles inundation of water, unique silver fluted trunk.
Chionanthus retusus	Chinese Fringetree	12-20 ft.		Sun	Deciduous; Rounded.
Chionanthus virginicus	Fringe Tree	12-20 ft.	2	Sun/shade	Moist soils; excellent small urban tree; Can be shrubby; fragrant pendulous white spring flowers and gold fall color.
Cornus florida	Flowering Dogwood	15-30 ft.		Sun/shade	Deciduous; Upright.
Fagus grandifolia					
Ilex opaca	American Holly	15-50 ft.	1,2	Sun/shade	Medium drought tolerance; Bioretention soil must be sandy loam - intolerant to coarse soils (loamy sand); Sun to shade evergreen, slow growing, white flowers, red berries.
Magnolia stellata	Star magnolia	10-20 ft.		Sun	Deciduous; Oval to rounded.
Magnolia virginiana	Sweetbay Magnolia	15-30 ft.	3	Sun/ part shade	Sun to shade semi-evergreen, fragrant flowers, bright red berries, often multi-stem.
Nyssa sylvatica	Black gum	30-50 ft.		Sun/ part shade	Deciduous; Upright/oval.
Quercus bicolor	Swamp White Oak	50-60 ft.		Sun	Deciduous.
Sassafras albidum	Sassafras	30-60 ft.		Sun/ part shade	Deciduous; Upright, open.
Taxodium distichum	Cascade Falls/ Bald Cypress	<20 ft.		Sun	Deciduous; Weeping.
Vines					
Bignonia capreolata	Cross Vine			Sun	Semi-evergreen; Coarse texture.
Campsis radicans	Trumpet creeper				
Gelsemium sempervirens	Carolina Jessamine	10-20 ft.		Sun	Evergreen; Fine texture, shiny leaves.
Lonicera sempervirens	Trumpet Honeysuckle	15-25 ft.		Sun	Evergreen/Deciduous; Medium texture.
Shrubs					
Abelia x grandiflora	Glossy abelia	3-6 ft.		Sun	Semi-evergreen; Spreading to rounded, arching.
Aucuba japonica	Japanese aucuba	6-10 ft.		Shade	Evergreen; Upright.

Botanical Name	Common Name	Height	Zone*	Light	Description
Buddleia davidii	Butterfly Bush	5-10 ft.		Sun	Deciduous; Rounded.
Callicarpa americana	American Beautyberry	4-8 ft.	2	Sun/ shade	Average to droughty soils ; no anaerobic tolerance; Striking purple berries on new growth, yellow fall color, sun to part shade; well-suited for mountains.
Calycanthus floridus	Sweetshrub/Allspice	6 ft.		Shade	Deciduous; Rounded.
Chaenomeles speciosa	Flowering quince	6-10 ft.		Sun	Deciduous; Rounded.
Cornus alba (sericea L.)	Redtwig dogwood	3-4 ft.			Deciduous; Upright/vertical.
Hamamelis vernalis	Ozark Witch Hazel	15-30 ft.			Deciduous; Rounded.
Hamamelis virginiana	Witch Hazel	15-30 ft.		Sun/ Part shade	Deciduous; Rounded.
Hibiscus syriacus	Rose of Sharon	8-12 ft.		Sun	Deciduous; Erect shrub/small tree.
Ilex glabra	Inkberry Holly	6-8 ft.	3	Sun/shade	Very flood tolerant; high anaerobic tolerance. White flowers with black berries.
Ilex verticillata	Common Winterberry/ Deciduous Holly	6-10 ft.	3	Sun/ part shade	Very flood tolerant intermediate drought resistance; Bioretention soil must be sandy loam - intolerant to coarse soils (loamy sand). White flowers with red berries retained in winter; sun to part shade; well-suited for mountains.
Itea virginica	Virginia Sweetspire	3-6 ft.	3	Sun/shade	Medium shrub. Fragrant white tassel flowers, deep red or purple fall foliage. Well suited for Piedmont. Prefers moist soils.
Ilex vomitoria	Dwarf Yaupon/ Yaupon Holly	8-15 ft.	1,2	Sun/ part shade	High drought tolerance, No anaerobic tolerance. Red fruit in fall & winter. Long lasting translucent berries.
Illicium floridanum	Florida Anise	6-8 ft.		Shade	Evergreen; Upright.
Lindera benzoin	Spicebush	8 ft.	3	Part shade/ shade	Very early chartreuse flowers, fragrant leaves, pale yellow fall color. Suitable for Coast.
Myrica cerifera (evergreen)	Wax Myrtle	10-20 ft.	1,2	Sun/ part shade	Very flood tolerant; medium drought resistance; medium anaerobic tolerance. Fragrant leaves, berries for candles, can prune as a hedge.
Physocarpus opulifolius	Common Ninebark	5-10 ft.		Sun	Deciduous; Upright.
Rhododendron viscosum	Swamp Azalea	6 ft.		Part shade	Deciduous; Upright and spreading.
Sabal minor	Dwarf palometto	10 ft.		Sun	Evergreen; Upright.
Sambucus canadensis	Elderberry/Black Lace	6-8 ft.		Sun	Deciduous; Leggy, open-purple foliage, flowers, and berries.
Spiraea japonica	Fortune meadowsweet	2-3 ft.		Sun	Deciduous; Mounded.
Spiraea thunbergii	Thunberg's meadowsweet	3-5 ft.		Sun	Deciduous; Rounded.
Viburnum dentatum	Southern Arrowhead	6-10 ft.		Sun	Deciduous; Upright.

