BIORETENTION GUIDANCE

Lake County, Ohio

September 16, 2005

Prepared by

Biohabitats Incorporated

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1.0 Description & Applications for Bioretention

Bioretention areas are landscaping features adapted to store and treat stormwater runoff on the development site. They are commonly located in or adjacent to parking lots or within small pockets in residential neighborhoods, but have wide applicability. Surface runoff is directed into shallow, landscaped depressions. These depressions are designed to incorporate many of the pollutant removal mechanisms that operate in forested ecosystems. During storms, runoff ponds temporarily within the shallow depression and subsequently filters down through the various layers in the bioretention area: plants, mulch or ground cover, engineered soil mix, and, in most cases, an underdrain system. Runoff from larger storms is generally diverted through or around the facility to the storm drain system or overland relief.

A bioretention area is not a stormwater wetland, as the facility is designed to drain relatively quickly after a storm event. Accordingly, the plant community in a bioretention area resembles a wet meadow or bottomland forest rather than a wetland.

Bioretention has several particular applications for Lake County:

- Commercial/Industrial – Bioretention can be used in modified parking lot islands or as a component of landscape areas adjacent to parking lots or buildings. The facilities can be designed to treat runoff from parking lots, roads, rooftops, other impervious surfaces, and/or pervious areas such as managed lawns.

- Institutional (e.g., schools, government buildings, parks, etc.) – Institutional settings are particularly good sites. Bioretention can be incorporated into bus loops, parking lot islands, roof downspout areas, access road shoulders, and other demonstration sites.

- Residential – Bioretention areas are appropriate for residential settings. In this regard, they should be designed as distributed practices within areas designated as open space and covered by drainage easements.

Figure 1 and **Figure 2**, following, demonstrate diagrammatic examples of bioretention.

As with all stormwater BMPs, design, construction, and maintenance practices are critical for the success of bioretention. Subsequent sections outline siting, design, and construction considerations, as well as long-term inspection and maintenance requirements.

