Bioretention

Description: Bioretention cells are vegetated, shallow depressions. Captured runoff is treated by filtration through an engineered soil medium and is either infiltrated into the subsoil or exfiltrated through an underdrain.

Advantages/Benefits:

- Reduced runoff volume
- Reduced peak discharge rate
- Reduced Total Suspended Solids (TSS)
- Reduced pollutant loading
- Reduced runoff temperature
- Groundwater recharge (if soils are sufficiently permeable)
- Habitat creation
- Enhanced site aesthetics
- Reduced heat island effect

Disadvantages/Limitations:

- Problems with installation can lead to failure
- Minimum 2-foot separation from groundwater and bedrock is required
- Geotechnical testing required

Selection Criteria:

60% – 80% Runoff Reduction Credit

Land Use Considerations:

- [x] **Residential**
- [x] **Commercial**
- [x] **Industrial**

Maintenance:

- Regular maintenance of landscaping to maintain healthy vegetative cover
- Irrigation when necessary during first growing season
- Periodic trash removal

M **Maintenance Burden**
L = Low M = Moderate H = High

SECTION 1: DESCRIPTION

Bioretention Basins are structures treating parking lots and/or commercial rooftops, usually in commercial or institutional areas. Throughout this GIP bioretention basins are simply referred to as Bioretention. Inflow can be either sheet flow or concentrated flow. Bioretention basins may also be distributed throughout a residential subdivision, but they should be located in common areas and within drainage easements, to treat a combination of roadway and lot runoff.

The major design goal for bioretention is to maximize runoff volume reduction and pollutant removal. To this end, designers may choose to go with the baseline design (Level 1) or choose an enhanced design (Level 2) that maximizes pollutant and runoff reduction. If soil conditions require an underdrain, bioretention areas can still qualify for the Level 2 design if they contain a stone storage layer beneath the invert of the underdrain. **Table 1.2** outlines the Level 1 and 2 bioretention design guidelines. Local simulation modeling supports these runoff reduction credits for the mentioned contributing drainage area (CDA) to surface area ratios.

Figure 1.1. A typical bioretention basin treating a parking lot

SECTION 2: PERFORMANCE

The overall runoff reduction capabilities of bioretention in terms of the Runoff Reduction Method are summarized in **Table 1.1**. Bioretention creates a good environment for runoff reduction, filtration, biological uptake, and microbial activity, and provides high pollutant removal. Bioretention can become an attractive landscaping feature with high amenity value and community acceptance.

Table 1.1. Runoff Volume Reduction Provided by Bioretention Basins		
Stormwater Function	**Level 1 Design**	**Level 2 Design**
Runoff Volume Reduction (RR)	60%	80%
Treatment Volume (Tv) Multiplier*	1.10	1.25

*Incorporated into LID Site Design Tool calculations
Sources: CSN (2008) and CWP (2007)

SECTION 3: TYPICAL DETAILS

See Appendix 1-B and 1-C for required standard notes and applicable details for use in construction plans.

SECTION 4: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

Bioretention can be applied in most soils or topography, since runoff simply percolates through an engineered soil bed and can be returned to the stormwater system if the infiltration rate of the underlying soils is low. Key considerations with bioretention include the following:

Infiltration/Soils. Infiltration is a key component of Low Impact Development (LID) design. Infiltration testing shall be required for all bioretention locations (see **Section 5.1**). Soil conditions do not constrain the use of bioretention but can affect the design requirements. Hydrologic Soil Groups (HSG) should be determined from NRCS soil data. For more information on soil types go to: http://websoilsurvey.nrcs.usda.gov/app/. Alternative HSG classifications will be considered when supporting reports from a licensed soil scientist or geotechnical engineer are provided.

Available 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 required surface area. The bioretention surface area will be approximately 3% to 10% of the contributing drainage area, depending on the imperviousness of the contributing drainage area (CDA), the subsoil infiltration rate, and the desired bioretention design level. The minimum length and width dimension of the bioretention area shall be 10 feet.

Accessibility. Bioretention facilities require periodic maintenance and must be accessible to various types of equipment. A path of travel for equipment no less than ten feet in width with a maximum slope of 3:1 must be provided for the bioretention facility. The path of travel shall be along no less than 50% of the perimeter of the bioretention area and must be accessible by common equipment and vehicles at all times. MWS staff can consider alternate access paths.

Elevation Considerations. Bioretention is best applied when the grade of contributing slopes is greater than 1% and less than 5%. Terracing or other inlet controls may be used to slow runoff velocities entering the facility. 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).

Subsurface Constraints. Vertical constraints such as retaining walls, structures, or other impermeable barriers are limited to a maximum of 50% of the bioretention perimeter (>50% see **GIP-02**). Vertical constraints are not permitted on the down gradient side of a bioretention area. Subsurface constraints five feet from the bioretention media will not count under this section. Bioretention subgrade shall always be separated from the water table and bedrock. Groundwater intersecting the filter bed can lead to possible groundwater contamination or failure of the bioretention facility. A separation distance of 2 feet is required between the bottom of the excavated bioretention area and the seasonally high ground water table and/or bedrock.

Utilities. Designers must ensure that future tree canopy growth in the bioretention area will not interfere with existing overhead public utility lines. Public underground utilities and associated easements shall not be located within the bioretention footprint. Local utility design guidance shall be consulted in order to determine clearances required between stormwater infrastructure and other dry and wet utility lines. Private utilities should not be located within the bioretention area when possible.

Contributing Drainage Area. Bioretention works best with smaller contributing drainage areas, where it is easier to achieve flow distribution over the filter bed without experiencing erosive velocities and excessive ponding times. The maximum amount of impervious cover contributing to a bioretention should be a maximum of 5 acres. The maximum amount of impervious cover per outfall into a bioretention should be a maximum of 2.5 acres. Contributing drainage areas to bioretention areas shall be clearly conveyed in the construction plans.

Hotspot Land Uses. Runoff from hotspot land uses should not be treated with infiltrating bioretention without appropriate pretreatment and MWS staff approval. For additional information on stormwater hotspots, please consult **Section 6.3**.

Floodplains. Bioretention areas shall be constructed outside the limits of the 100-year floodplain. Flood waters from the 100-year event or smaller shall be prohibited from entering the bioretention underdrain or overflow system.

No Irrigation or Baseflow. The planned bioretention area shall not receive baseflow, irrigation water, chlorinated wash-water or other such non-stormwater flows, except for irrigation as necessary during the first growing season for the survival of plantings within the bioretention area (see **Section 9.2**).

Setbacks. It is not recommended to place bioretention areas immediately adjacent to structures. To avoid the risk of seepage, a licensed professional engineer should be consulted to determine the appropriate setbacks necessary to prevent bioretention infiltration from compromising structural foundations or pavement. At a minimum, bioretention basins should be located a horizontal distance of 100 feet from any water supply well and 50 feet from septic systems.

Applications. Bioretention has been used at commercial, institutional and residential sites in spaces that are traditionally pervious and landscaped. It should be noted that special care must be taken to provide adequate pretreatment for bioretention cells in space-constrained high traffic areas. Typical locations for bioretention could include parking lot features, courtyards, and unused pervious areas on a site.

SECTION 5: DESIGN CRITERIA

5.1 Soil Infiltration Rate Testing

One must measure the infiltration rate of subsoils at the subgrade elevation of the bioretention area. If the infiltration rate exceeds 0.5 inch per hour, an underdrain should not be utilized. If the infiltration rate of subsoils is greater than 0.1 inch per hour and less than or equal to 0.5 inch per hour, underdrains will be required. If the infiltration rate is 0.1 inch per hour or less bioretention should not be used. On-site soil infiltration rate testing procedures are outlined in **Appendix 1-A**. The number of soil tests varies base on the size of the bioretention area:

- < 1,000 ft^2 = 2 tests
- 1,000 – 10,000 ft^2 = 4 tests
- >10,000 ft^2 = 4 tests + 1 test for every additional 5,000 ft^2

A separation distance of 2 feet is required between the bottom of the excavated bioretention area and the seasonally high ground water table and/or bedrock.

For sites with large amounts of cut or fill it may not be practical to perform infiltration testing prior to grading the site. In these cases, a mass grading permit will be required.

MWS staff may work with design engineers to evaluate infiltrative testing alternatives when extreme site limitations exist.

5.2 Sizing of Bioretention Practices

5.2.1 Stormwater Quality

Sizing of the surface area (SA) for bioretention practices is based on the computed Treatment Volume (T_v) of the contributing drainage area and the storage provided in the facility. The required surface area (in square feet) is computed as the Treatment Volume (in cubic feet) divided by the equivalent storage depth (in feet). The minimum length and width dimension shall be 10 feet. The equivalent storage depth is computed as the depth of media, gravel, and surface ponding (in feet) multiplied by the accepted porosity (see **Table 1.2**). All layer depths shall be uniform with regard to surface area. The filter bed surface should generally be flat so the bioretention area fills up like a bathtub. See **Section 5.5** for material specifications.

Table 1.2 Bioretention Typical Section for Water Quality Calculations					
Infiltration (i)	**i > 0.5"/hr (no underdrain permitted)**		**0.1"/hr< i ≤0.5"hr (underdrain required)**		**Porosity Value (n)**
Layer	**Level 1 (inches)**	**Level 2 (inches)**	**Level 1 (inches)**	**Level 2 (inches)**	
Ponding	8				1.0
Surface Cover*	3	3	3	3	N/A
Media	24-72	36-72	24-72	36-72	0.25
Choker	3	3	3	3	0.40
Reservoir	0-9	9	9	9	0.40
Sump*	0	0	0	12	N/A

* Cannot be used in De and surface area calculations.