Botanical Name	Common Name	Height	Zone*	Light	Description
Viburnum lantana	Wayfaringtree virburnum	10-15 ft.		Sun	Deciduous; Upright.
Viburnum lantanoides	Hobblebush	3-6 ft.		Sun	Deciduous; Upright.
Viburnum x rhytidophylloides	Lantanaphyllum Viburnum	8-10 ft.			Semi-evergreen; Upright and spreading.
Perennials					
Achillea millefolium	Common Yarrow	1-2 ft.		Sun	Herbaceous; mounded.
Amsonia hubrichtii	Hubricht's bluestar				
Amsonia tabernaemontana	Eastern Bluestar	1-3 ft.	3	Sun/ part shade	Wetland plant that is Drought resistant; pale blue tubular flowers.
Aquilegia canadensis	Columbine				Herbaceous; Tall, shade, and well-drained.
Asclepias incarnata	Swamp Milkweed	2-4 ft.	3	Sun	Pink rose-purple blooms in mid-summer, attracts butterflies. Thrives in mucky clay soils
Asclepias tuberosa	Butterfly Milkweed	2-3 ft.	1	Sun/ part shade	Prefers well-drained sandy soils. Tolerates drought. Striking and rugged plant with orange flowers that attract butterflies. Slow to establish and easy to grow from seed.
Aster novae-angliae	New England Aster	2-6 ft.		Sun	Herbaceous; Upright, mounded.
Canna glauca	Canna Lily	3-5 ft.		Sun	Herbaceous
Chelone glabra	White Turtlehead	1-4 ft.	3	Sun	Snapdragon type white flowers, often lavender tinged. Attracts butterflies and hummingbirds. Suitable for Piedmont.
Chelone lyonii	Pink Turtlehead	1-4 ft.		Sun	Herbaceous; Mounding.
Conoclinium coelestinum	Blue Mistflower	1-3 ft.		Sun	Herbaceous; Rounded.
Epimedium spp.	Epimedium	8-10 in.		Shade	Herbaceous; Spreading mound.
Eutrochium purpureum	Joe Pye Weed	3-6 ft.	3	Sun	Rapid grower with large pink to purple flowers that attract butterflies.
Helianthus angustifolius	Swamp Sunflower	4-7 ft.	3	Sun/ part shade	Tall yellow daisy flowers with maroon center. Good seed source for birds.
Hemerocallis sp.	Daylily	8-24 in.		Sun/ Part shade	Herbaceous; Mounding.
Heuchera americana	American Alumroot	8-18 in.		Shade	Herbaceous; Mounding.
Hibiscus coccineus	Scarlet rosemallow	4-7 ft.		Sun	Deciduous; Upright, fine.
Iris cristata	Crested Iris	3-6 in.		Shade	Herbaceous; Upright.
Iris sibirica	Siberian Iris	18-24 in.			Herbaceous
Iris versicolor	Harlequin Blueflag	2 ft.		Sun	Herbaceous; Upright.
Iris virginica	Virginia Iris	18-24 in.		Sun	Herbaceous; Upright.