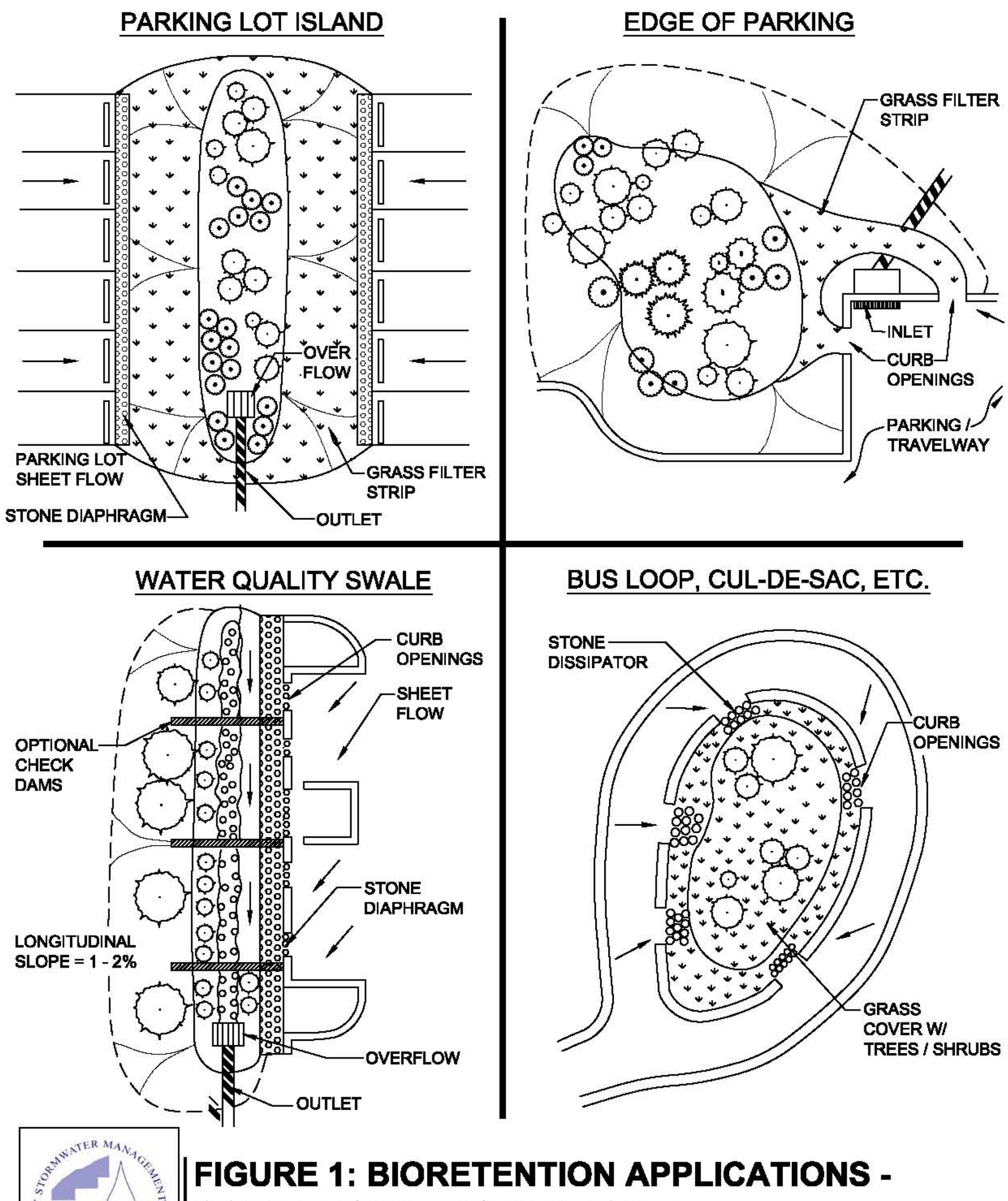

FIGURE 1: BIORETENTION APPLICATIONS - COMMERCIAL, INSTITUTIONAL

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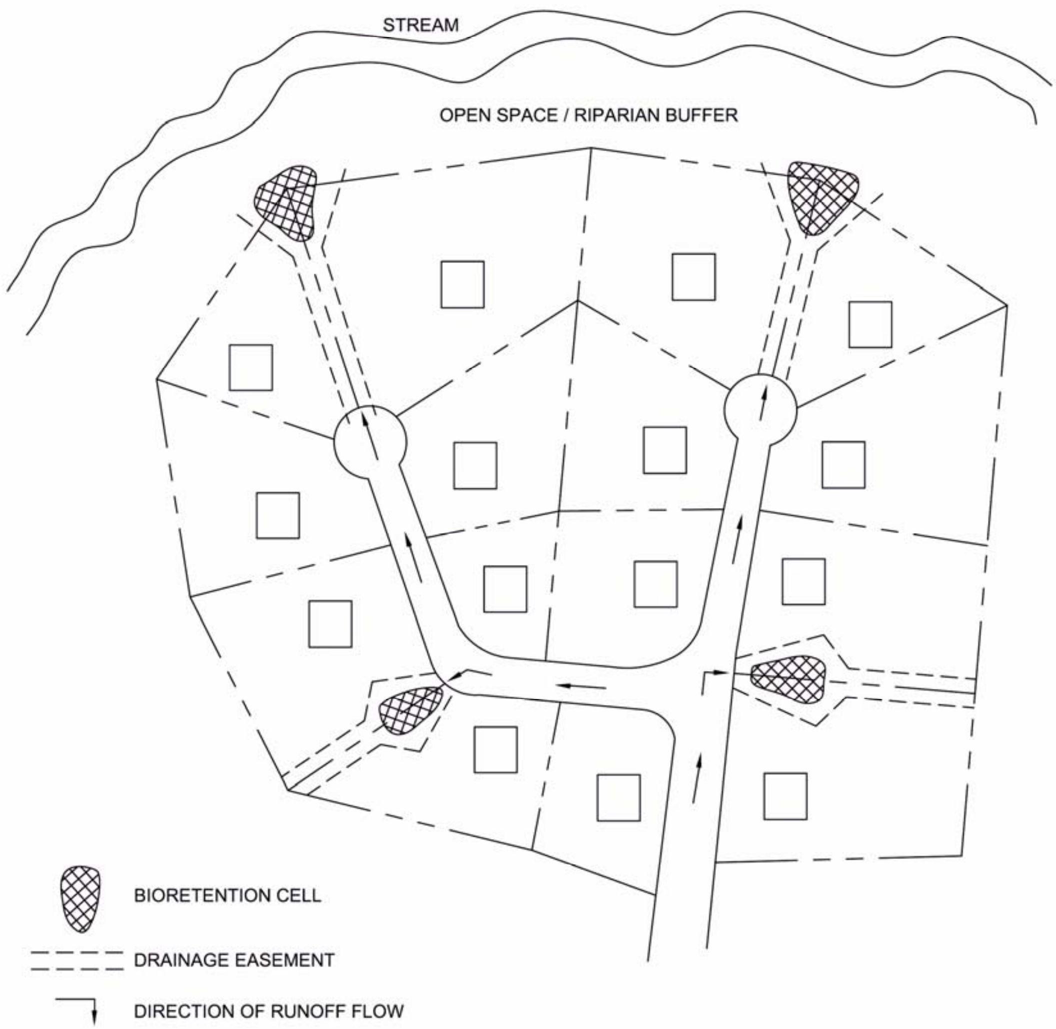