The equivalent storage depth for Level 1 is therefore computed as:

Equation 1.1. Bioretention Level 1 Design Storage Depth

$$\text{Equivalent Storage Depth} = D_E = n_1(D_1) + n_2(D_2) + \cdots$$

$$D_E = (2 \text{ to } 6 \text{ ft.} \times 0.25) + (1 \text{ ft} \times 0.40) + (0.67 \text{ ft} \times 1.0) = 1.57 \text{ to } 2.57 \text{ ft.}$$

Where n_1 and D_1 are for the first layer, etc.

And the equivalent storage depth for Level 2 is computed as:

Equation 1.2. Bioretention Level 2 Design Storage Depth

$$D_E = (3 \text{ to } 6 \text{ ft.} \times 0.25) + (1 \text{ ft.} \times 0.40) + (0.67 \text{ ft} \times 1.0) = 1.82 \text{ to } 2.57 \text{ ft}$$

While this method is simplistic, simulation modeling has proven that it yields a total storage volume equivalent to 80% total average rainfall volume removal for infiltration rates from 0.5 in/hr through 1.2 in/hr.

Therefore, the Level 1 Bioretention Surface Area (SA) is computed as:

Equation 1.3. Bioretention Level 1 Design Surface Area

$$SA \text{ (sq. ft.)} = [(1.10 * T_v) - \text{the volume reduced by an upstream SCM}] / D_E$$

And the Level 2 Bioretention Surface Area is computed as:

Equation 1.4. Bioretention Level 2 Design Surface Area

$$SA \text{ (sq. ft.)} = [(1.25 * Tv) - \text{the volume reduced by an upstream SCM}] / D_E$$

Where:

SA = Minimum surface area of bioretention filter (sq. ft.)

D_E = *Equivalent Storage Depth (ft.)*

T_v = Treatment Volume (cu. ft.) = [(1.0 in.)(R_v)(A)*3630]

5.2.2 Stormwater Quantity

It is recommended that rain events larger than the 1-inch storm bypass bioretention areas to prevent additional maintenance burden. However, if designed with sufficient volume and appropriate outlet structures, peak attenuation control may be provided by the bioretention area. Hydrologic calculations utilizing the SCS method may be necessary to demonstrate pre versus post peak flow rates.

Surface Storage. Designers may be able to create additional surface storage for flow attenuation by expanding the surface ponding without necessarily increasing the bioretention footprint. In other words, the engineered soil media would only underlay part of the surface area of the bioretention (see **Figure 1.3**). During the 100-year storm event, a maximum ponding depth of 15 inches above the top of the surface cover is allowed. Water quality calculations are limited to 8 inches of ponding

Subsurface Storage. Designers may be able to create additional subsurface storage for flow attenuation by increasing the subsurface volume without necessarily increasing the bioretention footprint. Additional volume can be provided by increasing the depth of media, stone, or approved proprietary storage products. Subsurface storage will not be allowed without sufficient infiltration (see **Section 5.1**). The bioretention depth including subsurface storage shall not exceed 10 feet.

Adjusted CN. With infiltration rates greater than 0.5 inch per hour (see **Section 5.1**), the removal of volume by bioretention changes the runoff depth entering downstream flood control facilities. An approximate approach to accounting for the removal of volume is to calculate an "effective SCS curve number" (CN_{adj}), which is less than the actual curve number (CN). CN_{adj} can then be used in hydrologic calculations and in routing. This method is detailed in Volume 5 Section 3.2.5.

5.3 Pretreatment

Pretreatment facilities must always be used in conjunction with bioretention to remove floatables and sediment to prevent clogging and failure. Every infiltration practice must include multiple pretreatment techniques, although the nature of pretreatment practices depends on the type of flow received. Pretreatment measures should be designed to evenly spread runoff across the entire width of the bioretention area. Several pretreatment measures are feasible, depending on the scale of the bioretention practice and whether it receives sheet flow, shallow concentrated flow or deeper concentrated flows. The number, volume and type of acceptable pretreatment techniques needed for the types of receiving flow are found in **Table 1.3**.

Volumetric pretreatment practices, such as forebays, are sized based on a percentage of the required treatment volume of the GIP. The percentage requirement for the pretreatment practice is exclusive of the required treatment volume for the GIP. Exclusive, in this application, is defined as being separate from the required treatment volume of the GIP. The volume provided by pretreatment practices cannot be included in the calculation for overall treatment volume provided by the GIP.

Table 1.3. Required Pretreatment Elements for Infiltration Practices

Flow Type	***Pretreatment Options***
Point/ Concentrated*	• ***Forebay*** ○ *15% pretreatment volume (exclusive)* ○ *enhanced check dam (TDOT EC-STR-6A); or approved equivalent* ○ *flat bottom without stone* • ***Proprietary structure (MWS approval)***
Sheet	*Gravel diaphragm to grass filter strip (15' with maximum 3:1 slope)*
Upstream GIP	*Outlet protection may be required at upstream GIP outfall*

* Roof drains may bypass the forebay and directly enter the bioretention area with sufficient flow dissipation; however, the forebay volume shall be calculated using the total treatment volume of the GIP.

5.4 Conveyance and Overflow

For On-line bioretention: An overflow structure should always be incorporated into on-line designs to safely convey larger storms through the bioretention area. Common overflow systems within bioretention practices consist of an outlet structure(s) and/or emergency spillway in compliance with the Stormwater Management Manual, Volume 2, Section 8.

Off-line bioretention: Off-line designs are preferred (see **Figure 1.8** for an example). One common approach is to 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 filtrates through the soil media.

Another option is to utilize a low-flow diversion or flow splitter at the inlet to allow only the Treatment Volume to enter the facility. This may be achieved with a weir or curb opening sized for the target flow, in combination with a bypass channel. Using a weir or curb opening helps minimize clogging and reduces the maintenance frequency.

5.5 Bioretention Material Specifications

Table 1.4 outlines the standard material specifications used to construct bioretention areas.

Table 1.4. Bioretention Material Specifications

Material	Specification	Notes
Surface Layer	• Shredded hardwood • Hardwood bark • River stone • Coir or jute matting • Turf	Lay a 3-inch layer on the surface of the filter bed in order to suppress weed growth & prevent erosion. Stone shall not comprise more than 50% of the surface area.
Filter Media Composition (by volume)	• 70% - 85% sand; • 10%-30% silt + clay, with clay $\leq$ 10%; and • 5% to 10% organic matter	The volume of filter media based on 110% of the plan volume, to account for settling or compaction. Contact staff for testing procedures.
Geotextile	Use a non-woven geotextile fabric with a flow rate of > 110 gal./min./ft^2 (e.g., Geotex 351 or equivalent)	Apply only to the sides and above the underdrain (2'-4' wide strip). AASHTO M288-06, ASTM D4491 & D4751
Choker Layer	#8 or #89 clean washed stone	Meet TDOT Construction Specifications.
Reservoir Layer	#57 clean washed stone	Meet TDOT Construction Specifications.
Underdrain	6-inch dual wall HDPE or SDR 35 PVC pipe with 3/8-inch perforations at 6 inches on center	AASHTO M 252 Place perforated pipe at base of reservoir layer.
Cleanout	6-inch SDR 35 PVC pipe with vented cap	Provide cleanouts at the upper end of the underdrain.
Observation Well	6-inch SDR 35 PVC pipe with vented cap and anchor plate	Number of wells equals the number of test pits required for infiltration testing (see Appendix 1-A)
Sump Layer	#57 clean washed stone	Meet TDOT Construction Specifications.

5.6 Bioretention Planting Plans

A landscaping plan must be provided for each bioretention area. Minimum plan elements shall include the proposed planting plan for the surface area of the bioretention, the list of planting stock, sources of plant species, sizes of plants, and the planting sequence along with post-nursery care and initial maintenance requirements. The planting plan must address 100% of the planting area and achieve a surface area coverage of at least 75% in the first two years. 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. **Appendix 1-D** lists native plant species suitable for use in bioretention. For a bioretention area to qualify for Level 2 Design, a minimum of one tree must be planted for every 400 square feet.

The planting plan must be prepared by a qualified Landscape Architect. The Landscape Architect shall certify the planting plan with certification statement, located on the bioretention planting plan. Standard certification statement can be found in **Appendix 1-B**.

Recommended planting templates include the following:

- Ornamental planting. This option includes perennials, sedges, grasses, shrubs, and/or trees in a mass bed planting. This template is recommended for commercial sites where visibility is important. This template requires maintenance similar to traditional landscape beds.
- Meadow. This is a lower maintenance approach that upon maturity may resemble a wildflower meadow or prairie. It can include a mixture of densely planted grasses and/or perennials.

Designs should utilize more mature plants densely spaced to achieve coverage and minimize maintenance. Planting species in groups will help maintenance staff differentiate weeds from desired species. Establishing a solid ground cover can also prevent weed intrusion and eliminate the need for continued mulching. **Table 1.5** contains the recommended number of perennials, grasses, and shrubs per one hundred square feet of bioretention area based upon the spacing provided in **Appendix 1-D**.

Example: A 300 square foot meadow bioretention is designed with one-gallon perennials and grasses planted on 24" centers. How many plants should be included in the design?