Botanical Name	Common Name	Height	Zone*	Light	Description
Juncus effusus	Soft rush	1-3 ft.		Sun	Evergreen; Vertical.
Kniphofia uvaria	Redhot Poker	1.5-4 ft.		Sun	Herbaceous; Vertical.
Lobelia cardinalis	Scarlet Lobelia/ Cardinal Flower	3-5 ft.	3	Sun/shade	Drought resistant; Bioretention soil must be sandy loam - intolerant to coarse soils (loamy sand). Brilliant red flower spikes that attract butterflies and hummingbirds.
Lobelia siphilitica	Great Blue Lobelia	1-3 ft.		Part shade/ shade	Herbaceous; Upright.
Mertensia virginica	Virginia Bluebells	1 ft.		Part shade/ shade	Herbaceous; Low mound.
Monarda didyma	Scarlet beebalm	2-3 ft.			
Penstemon digitalis	Smooth Penstemon	2 ft.		Sun	Herbaceous; Upright.
Phlox divaricata	Woodland phlox	10-20 in.		Part shade/ shade	Herbaceous; Upright.
Physostegia virginiana	Obedient Plant	2-3 ft.		Sun	Herbaceous; Upright and mounded.
Polygonatum biflorum	Smooth Solomon's Seal	1-3 ft.		Shade	Herbaceous; Arching.
Ruellia brittoniana	Mexican petunia				
Rudbeckia fulgida	Black-eyed Susan/ Goldstrum	1-3 ft.	2	Sun	Moist to dry soils; showy flowers; other species & cultivars. Self-sows and produces abundant offsets.
Salvia uliginosa	Bog-Sage	4-5 ft.		Sun	Herbaceous; Upright.
Solidago speciosa	Goldenrod	2-3 ft.	3	Sun	Thin sprays of arching flowering stems occur at the top of sturdy stems.; Other species & cultivars
Tradescantia virginiana	Virginia spiderwort	1-2 ft		Sun/ Part shade	Herbaceous; Mounded.
Verbena bonariensis	Tall Verbena	2-4 ft.		Sun/ Part shade	Herbaceous; Upright and spreading.
Symphyotrichum spp. (Boltonia asteroides)	Common Aster	1-3 ft.		Sun	Herbaceous; Mounded.
Vernonia noveboracensis	Ironweed	3-6 ft.	3	Sun	Tall red-purple flower clusters late summer & early fall that attract butterflies. Tolerates inundation.
Veronica spicata	Spiked speedwell	1-2'		Sun	Herbaceous; Rounded and upright.
Grasses					
Acorus gramineus	Sweet Flag	4-8 in.		Part shade/ shade	Evergreen; Stiff, upright spreading.
Andropogon gerardii	Big Bluestem	6-8 ft.	1,2	Sun/ part shade	Bunch grass with a blue-green color turning maroon-tan color in fall. Deep roots and drought resistant. Moderately tolerant of acidity and salinity

Botanical Name	Common Name	Height	Zone*	Light	Description
Calamagrostis x acutiflora	Feather reed grass	4-5 ft.		Sun	Herbaceous; Vertical, tightly clustered.
Carex appalachica	Appalachian Sedge	8-12 in.			Herbaceous; Dry side.
Carex stricta	Tussock Sedge	8-12 in.		Part shade/ shade	Herbaceous; Upright or slightly arching.
Chasmanthium latifolium	River Oats	2-4 ft.	1,3	Part shade/ shade	Clump forming. Dangling oats are ornamental and copper in fall. Medium drought and anaerobic tolerance; showy seed clusters, spreads by seed.
Muhlenbergia capillaris	Muhly Grass/ Mist Grass	1-3 ft.	1,3	Sun	In the fall, creates a stunning pink to lavender floral display. Functions well in meadow gardens.
Panicum virgatum	Panic Grass/ Switchgrass	3-6 ft.	1,3	Sun/ part shade	Clump forming grass very tolerant of flooding and tolerates dry soils and is drought resistant; fuzzy flower heads.
Pennisetum alopecuroides	Dwarf Fountain Grass/Cassian		2-3 ft.		Herbaceous
Schizachyrium scoparium	Little Bluestem	2-18 ft.	1,2	Sun/ part shade	Clump grass that attracts birds and mammals. Blue-green stems that turn mahogany-red with white seed tufts in the fall. Readily reseeds. Suitable for the Coast.
Sorghastrum nutans	Indian Grass	3-6 ft.	1,2	Sun/shade	Tall, bunching sod-former, with broad blue-green blades and a large, plume-like, soft, golden-brown seed head. Fall color is deep orange to purple. Drought tolerant
					Turf Grasses
Cynodon dactylon	Bermudagrass				
Festuca arundinacea	Tall Fescue				
Zoysia japonica	Japanese/Korean Lawngrass				
					Ferns
Athyrium filix-femina	Lady Fern	1.5-3 ft.		Shade	Herbaceous; Mounding.
Onoclea sensibilis	Sensitive Fern	3-4 ft.		Part shade/ Shade	Herbaceous; Mounding.
Osmunda cinnamomea	Cinnamon Fern	2-4 ft.	3	Part shade/ shade	Ideal for moist areas of Bioretention area. Non-flowering plant that reproduces by spores.
Osmunda regalis	Royal Fern	2-3 ft.	3	Part shade/ shade	Tolerates year-round shallow water.
Polystichum acrostichoides	Christmas Fern	18-36 in.		Part shade/ shade	Herbaceous; Arching.