FIGURE 2: BIORETENTION APPLICATIONS - RESIDENTIAL

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2.0 Settings & Design Concepts

Since the geology and soils of Lake County are variable, bioretention concepts must remain flexible to be used in various settings. Four design concepts are presented here that can be used in the County:

<u>Design Concept #1 -- Clay Soils with Little or No Infiltration Expected:</u> For areas of the County with heavy clay soils, bioretention facilities have an underdrain system consisting of perforated pipes that outfall to a storm sewer or daylight in a stable channel. **Figure 3** shows typical details for Design Concept #1. Note that the typical drawing shows an edge of pavement system with a drop inlet overflow device. However, system components will vary depending on the particular application.

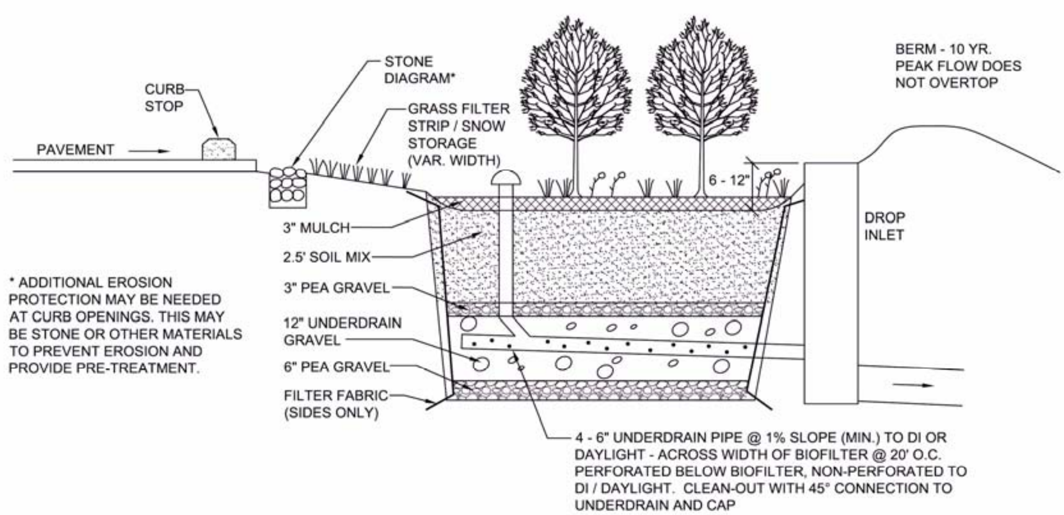


FIGURE 3: DESIGN CONCEPT #1
CLAY SOILS - LITTLE OR NO INFILTRATION EXPECTED
CONCEPT: UNDERDRAIN PROVIDED TO DRAIN BIOFILTER
DETAIL NTS

Design Concept #2 – High Water Table or Shallow to Bedrock: These systems must remain very shallow to function properly. This design concept is not a full bioretention design, so does not achieve the same pollutant removal functions as the other designs. Accordingly, more surface area is required to accomplish the same water quality objectives. The system features a relatively thin soil layer above specially designed drain cells. The outfall can be directed to a drain pipe or daylighted. See **Figure 4** for this design concept.