300 sq. ft (29 plants/100 sq. ft) = 87 plants

Table 1.5 Plant Spacing for Perennials, Grasses, Sedges and Shrubs

Spacing (O.C.)	Plants per 100 sq.ft.
18" o.c.	51.2
24" o.c.	29
28" o.c.	22
30" o.c.	18.5
36" o.c.	12.8
42" o.c.	10
4' o.c.	7.23
5' o.c.	4.61
6' o.c.	3.2
8' o.c.	1.8

SECTION 6: SPECIAL CASE DESIGN ADAPTATIONS

6.1 Shallow Bedrock and Groundwater Connectivity

Many parts of Nashville have shallow bedrock, which can constrain the application of deeper bioretention areas (particularly Level 2 designs). In such settings, other GIPs may be more applicable. For more information on bedrock depths download the GIS data set from: http://water.usgs.gov/GIS/metadata/usgswrd/XML/regolith.xml.

6.2 Karst

Karst regions are found in much of Middle Tennessee, which complicates both land development and stormwater design. Infiltrative practices shall not be used in any area with a high risk of sinkhole formation.

6.3 Hotspots

Stormwater hotspots are operations or activities that are known to produce higher concentrations of stormwater pollutants and/or have a greater risk for spills, leaks or illicit discharges. Bioretention designs shall not be used in any area with a hotspot designation without appropriate pretreatment, impermeable barriers, and MWS staff approval. Staff may also require additional treatment for runoff from hotspots.

6.4 Internal Water Storage

Enhanced water quality can be achieved by utilizing an Internal Water Storage (IWS) system in bioretention areas. Utilizing an IWS configuration can create an anaerobic zone that can increase annual runoff reduction rates, promote denitrification, reduce levels of other pollutants, and increase groundwater recharge in bioretention areas (See **Figures 1.4 and 1.5**). An IWS system shall be used for water quality only <u>and in an offline configuration</u>. A minimum field-verified infiltration rate of 0.1 inches per hour is required in order to count the stone reservoir as storage volume. The following sections detail two different methods for creating an IWS system.

Cobra Head Style. The perforated underdrain is placed at the bottom of the stone reservoir layer and extends the full length of the bioretention. An upturned 90-degree elbow is added to the end of the underdrain. The underdrain transitions to a solid wall pipe until it is 12 inches from the top of the bioretention media. Another elbow is added and the outlet pipe discharges into a downstream structure or conveyance. The IWS will allow for a larger volume of water to percolate into the native soils while providing a high flow bypass when the exfiltration rate is exceeded. This IWS can reduce the cost of construction since the invert of the outlet is not as deep as a traditional underdrain configuration.

Weir. For this IWS configuration the underdrain transitions to a solid wall pipe prior to exiting the stone reservoir layer and is directed towards an outlet structure. This run of pipe should be straight and be set at a minimal grade. The outlet structure should be designed to facilitate maintenance. In order to create the higher outlet elevation, the outlet structure is configured with an internal weir wall with the top of the weir set a maximum of 12 inches from the top of the bioretention media. This design variant can also include a drain orifice in the bottom of the weir to allow the sump to be drained if, over time, the exfiltration into the soil becomes restricted. This orifice should be covered with a plate that is clearly marked to indicate that it remain blocked under normal operating conditions.

SECTION 7: CONSTRUCTION

7.1 Construction

Construction Stage Erosion and Sediment Controls. Small-scale bioretention areas should be fully protected by silt fence and construction fencing to prevent sedimentation and compaction. Ideally, bioretention should remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment. Sediment traps or basins may be located within bioretention excavation limits during construction. However, these must be accompanied by notes and graphic details on the erosion prevention and sediment control (EPSC) plan specifying that the maximum excavation depth at the construction stage must be at least 1 foot above the post-construction subgrade elevation. The plan must also show the proper procedures for converting the temporary sediment control practice to a bioretention facility, including dewatering, cleanout and stabilization.

Excavation. The proposed site should be checked for existing utilities prior to any excavation. It is very important to minimize compaction of both the base of the bioretention area and the required backfill. When possible, excavators should work from the sides of the bioretention area to remove original soil. If the bioretention area is excavated using a loader, the contractor must use wide track or marsh track equipment, or light equipment with turf type tires. Use of equipment with narrow tracks or narrow tires, rubber tires with large lugs, or high-pressure tires will cause excessive compaction resulting in reduced infiltration rates and is not acceptable. Compaction will significantly contribute to design failure.

7.2 Bioretention Installation

Construction should take place during appropriate weather conditions. 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. The designer and the installer should have a preconstruction meeting, checking the boundaries of the contributing drainage area and the actual inlet elevations to ensure they conform to original design. Since other contractors may be responsible for constructing portions of the site, it is quite common to find subtle differences in site grading, drainage and paving elevations that can produce hydraulically important differences for the proposed bioretention area. The designer should clearly communicate, in writing, any project changes determined during the preconstruction meeting to the installer and the plan review/inspection authority.

Step 2. Ensure that the entire contributing drainage area has been stabilized prior to bioretention construction. Otherwise, use EPSC measures as outlined in **Section 7.1**.

Step 3. Excavation of the bioretention area should follow the guidelines found in **Section 7.1**. Contractors should use a cell construction approach in larger bioretention basins, whereby the basin is split into 500 to 1,000 sq. ft. temporary cells with a 10-15 foot earth bridge in between, so that cells can be excavated from the side.

Step 4. It may be necessary to rip the bottom soils to a depth of 6 to 12 inches to promote greater infiltration.

Step 5. Install all layers, components, and landscaping of the bioretention per plans. Media shall be tested per MWS standards. Irrigate plantings as needed.

Step 6. Conduct the final construction inspection (see **Section 8**). Then log the GPS coordinates for each bioretention facility and submit them to MWS.

SECTION 8: AS-BUILT REQUIREMENTS

After the bioretention area has been constructed, the owner/developer must have an as-built certification of the bioretention area conducted by a registered Professional Engineer. The as-built certification verifies that the GIP was installed per the approved plan. The following items shall be provided in addition to the as-built requirements found in SWMM Volume 1.

1. Landscape Architect letter certifying that the SCM plantings have been installed in general conformance with the approved grading plans and, with proper maintenance, should achieve 75% coverage within the first two years.
2. The Engineer shall include a copy of the GIP summary table found in Appendix 1-E.
3. Supporting documents such as invoices, photos, and media test results shall be included in the submittal package.

SECTION 9: MAINTENANCE

9.1 Maintenance Document

The requirements for the Maintenance Document are in Appendix C of Volume 1 of the Manual. They include the execution and recording of an Inspection and Maintenance Agreement or a Declaration of Restrictions and Covenants, and the development of a Long-Term Maintenance Plan (LTMP) by the design engineer. The LTMP contains a description of the stormwater system components and information on the required inspection and maintenance activities.

9.2 First Year Maintenance Operations

Successful establishment of bioretention areas requires that the following tasks be undertaken in the first year following installation:

- ***Initial inspections.*** For the first 6 months following construction, the site should be inspected at least twice after storm events that exceed 0.5 inch of rainfall.
- ***Spot Reseeding.*** 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.
- ***Fertilization.*** One-time, spot fertilization may be needed for initial plantings.
- ***Watering.*** Depending on rainfall, watering may be necessary once a week during the first 2 months, and then as needed during first growing season (April-October), depending on rainfall.
- ***Remove and replace dead plants.*** Since up to 10% of the plant stock may die off in the first year, 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. The typical thresholds below which replacement is required are 85% survival of plant material and 100% survival of trees.

9.3 Maintenance Inspections

It is highly recommended that a spring maintenance inspection and cleanup be conducted at each bioretention area. The following is a list of some of the key maintenance problems to look for:

- Check to see if 75% to 90% cover (mulch plus vegetative cover) has been achieved in the bed, and measure the depth of the remaining mulch.
- Check for sediment buildup at curb cuts, gravel diaphragms or pavement edges that prevents flow from getting into the bed, and check for other signs of bypassing.
- Check for any winter- or salt-killed vegetation, and replace it with hardier species.
- Note presence of accumulated sand, sediment and trash in the pretreatment cell or filter beds, and remove it.
- Inspect bioretention side slopes and grass filter strips for evidence of any rill or gully erosion, and repair it.
- Check the bioretention bed for evidence of mulch flotation, excessive ponding, dead plants or concentrated flows, and take appropriate remedial action.
- Check inflow points for clogging, and remove any sediment.
- Look for any bare soil or sediment sources in the contributing drainage area, and stabilize them immediately.
- Check for clogged or slow-draining soil media, a crust formed on the top layer, inappropriate soil media, or other causes of insufficient filtering time, and restore proper filtration characteristics.

9.4 Routine and Non-Routine Maintenance Tasks

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. Pesticides should be limited to environmentally friendly pesticides that don't pose the risk of bioaccumulation within the underlying soils and water tables. Pesticide use should follow label instructions and stormwater basins should be considered aquatic sites. Some acceptable uses of pesticides would be around the edge of bioretention basins to prevent invasive species from propagating within the basin.

A customized maintenance schedule must be prepared for each bioretention facility, since the maintenance tasks will differ depending on the scale of bioretention, the landscaping template chosen, and the type of surface cover. A generalized summary of common maintenance tasks and their frequency is provided in **Table 1.6**.