*** = Wetness Zone**	**1** Plants that, once established, withstand drought (3-4 weeks without rainfall); Establishment is 1-2 yrs for trees & shrubs, 1 yr for perennials & grasses **2** Plants that grow best in moist to average soils and only tolerate short periods (1-2 days) of flooding. **3** Plants that tolerate longer periods of flooding (3-5 days), but also grow in moist to average soils.

1.3.6 Mulch Layer

Provide a uniform 3-inch layer of mulch on the surface of the Bioretention area that provides an environment to enhance plant growth, enhance plant survival, suppresses weed growth, reduce erosion of the filter media, maintain soil moisture, trap fine sediments, promote the decomposition of organic matter, and pre-treat runoff before it reaches the filter media.

Provide shredded hardwood bark that consists of bark from hardwood trees milled and screened to a maximum 4 inch particle size, uniform in texture, free from sawdust and foreign materials, and free from any artificially introduced chemical compounds detrimental to plant life. Provide mulch that is well aged a minimum of 6-months.

Do not use pine needles or pine bark mulch due to the ability of floatation.

Use alternative surface covers such as native groundcover, erosion control blankets, river rock, or pea gravel as directed by the Engineer. Use alternative surface covers based on function, cost and maintenance.

Do not provide a mulch layer for Bioretention areas that utilize turf grass as the vegetation material.

1.3.7 Pre-treatment System

Provide a pre-treatment system to reduce incoming velocities, evenly spread the flow over the entire Bioretention area, and to trap coarse sediment particles before they reach the filter media. Several pre-treatment systems are applicable, depending on whether the Bioretention area receives sheet flow, shallow concentrated flow or deeper concentrated flows. The following are appropriate pretreatment options:

- **Forebay** (for channel flow): Located at pipe inlets or curb cuts leading to the Bioretention area consisting of energy dissipation and flow dispersion sized for the expected peak discharge rate. The Forebay may be formed by a wooden or stone check dam or an earthen or rock berm. Ensure the Forebay is protected with the proper erosion prevention measures. The Forebay does not require an underlying filter media.
- **Grass Filter Strips** (for sheet flow): Extend a minimum of 10 feet from edge of pavement to the upstream edge of the Bioretention area with a maximum slope of 5%.
- **Gravel or Stone Diaphragms** (for sheet or concentrated flow): Located at the edge of pavement or other inflow point, running perpendicular to the flow path to promote settling. Size the stone according to the expected peak discharge rate.
- **Level Spreaders** (for sheet flow): Level spreaders reduce incoming energy from the runoff and convert concentrated flow to sheet flow that is evenly distributed across the entire Bioretention area. See Specification and Details for WQ-13 Level Spreader.
- **Manufactured Treatment Devices (MTDs):** An approved MTD may be used to provide pre-treatment (except in single-family residential developments).

1.4 Construction Requirements

Do not construct Bioretention areas until all contributing drainage areas are completely stabilized as directed by the Engineer. Do not use Bioretention areas as sediment control facilities during construction for sediment control. Do not operate heavy equipment within the perimeter of Bioretention areas during excavation, underdrain placement, backfilling, planting, or mulching.

Separate Bioretention areas from the water table to ensure groundwater does not enter the facility leading to groundwater contamination or Bioretention failure. Ensure a vertical distance of 4 feet between the bottom of the Bioretention area and the seasonally high ground water table, to be verified by a geotechnical report if requested by the County.

Ensure bedrock is not present in areas that must be excavated for Bioretention construction, including location of underdrain and filter media layer.

1.4.1 Site Preparation

Pre-treat stormwater runoff to reduce the incoming velocities, evenly spread the flow over the entire Bioretention area, and provides removal of coarse sediments. Because Bioretention areas are sensitive to fine sediments, do not install them on sites where the contributing area is not completely stabilized or is periodically being disturbed.