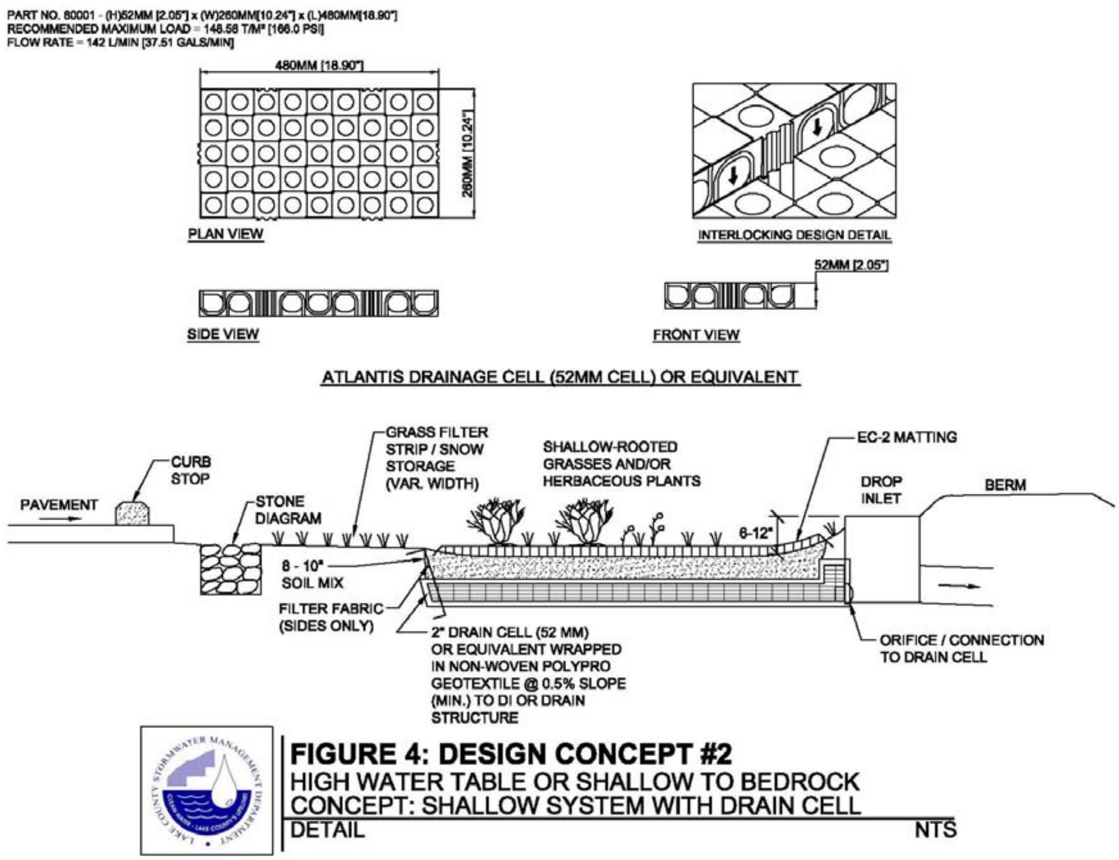


FIGURE 4: DESIGN CONCEPT #2
HIGH WATER TABLE OR SHALLOW TO BEDROCK
CONCEPT: SHALLOW SYSTEM WITH DRAIN CELL
DETAIL NTS

Design Concept #3 – Soils Suitable for Infiltration: In some areas of the County, the soils may be appropriate for infiltration (based on an on-site investigation – see Section 5.4). In these cases, the underdrain system can be modified to promote infiltration. The underdrain gravel layer is deeper, with the underdrain pipe near the top of the layer. This creates a gravel "sump" that temporarily stores water for infiltration. **Figure 5** portrays this design concept.