The most common non-routine maintenance problem involves standing water. If water remains on the surface for more than 48 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 (try the easiest things first, as listed below):

- 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 standpipe indicate standing water, then the underdrain must be clogged and will need to be snaked.
- Remove accumulated sediment and till 2 to 3 inches of sand into the upper 8 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 augering (using a tree auger or similar tool) down to the gravel storage zone to create vertical columns which are then filled with a clean open-graded coarse sand material (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

Table 1.6. Suggested Annual Maintenance Activities for Bioretention

Maintenance Tasks	Frequency
Mowing of grass filter strips and bioretention turf cover	At least 4 times a year
Spot weeding, erosion repair, trash removal, and mulch raking	Twice during growing season
Add reinforcement planting to maintain desired vegetation density	As needed
Remove invasive plants using recommended control methods	As needed
Stabilize the contributing drainage area to prevent erosion	As needed
Spring inspection and cleanup	Annually
Supplement mulch to maintain a 3-inch layer	Annually
Prune trees and shrubs	Annually
Remove sediment in pretreatment cells and inflow points	Once every 2 to 3 years
Replace the mulch layer	Every 3 years

SECTION 10: COMMUNITY & ENVIRONMENTAL CONCERNS

The following is a list of some community and environmental concerns that may arise when infiltration practices are proposed:

Nuisance Conditions. Poorly designed infiltration practices can create potential nuisance problems such as basement flooding, poor yard drainage and standing water. In most cases, these problems can be minimized through proper adherence to the setback, soil testing and pretreatment requirements outlined in this specification.

Mosquito Risk. Infiltration practices have some potential to create conditions favorable to mosquito breeding, if they clog and have standing water for extended periods. Proper installation and maintenance of the bioretention area will prevent these conditions from occurring.

Groundwater Injection Permits. Groundwater injection permits are required if the infiltration practice is deeper than the longest surface area dimension of the practice. Designers should investigate whether or not a proposed infiltration practice is subject to Tennessee groundwater injection well permit requirements.

SECTION 11: REFERENCES

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APPENDIX 1-A

INFILTRATION SOIL TESTING PROCEDURES

I. Test Pit/Boring Procedures

1. The number of required test pits or standard soil borings is based on proposed infiltration area:
   - < 1,000 ft^2 = 2 tests
   - 1,000 – 10,000 ft^2 = 4 tests
   - >10,000 ft^2 = 4 tests + 1 test for every additional 5,000 ft^2
2. The location of each test pit or standard soil boring should correspond to the location of the proposed infiltration area and be performed in in situ soils.
3. Excavate each test pit or penetrate each standard soil boring to a depth at least 2 feet below the bottom of the proposed infiltration area.
4. If the groundwater table is located within 2 feet of the bottom of the proposed facility, determine the depth to the groundwater table immediately upon excavation and again 24 hours after excavation is completed.
5. Determine the USDA or Unified Soil Classification system textures at the bottom of the proposed infiltration area and at a depth that is 2 feet below the bottom. All soil horizons should be classified and described.
6. If bedrock is located within 2 feet of the bottom of the proposed infiltration area, determine the depth to the bedrock layer.
7. Test pit/soil boring stakes should be left in the field to identify where soil investigations were performed.

II. Infiltration Testing Procedures

1. The number of required infiltration tests is based on proposed infiltration area:
   - < 1,000 ft^2 = 2 tests
   - 1,000 – 10,000 ft^2 = 4 tests
   - >10,000 ft^2 = 4 tests + 1 test for every additional 5,000 ft^2
2. The location of each infiltration test should correspond to the location of the proposed infiltration area.
3. Install a test casing (e.g., a rigid, 4 to 6-inch diameter pipe) to the bottom of the proposed infiltration area. Record the testing elevation.
4. Remove all loose material from the sides of the test casing and any smeared soil material from the bottom of the test casing to provide a natural soil interface into which water may percolate. If desired, a 2-inch layer of coarse sand or fine gravel may be placed at the bottom of the test casing to prevent clogging and scouring of the underlying soils. Fill the test casing with clean water to a depth of 2 feet and allow the underlying soils to presoak for 24 hours.
5. After 24 hours, refill the test casing with another 2 feet of clean water and measure the drop in water level within the test casing after one hour. Repeat the procedure three (3) additional times by filling the test casing with clean water and measuring the drop in water level after one hour. A total of four (4) observations must be completed.
6. The infiltration rate of the underlying soils may be reported either as the average of all four observations or the value of the last observation. The infiltration rate shall be reported in terms of inches per hour along with the elevations and locations of the test pits. Locations shall be shown on site map.
7. Infiltration testing may be performed within an open test pit or a standard soil boring. After infiltration testing is completed, the test casing should be removed, and the test pit or soil boring should be backfilled and restored.

APPENDIX 1-B
STANDARD NOTES

Required Bioretention Notes:

- Contractor, Engineer, or Owners Representative shall notify MWS NPDES Staff at least 48 hours prior to the installation of the bioretention filter media. At the completion of installation, the above referenced person will collect one sample per bioretention area for analysis and confirmation of the filter media as defined by GIP-01. Media testing not required when using a certified media product.
- I hereby certify that this bioretention planting plan is in keeping with the requirements listed in GIP-01 Section 5.6. Only native species and/or non-invasive species of plants were used in the design of this bioretention planting plan. This plan will achieve at least 75% surface area coverage within the first two years, and has the minimum amount of required trees.
- Vehicular and equipment traffic shall be prohibited in the bioretention area to prevent compaction and sediment deposition.

APPENDIX 1-C
STANDARD DETAILS

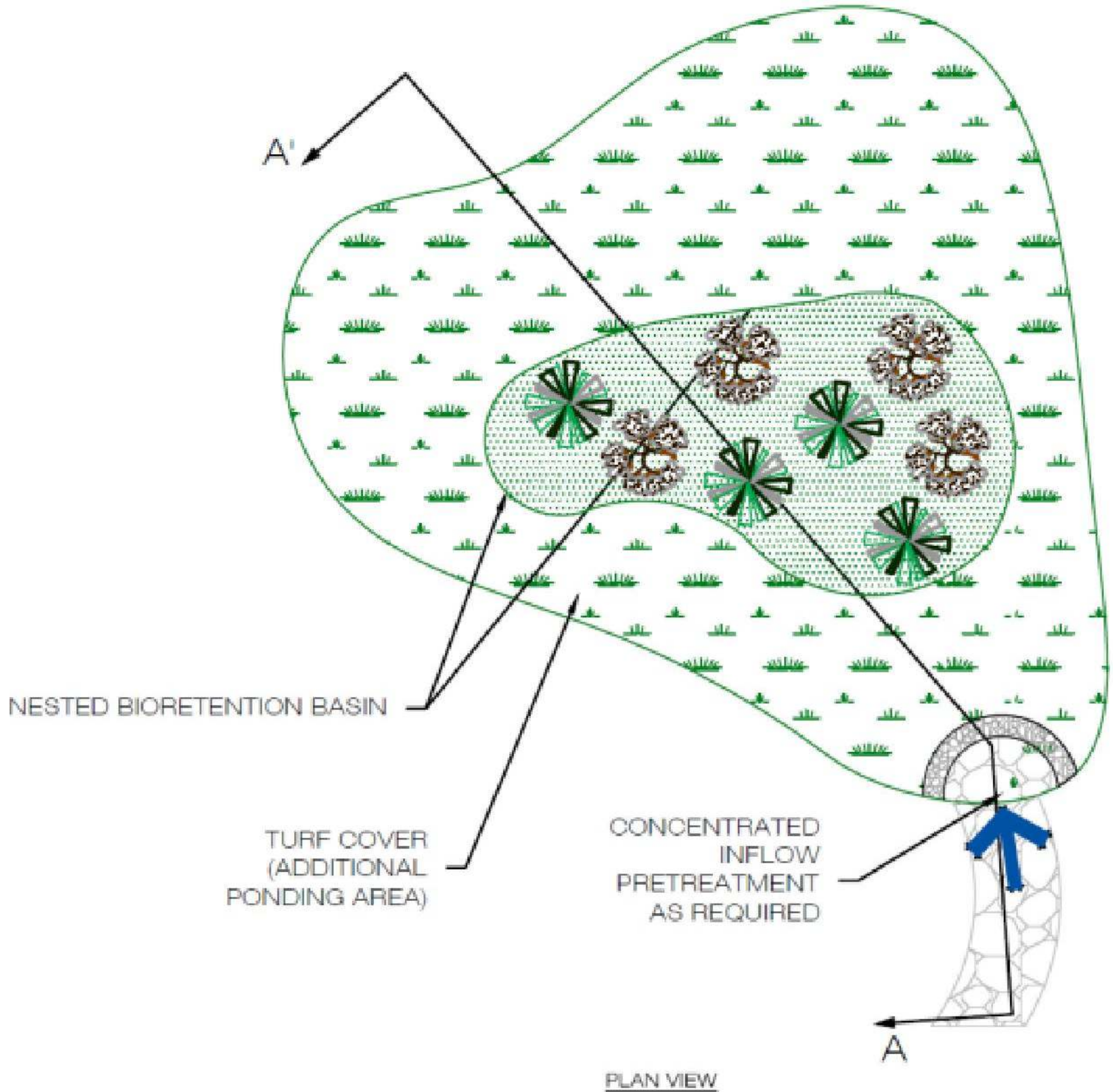
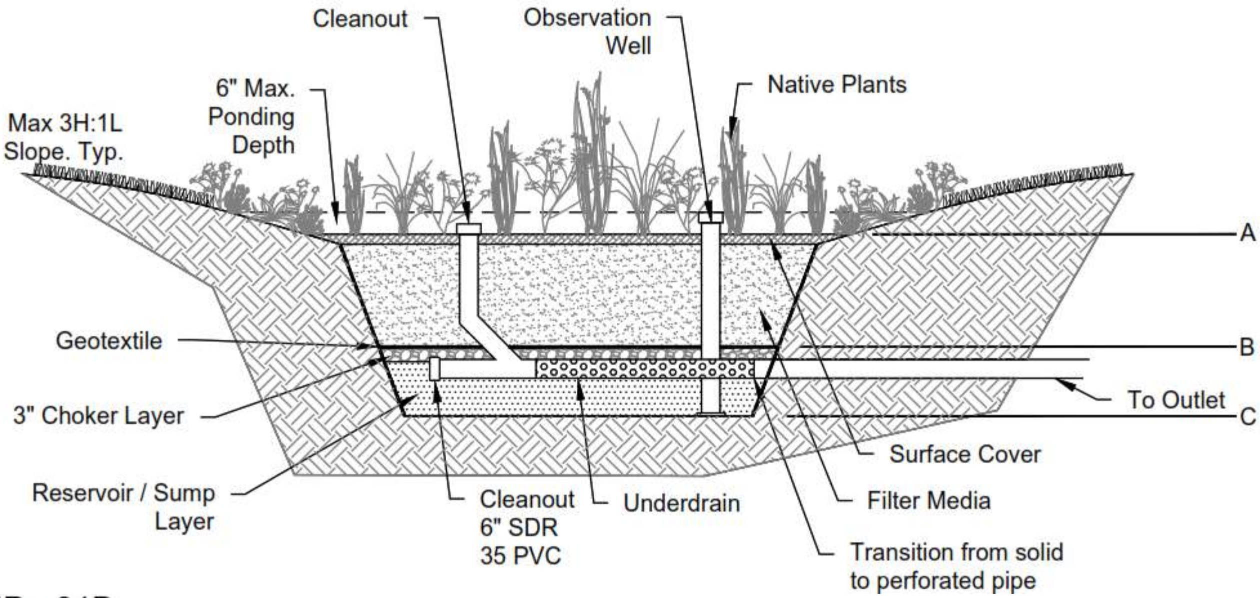
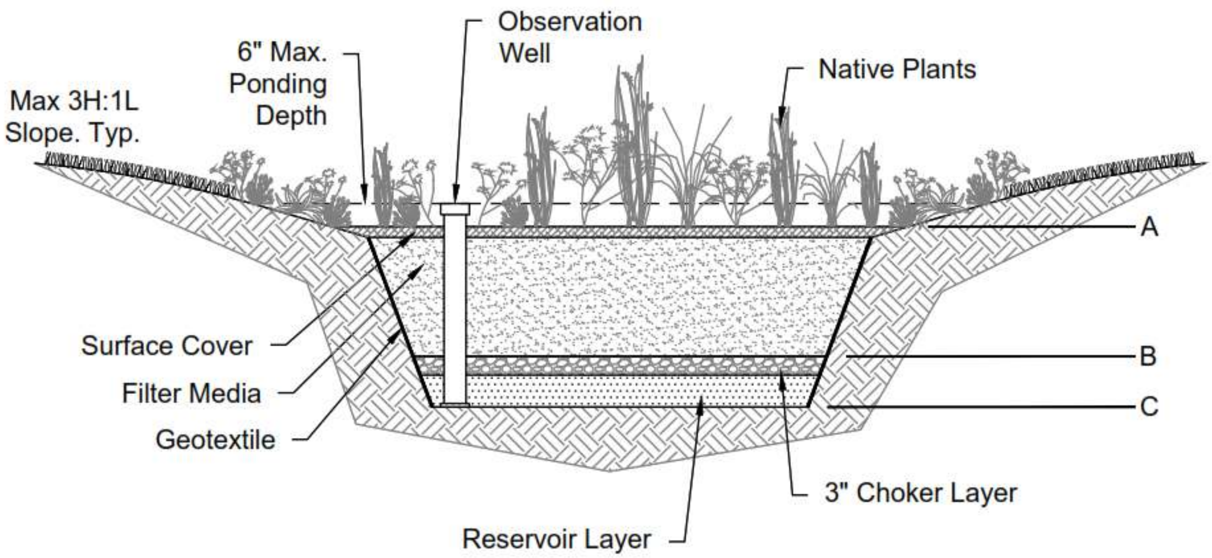