1.4.2 Installation

Install Bioretention areas around the natural topography to complement the surrounding landscape by fitting around sensitive areas, natural vegetation, roads, driveways, and parking lots. Bioretention areas have a minimum width of 10 feet and a minimum flow length of 40 feet to establish a strong healthy stand of vegetation.

1.4.2.1 Excavation

Excavate the Bioretention area to the dimensions, side slopes, and elevations shown on the Plans. Excavate Bioretention areas to the required depth based on the plantings utilized. Refer to Table 3 for recommended filter media depth for Bioretention plantings.

Ensure excavation minimizes the compaction of the bottom of the Bioretention area. Operate excavators and backhoes on the ground adjacent to the Bioretention area or use low ground-contact pressure equipment. Do not operate heavy equipment on the bottom of the Bioretention area.

Remove excavated materials from the Bioretention area and dispose of them properly.

1.4.2.2 Underdrain System

Prior to placing the underdrain system, alleviate compaction on the bottom of the Bioretention area by using a primary tilling operation such as a chisel plow, ripper, or subsoiler to a depth of 12 inches. Substitute methods must be approved by the Engineer. Rototillers typically do not till deep enough to reduce the effects of compaction from heavy equipment.

Remove any ponded water from the bottom of the excavated area. Line the excavated area with a Class 2, Type C non-woven geotextile fabric.

Place a layer of No. 5 or No. 57 Aggregate 3-foot wide, and minimum of 3 inches deep on top of the non-woven filter fabric. Place the pipe underdrains on top of the underlying aggregate layer. Wrap underdrain pipes with a non-woven geotextile filter fabric before they are installed. Lay the underdrain pipe at a minimum 0.5% longitudinal slope. The perforated underdrain drain pipe is connected to a stormwater conveyance system or discharges to a stabilized outlet. Cap the ends of underdrain pipes not terminating in an observation well.

Install observation wells/cleanouts made of non-perforated pipe vertically in the Bioretention area. Install observation wells and/or clean-out pipes at the ratio of one minimum per every 1,000 square feet of surface area as shown on the Plans. Connect the wells/cleanouts to the perforated underdrain with the appropriate manufactured connections as shown on the Plans. Extend the wells/cleanouts 6 inches above the top elevation of the Bioretention area mulch layer, and cap with a screw cap.

Place No. 5 or No. 57 Aggregate around the pipe underdrain system to a minimum depth of 8 inches. Place a Class 2, Type C non-woven geotextile fabric at the boundary between the gravel and the filter media to prohibit the filter media from filtering down to the perforated pipe underdrain.

Place an outflow structure at the elevation of the maximum 9-inch to 12-inch ponding depth of the Bioretention area to carry excess runoff from the Bioretention area to a stormwater conveyance system, or stabilized outlet.

1.4.2.3 Internal Water Storage Zone (Denitrification Zone)

If additional treatment for nitrogen is needed or required, create an Internal Water Storage Zone by constructing a 90 degree angle (elbow) in the outlet structure. The 90 degree elbow should extend a minimum height of 12 inches above the invert of the underdrain system. The pipe should also extend 6 inches beyond the elbow and have a screw cap on the end which can be opened from inside the outlet structure to drain the IWS for maintenance.

1.4.2.4 Filter Media

Install a permeable non-woven geotextile filter fabric between the filter media and the underlying on-site soils. Place and grade the filter media using low ground-contact pressure equipment or excavators and/or backhoes operating on the ground adjacent to the Bioretention area. Do not use heavy equipment within the perimeter of the Bioretention area before, during, or after the placement of the filter media. Place the filter media in vertical layers with a thickness of 12 to 18 inches. Compact the filter media by saturating the entire Bioretention area after each lift of filter media is placed until water flows from the underdrain system. Apply water for saturation by spraying or sprinkling. Perform saturation of each lift in the presence of the Engineer. Do not use equipment to compact the filter media. Use an appropriate sediment control BMP to treat any sediment-laden water discharged from the underdrain during the settling process.

The Engineer will provide documentation from the supplier to verify the makeup of the pre-mixed filter media to the County.

1.4.2.5 Plantings

Plant all Bioretention areas grasses, native grasses, perennials, shrubs, trees, and other plant materials specified to applicable landscaping standards.