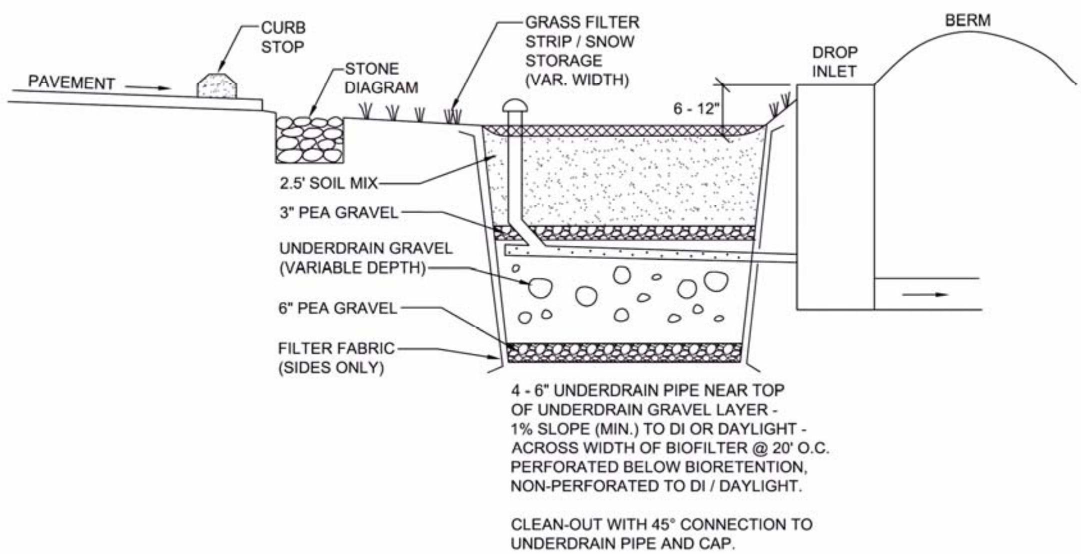


FIGURE 5: DESIGN CONCEPT #3
SOILS SUITABLE FOR INFILTRATION
CONCEPT: GRAVEL SUMP BELOW UNDERDRAIN PIPE
DETAIL NTS

Design Concept #4 – Water Quality Swale: Conventionally, the filter area of a bioretention facility is flat, or very close to it. Each of the three design concepts outlined above can be modified to fit on gently sloping ground, using check dams to create relatively flat "cells." A long, skinny version of this design is called a water quality swale, and may be able to fit better on very tight sites or sites where with sloping topography. It should be noted that it may be more difficult to capture the entire Water Quality Volume with this design, as storage is provided behind check dams. See **Figure 6** for a typical water quality swale design.