Figure 1.2a. Typical Detail of Bioretention with Additional Surface Ponding (source: VADCR, 2010, MWS edited 2020)

GIP - 01A
BIORETENTION WITH
UNDERDRAIN



GIP - 01B
BIORETENTION
WITHOUT
UNDERDRAIN



(source: VADCR, 2010, MWS edited 2020)

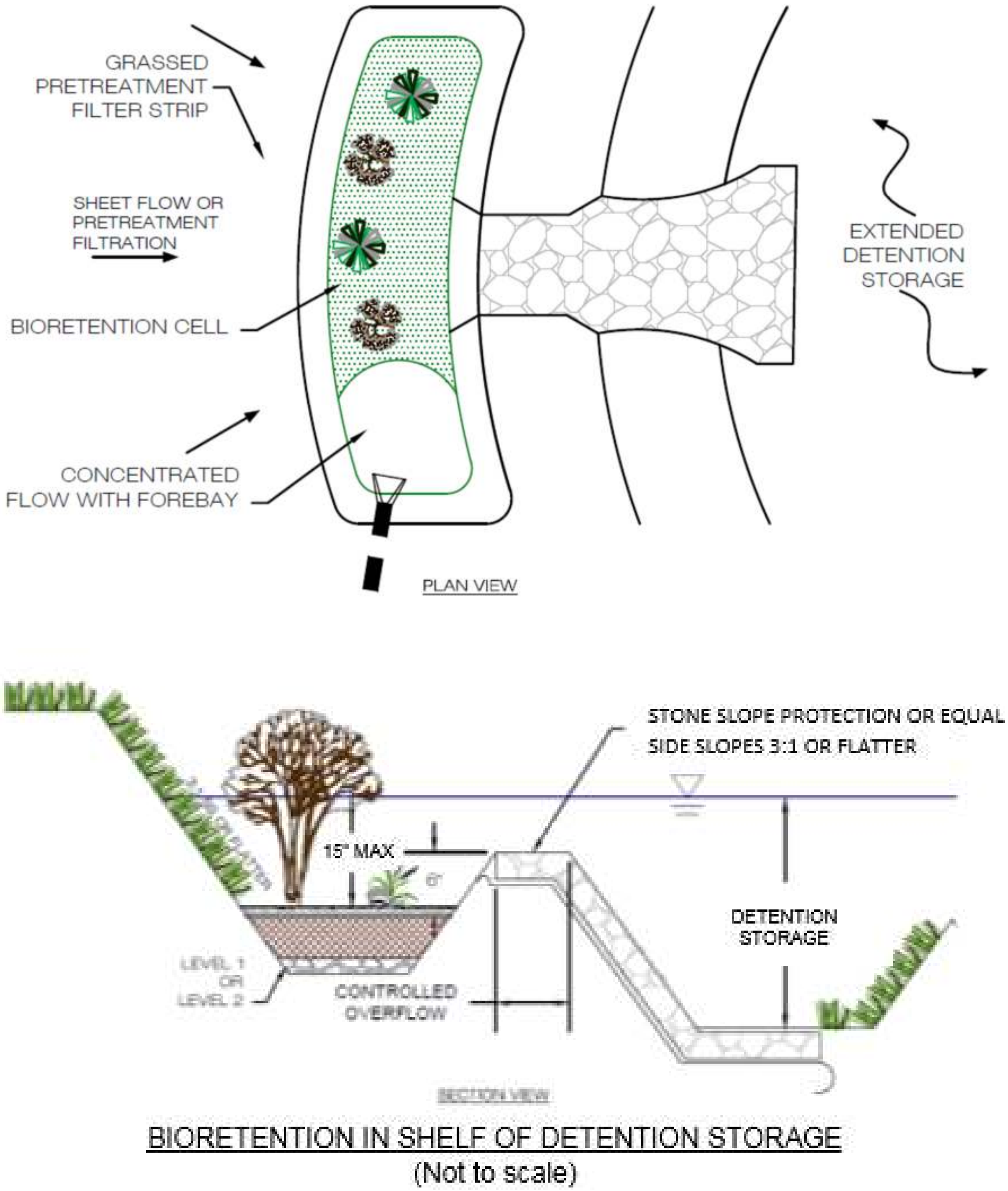


Figure 1.3. Typical Detail of a Bioretention Basin within the Upper Shelf of an ED Pond (source: VADCR, 2010, MWS edited 2020)