Ensure all plant materials are kept moist during transport and on-site storage. Plant the root ball so 1/8th of the ball is above final filter media surface. Ensure the diameter of the planting pit/hole is at least 6 inches larger than the diameter of the planting ball. Set and maintain the plant straight during the entire planting process. Thoroughly water all plantings after installation.

Brace trees using 2-inch by 2-inch stakes only as necessary. Ensure stakes are equally spaced on the outside of the tree ball.

1.4.2.6 Mulch

Immediately mulch the entire Bioretention area to a uniform thickness of 3 inches after all planting are in place. Do not use mulch for Bioretention areas that utilize turf grass as the only vegetation material.

1.5 Inspection and Maintenance

Regular inspection and maintenance are critical to the effective operation of Bioretention areas. Maintenance responsibility of the Bioretention area is vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

The surface of the ponding area may become clogged with fine sediments over time. Perform light core aeration or cultivate unvegetated areas as required to ensure adequate filtration. Other required maintenance includes but is not limited to:

- Perform pruning and weeding to maintain appearance periodically as needed.
- Replace or replenish mulch periodically as needed.
- Remove trash and debris periodically as needed.

Required maintenance activities and their frequencies are listed in Table 5.

Table 5: Summary of Maintenance Requirements

Required Maintenance	Frequency
Pruning and weeding.	As needed
Remove trash and debris.	As needed
Inspect inflow points for clogging. Remove any sediment	Semi-annual (every 6 months)
Repair eroded areas. Re-seed or sod as necessary.	Semi-annual (every 6 months)
Mulch void areas.	Semi-annual (every 6 months)
Inspect trees and shrubs to evaluate their health.	Semi-annual (every 6 months)
Remove and replace dead or severely diseased vegetation.	Semi-annual (every 6 months)
Removal of invasive vegetation.	Semi-annual (every 6 months)
Test filter media for nutrient/fertilizer requirements.	Annual
Nutrient management per soil test results.	As needed
Pesticide management.	As needed
Water vegetation, shrubs and trees.	Semi-annual (every 6 months)
Remove mulch, reapply new layer.	Annual
Test filter media for pH.	Annual
Apply pelletized lime if pH < 5.2.	As needed
Add iron sulfate + sulfur if pH > 8.0.	As needed
Place fresh mulch over entire area.	As needed
Replace pea gravel diaphragm	Every 2 to 3 years if needed

1.6 IDEAL Modeling

The County's required method of demonstrating compliance with its water quality standards is to use the Greenville County IDEAL model. To facilitate use of this model, Table 6 shows how to represent this BMP and BMPs similar to this one in the IDEAL model. It lists the parameters needed to successfully run the model and the parameters that affect the sediment trapping efficiency of the BMP.

Table 6: IDEAL Modeling Guide

Bioretention Cell Modeling in IDEAL		
What to Model as in IDEAL	Bioretention Cell	
Similar BMPs	Stormwater Alley	
	Green Roofs	
	Planter Box	
	Rain Gardens	
	Natural Infiltration Area/Basin	
	Bioretention Area/Swale/Basin	
Specifications Needed for IDEAL	Cell area and number of layers within the cell	
	If applicable, underdrain details such as: - Subgrade infiltration soil texture and degree of saturation - Underdrain orifice diameter - Height of upturned elbow	
	Type of media and depth of each layer of the cell	
	Shape and dimensions of the riser	
	Dimensions, slope, Manning's roughness coefficient, and entrance loss coefficient of the barrel	
	Type, shape, and dimensions of the emergency spillway if present	
	Direct loading of bacteria that will be entering the cell	
Parameters that Drive Performance	Feature	How Value Affects Sediment Trapping Efficiency (TE)
	Underlying Soil Texture	Soils with higher infiltration capabilities increase TE
	Area	Increasing area increases TE
	Amount of Clay in Media	More clay increases TE but decreases infiltration rate

1.7 References

Clemson University Extension Carolina Clear, A Guide to Rain Gardens in South Carolina, 2016.

Clemson University Public Service Activities Carolina Clear, Rain Gardens, A Rain Garden Manual for South Carolina, 2009.

NCDENR Stormwater BMP Manual, Chapter 12 Bioretention, Chapter Revised 07-24-09

Prince George's County, Maryland, Bioretention Design Specifications and Criteria, Section 2.0 - Siting and Design Criteria

Rain Gardens Urban Waterways / Urban Stormwater Structural Best Management Practices (BMPs), North Carolina Extension Service, June, 1999.