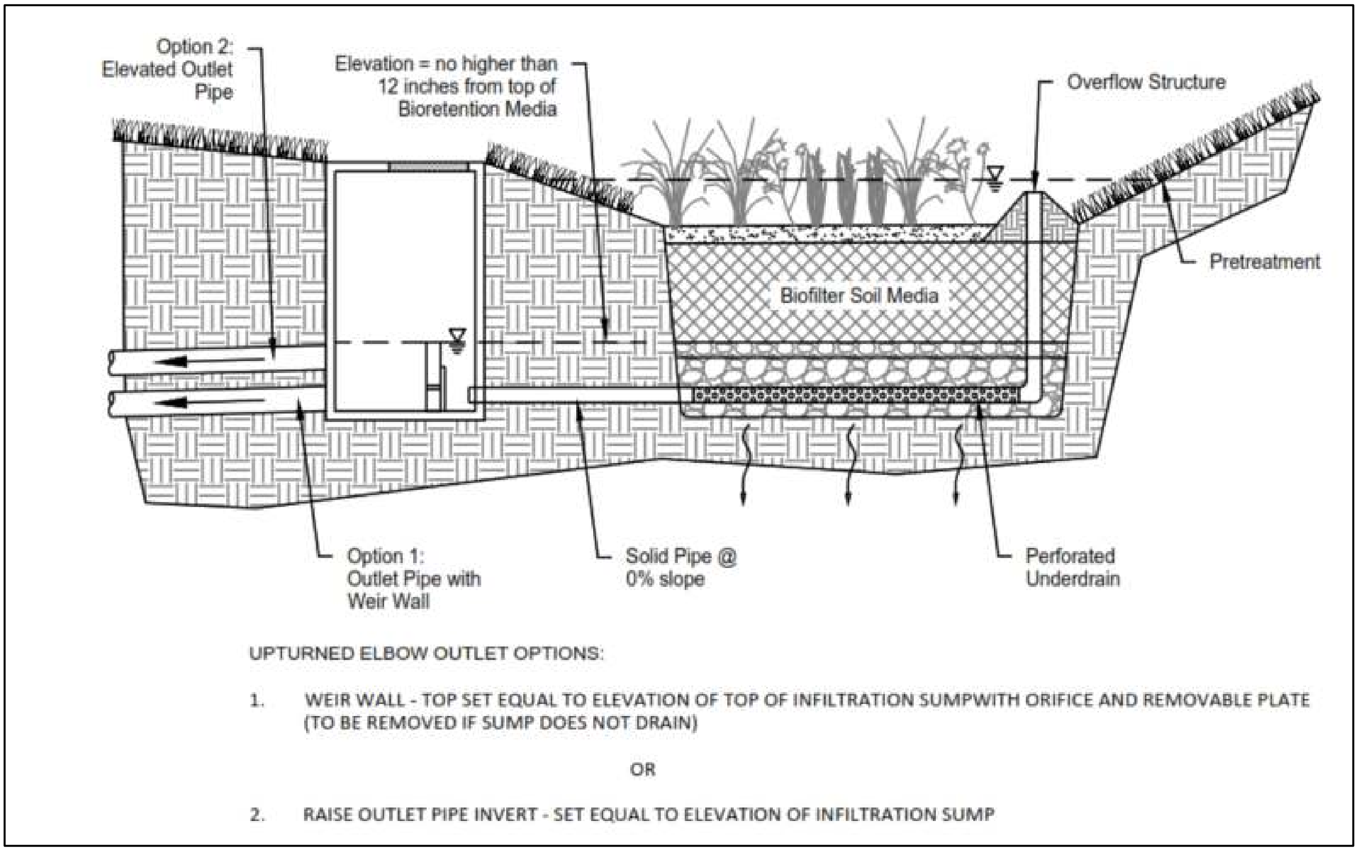


Figure 1.4. Typical Bioretention Basin Level 2: Infiltration Sump with Internal Water Storage (source: VADCR, 2013, MWS edited 2020)

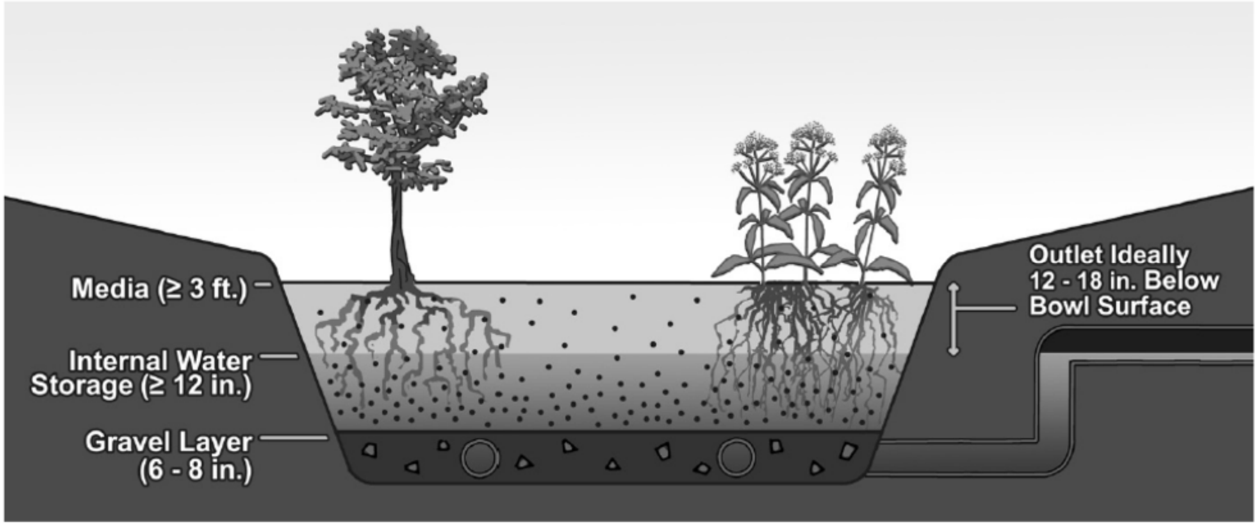


Figure 1.5. Bioretention with Internal Water Storage (source: Brown, 2009)

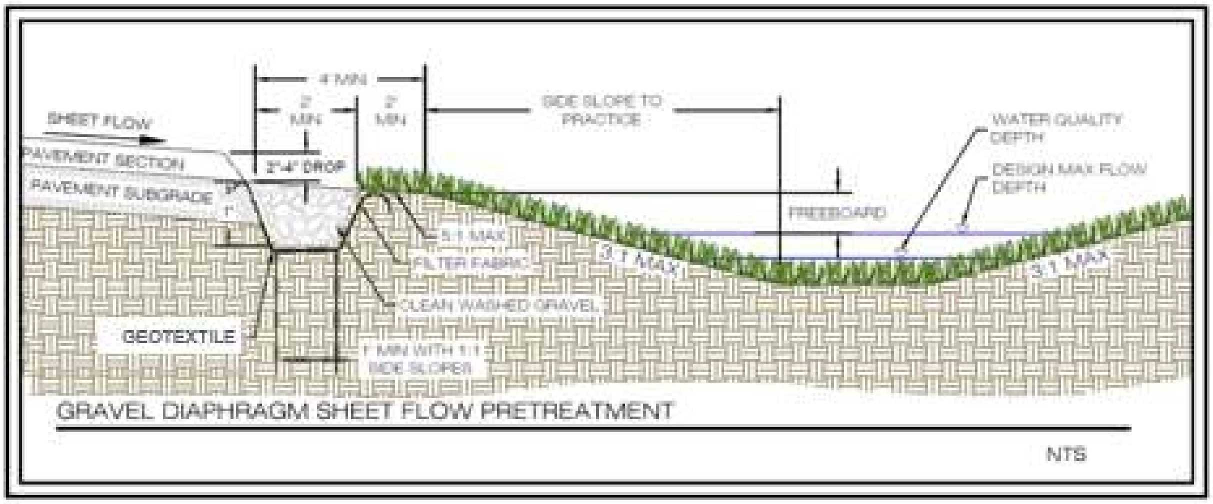


Figure 1.6- Pretreatment Option – Gravel Diaphragm for Sheet (source: VADCR, 2010, MWS edited 2020)

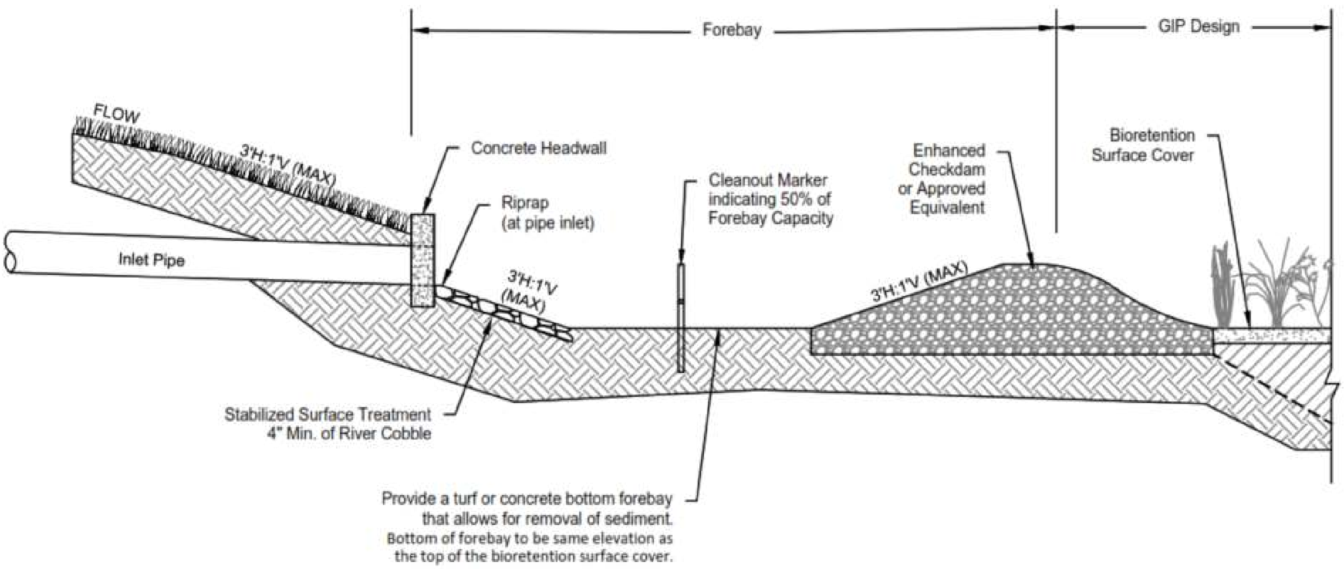


Figure 1.7: Forebay Detail

PLAN VIEW

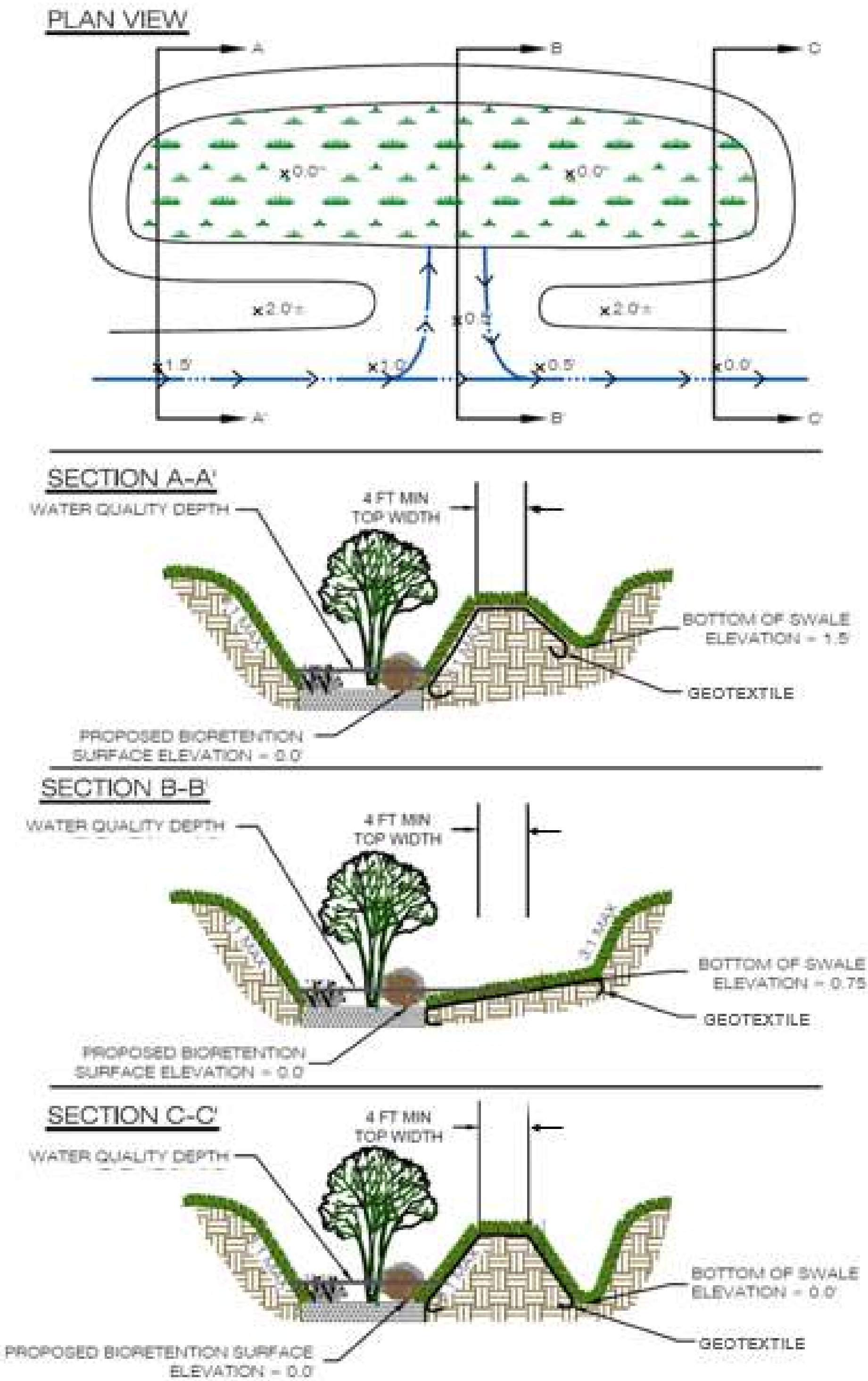


Figure 1.8. Typical Details for Off-Line Bioretention (source: VADCR, 2010, MWS edited 2020)

APPENDIX 1-D
NATIVE PLANTINGS

Popular Native Perennials for Bioretention – Full Sun						
Latin Name	**Common Name**	**Size**	**Spacing**	**Moisture**	**Color**	**Height**
Asclepias incarnate	Marsh milkweed	Plugs – 1 gal.	1 plant/24" o.c.	Wet	Pink	3-4'
Asclepias purpurescens	Purple milkweed	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Purple	3'
Asclepias syriaca	Common milkweed	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Orange	2-5'
Asclepias tuberosa	Butterfly milkweed	Plugs – 1 gal.	1 plant/18" o.c.	Dry-moist	Orange	2'
Asclepias verdis	Green milkweed	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Green	2'
Asclepias verdicillata	Whorled milkweed	Plugs – 1 gal.	1 plant/18" o.c.	Moist	White	2.5'
Aster laevis	Smooth aster	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Blue	2-4'
Aster novae-angliae	New England aster	Plugs – 1 gal.	1 plant/24" o.c.	Wet-moist	Blue	2-5'
Aster sericeus	Silky aster	Plugs – 1 gal.	1 plant/18" o.c.	Dry	Purple	1-2'
Chamaecrista fasciculata	Partridge pea	Plugs – 1 gal.	1 plant/18" o.c.	Dry	Yellow	1-2'
Conoclinium coelestinum	Mist flower	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Blue	1-2'
Coreopsis lanceolata	Lance-leaf coreopsis	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Yellow	6-8'
Echinacea pallida	Pale purple coneflower	Plugs – 1 gal.	1 plant/18" o.c.	Dry	Purple	2-3'
Echinacea purpurea	Purple coneflower	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	3-4'
Eupatorium perfoliatum	Boneset	Plugs – 1 gal.	1 plant/24" o.c.	Wet	White	3-5'
Eupatorium purpureum	Sweet Joe-Pye Weed	Plugs – 1 gal.	1 plant/24" o.c.	Wet-moist	Purple	3-6'
Iris virginica	Flag Iris	Plugs – 1 gal.	1 plant/18" o.c.	Moist-Wet	Blue	2'
Liatris aspera	Rough blazingstar	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	2-5'
Liatris microcephalla	Small-headed	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	3'
Liatris spicata	Dense blazingstar	Plugs – 1 gal.	1 plant/24" o.c.	Wet-moist	Purple	1.5'
Liatris squarrulosa	Southern blazingstar	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	2-6'
Lobelia cardinalis	Cardinal flower	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Red	2-4'
Monarda didyma	Bee balm	Plugs – 1 gal.	1 plant/24" o.c.	Wet-moist	Red	3'
Monarda fistulosa	Wild bergamot	Plugs – 1 gal	1 plant/18" o.c.	Moist	Purple	1-3'
Oenethera fruticosa	Sundrops	Plugs – 1 gal	1 plant/18" o.c.	Moist-dry	Yellow	
Penstemon digitalis	Smooth white	Plugs – 1 gal	1 plant/24" o.c.	Wet	White	2-3'
Penstemon hirsutus	Hairy beardtongue	Plugs – 1 gal	1 plant/18" o.c.	Dry	White	1-3'
Penstemon smallii	Beardtongue	Plugs – 1 gal	1 plant/18" o.c.	Moist	Purple	1-2'
Pycanthemum	Slender mountain mint	Plugs – 1 gal	1 plant/18" o.c.	Moist	White	1.5-2.5'
Ratibida piñata	Gray-headed	Plugs – 1 gal	1 plant/18" o.c.	Moist	Yellow	2-5'
Rudbeckia hirta	Black-eyed Susan	Plugs – 1 gal	1 plant/18" o.c.	Moist-dry	Yellow	3'
Salvia lyrata	Lyre-leaf sage	Plugs – 1 gal	1 plant/18" o.c.	Moist	Purple	1-2'
Solidago nemoralis	Gray goldenrod	Plugs – 1 gal.	1 plant/18" o.c.	Dry	Yellow	2'
Solidago rugosa	Rough-leaved goldenrod	Plugs – 1 gal.	1 plant/18" o.c.	Wet	Yellow	1-6'
Veronacastrum	Culver's root	Plugs – 1 gal.	1 plant/24" o.c.	Dry	White	3-6'
Veronia veboracensis	Tall ironweed	Plugs – 1 gal.	1 plant/24" o.c.	Wet-moist	Purple	3-4'

Plant material size and grade to conform to "American Standards for Nursery Stock" American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1

Popular Native Perennials for Bioretention – Shade						
Latin Name	**Common Name**	**Size**	**Spacing**	**Moisture**	**Color**	**Height**
Aquilegia canadensis	Wild columbine	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Pink	1-2.5'
Athyrium filix-femina	Lady Fern	1 gal.	1 plant/18" o.c.	Moist	Green	3'
Arisaema triphyllum	Jack-in-the-pulpit	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Green	1.5-2.5'
Arisaema dricontium	Green dragon	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Green	3'
Asarum canadense	Wild ginger	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Red-brown	0.5-1'
Aster cardifolius	Blue wood aster	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Blue	1-3'
Aster novae-angliae	New England aster	Plugs – 1 gal.	1 plant/24" o.c.	Moist-dry	Blue/ purple	3-4'
Aster oblongifolius	Aromatic Aster	Plugs – 1 gal.	1 plant/24" o.c.	Moist-dry	Blue/ purple	1.5-3'
Coreopsis major	Tickseed coreopsis	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Yellow	3'
Dryopteris marginalis	Shield Fern	1 gal.	1 plant/18" o.c.	Moist	Green	2-3'
Geranium maculatum	Wild geranium	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Pink	2'
Heuchera americana	Alumroot	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	1'
Iris cristata	Dwarf crested iris	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Purple	4"
Lobelia siphilicata	Great blue lobelia	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Blue	1.5-3'
Lobelia cardinalis	Cardinal flower	Plugs – 1 gal.	1 plant/18" o.c.	Wet-moist	Red	2-4'
Mertensia virginica	Virginia bluebells	Plugs – 1 gal.	1 plant/18" o.c.	Moist	Blue	1.5'
Osmunda cinnamomea	Cinnamon Fern	1 gal.	1 plant/24" o.c.	Wet-moist	Green	3-4'
Phlox diverricata	Blue phlox	Plugs – 1 gal.	1 plant/18" o.c.	moist	Blue	0.5-2'
Polemonium reptans	Jacob's ladder	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Blue	15"
Polystichum acrostichoides	Christmas fern	Plugs – 1 gal.	1 plant/24" o.c.	Moist-dry	Evergree n	2'
Stylophoru diphyllum	Wood poppy	Plugs – 1 gal.	1 plant/18" o.c.	Wet -moist	Yellow	1.5'

Plant material size and grade to conform to "American Standards for Nursery Stock" American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

Popular Native Grasses and Sedges for Bioretention						
Latin Name	**Common Name**	**Size**	**Spacing**	**Moisture**	**Color**	**Height**
Carex grayi	Gray's Sedge	1 gal.	1 plant/24" o.c.	Moist	Green	3'
Carex muskingumensis	Palm Sedge	1 gal.	1 plant/24" o.c.	Moist	Green	3'
Carex stricta	Tussock Sedge	1 gal.	1 plant/24" o.c.	Moist	Green	3-4'
Chasmanthium latifolium	Upland Sea Oats	Plugs – 1 gal.	1 plant/18" o.c.	Moist-dry	Green	4'
Equisetum hyemale	Horsetail	Plugs – 1 gal.	1 plant/18" o.c.	Wet	Green	3'
Juncus effesus	Soft Rush	Plugs – 1 gal.	1 plant/24" o.c.	Wet-dry	Green	4-6'
Muhlenbergia capallaris	Muhly Grass	1 gal.	1 plant/24" o.c.	Moist	Pink	3'
Panicum virgatum	Switchgrass	1-3 gal.	1 plant/48" o.c.	Moist-dry	Yellow	5-7'
Schizachyrium scoparium	Little Blue Stem	1 gal.	1 plant/24" o.c.	Moist-dry	Yellow	3'
Sporobolus heterolepsis	Prairie Dropseed	1 gal.	1 plant/24" o.c.	Moist-dry	Green	2-3'

Plant material size and grade to conform to "American Standards for Nursery Stock" American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

Popular Native Trees for Bioretention							
Latin Name	**Common Name**	**DT-FT**	**Light**	**Moisture**	**Notes**	**Flower Color**	**Height**
Acer rubrum	Red Maple	DT-FT	Sun-shade	Dry-wet	Fall color		50-70’
Acer saccharum	Sugar Maple		Sun-pt shade	Moist	Fall color		50-75’
Ameleanchier Canadensis	Serviceberry		Sun-pt shade	Moist-wet	Eatable berries	White	15-25’
Asimina triloba	Paw Paw		Sun-pt shade	Moist	Eatable fruits	Maroon	15-30’
Betula nigra	River Birch	FT	Sun-pt shade	Moist-wet	Exfoliating bark		40-70’
Carpinus caroliniana	Ironwood		Sun-pt shade	Moist		White	40-60’
Carya aquatica	Water Hickory	FT-DT	Sun	Moist	Fall color		35-50’
Cercus Canadensis	Redbud	DT	Sun-shade	Moist	Pea-like flowers, seed pods	Purple	20-30’
Chionanthus virginicus	Fringetree		Sun-pt shade	Moist	Panicled, fragrant flowers	White	12-20’
Cladratis lutea	Yellowwood	DT	Sun	Dry-moist	Fall color	White	30-45’
Cornus florida	Flowering Dogwood		Part shade	Moist	Red fruit, wildlife	White	15-30’
Ilex opaca	American Holly	DT	Sun-pt shade	Moist	Evergreen	White	30-50’
Liquidambar styraciflua	Sweetgum	DT-FT	Sun-pt shade	Dry-moist	Spiny fruit		60-100’
Magnolia virginiana	Sweetbay Magnolia		Sun-pt shade	Moist-wet	Evergreen	White	10-60’
Nyssa sylvatica	Black Gum		Sun-Shade	Moist	Fall color		35-50’
Oxydendrum arboretum	Sourwood		Sun-pt shade	Dry-moist	Wildlife	White	20-40’
Platanus occidentalis	Sycamore	FT	Sun-pt shade	Moist	White mottled bark		70-100’
Quercus bicolor	Swamp White Oak	DT	Sun-pt shade	Moist-wet	Acorns		50-60’
Quercus nuttalli	Nuttall Oak	DT	Sun	Dry-moist	Acorns		40-60’
Quercus lyrata	Overcup Oak	FT	Sun	Moist	Acorns		40-60’
Quercus shumardii	Shumard Oak	DT	Sun	Moist	Acorns		40-60’
Rhamnus caroliniana	Carolina Buckthorn		Sun	Moist	Black fruit		15-30’
Salix nigra	Black Willow	FT	Sun-pt shade	Moist-wet	White catkins	Yellow	40-60’
Ulmus americana	American Elm	DT-FT	Sun-pt shade	Moist			
Salix nigra	Black Willow	FT	Pt shade	Moist-wet	White catkins	Yellow	40-60’

Size: min. 2” caliper if not reforestation. DT: Drought Tolerant FT: Flood Tolerant
Plant material size and grade to conform to “American Standards for Nursery Stock” American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

Popular Native Shrubs for Bioretention								
Latin Name	**Common Name**	**D TF**	**Light**	**Moisture**	**Spacing (0 C)**	**Notes**	**Flower Color**	**Height**
Aronia arbutifolia	Red Chokeberry	FT	Sun-pt shade	Dry-wet	4’	Red berries, wildlife	White	6-12’
Buddleia davidii	Butterfly Bush	DT	Sun-pt shade	Dry-moist	4’	Non-native	Blue	5’
Callicarpa Americana	American Beautyberry	DT	Sun-pt shade	Dry-wet	5’	Showy purple fruit	Lilac	4-6’
Cephalanthus occidentalis	Button Bush	FT	Sun-shade	Moist-wet	5’	Attracts wildlife	White	6-12’
Clethra alnifolia	Sweet Pepper Bush		Sun-pt shade	Dry-moist	3’	Hummingbird	White	5-8’
Cornus amomum	Silky Dogwood		Sun-shade	Moist-wet	6’	Blue berries, wildlife	White	6-12’
Corylus americana	American Hazelnut		Sun-pt shade	Dry-moist	8’	Eatable nuts, wildlife	Yellow	8-15’
Hamemelis virginiana	Witch-hazel		Sun-pt shade	Dry-moist	8’	Winter bloom	Yellow	10’
Hibiscus moscheutos	Swamp Mallow	FT	Sun	Moist-wet	30”	Cold-hardy	White – red	4-7’
Hydrangea quercifolia	Oakleaf Hydrangea	DT	Pt shade – shade	Moist	4’	Winter texture	White	3-6’
Hypericum frondosum	Golden St. John’s Wort	DT	Sun-pt shade	Dry-moist	30”	Semi-evergreen	Yellow	2-3’
Hypericum prolificum	Shrubby St. John’s Wort	DT	Sun-pt shade	Dry-moist	3’	Semi-evergreen	Yellow	3’
Ilex decidua (dwarf var.)	Possumhaw Viburnum	DT	Sun-pt shade	Moist	4-6’	Red berries		6-14’
Ilex glabra	Inkberry	DT	Sun-pt shade	Moist-wet	3’	Evergreen		4-8’
Ilex verticillata	Winterberry Holly	FT	Sun-pt shade	Moist-wet	3’	Red berries		10’
Itea virginica	Virginia Sweetspire	DT FT	Sun-shade	Moist-wet	4’	Fall color	White	4-8’
Lindera benzoin	Spicebush	DT	Pt shade – shade	Moist-wet	8’	Butterflies, wildlife	Yellow	6-12’
Viburnum dentatum	Arrowwood Viburnum		Sun-shade	Dry-wet	6’	Wildlife	White	6-8’

Size: minimum 3 gal. container or equivalent. DT: Drought Tolerant FT: Flood Tolerant
This list provides plant species; there are multiple varieties within each species.
Plant material size and grade to conform to “American Standards for Nursery Stock” American Association of Nurserymen, Inc. latest approved revision, ANSI Z-60-1.

APPENDIX 1-E
AS-BUILT REQUIREMENTS

A printer friendly version of this table can be found on the MWS Development Services website or by request.

Forebay Number:

	Design	As-Built
Top of Bank Elevation		
Top of Check Dam		
Bottom of Forebay		
Surface Area, SF		
Pretreatment Volume, CF		
ALL Elevation shall be NAVD88		

Bioretention Number:

	Design	As-Built
Treatment Volume (Tv), CF		
Surface Area, SF		
Top of Bank Elevation		
Emergency Spillway Elevation*		
Overflow (TOC) Elevation*		
(A) GIP Surface Elevation		
(B) Top of Stone Elevation		
Underdrain Invert*		
Outlet Elevation*		
(C) Subgrade Elevation		
* N/A if not required		
ALL Elevation shall be NAVD88		

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