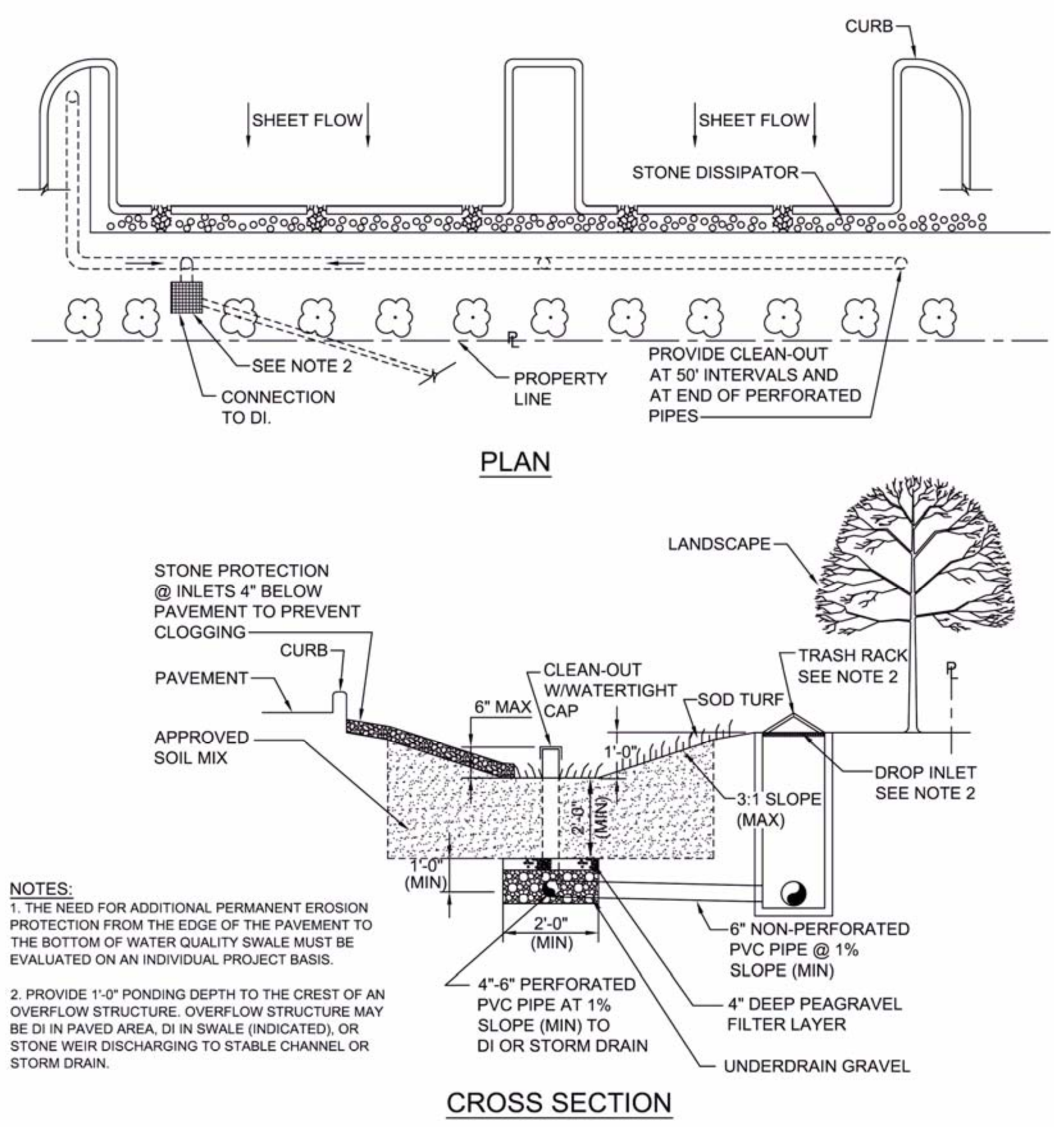


FIGURE 6: DESIGN CONCEPT #4, WATER QUALITY SWALE
CONCEPT: BIORETENTION W/ SLIGHT LONGITUDINAL SLOPE (1 - 2 %)
DETAIL NTS

3.0 Siting Considerations

This section outlines the most important siting considerations for bioretention facilities.

3.1 Soils, Bedrock, Water Table

The design concepts above already address issues with clay soils, shallow bedrock, and high water table. In general, bioretention facilities should be offset at least one foot from the seasonal high water table and bedrock, and more if groundwater contamination is a concern in the area. The Stormwater Management Department should be consulted in applications with a high water table and shallow bedrock. With Design Concept #2, the drain cell may be able to keep water draining from the facility, but care should be taken to not create standing water or other nuisance conditions.

3.2 Floodplains & Wetlands

Bioretention facilities should not be located in floodplains or wetlands, since these areas must be reserved for other functions.

3.3 Site Slopes

For designs that have an underdrain system, the layers of the bioretention facility can go several feet into the ground. The design consideration is for the underdrain system to have an adequate outfall with a minimum of 1% slope on the underdrain pipe.

For designs that utilize infiltration into the ground, bioretention facilities should have a horizontal offset from buildings and natural or constructed slopes (100 feet upslope and 20 feet downslope). Special precautions should be used in areas with nearby basements, fill slopes, roads, and/or parking lots to avoid problems with seepage.

3.4 Drainage Area

Bioretention areas are usually designed to treat relatively small drainage areas (5 acres or less). Larger drainage areas can lead to clogging and erosion. However, this can be partially mitigated with “off-line” designs (see Section 4). However, bioretention will usually work best for drainage areas of one acre of less in commercial settings and 5 acres or less in residential settings. For larger sites, multiple bioretention cells are usually distributed throughout the site.

3.5 Base Flows & Chlorinated Flows

It is very difficult for bioretention facilities to remain functional when a steady baseflow is flowing through the facility. Baseflows should be routed around the facility. Also, periodic chlorinated flows (e.g., swimming pool backwash) should be avoided.

3.6 Stormwater Hot Spots

Since bioretention depends on a healthy biological system, it may not be appropriate for areas that generate relatively high loads of hydrocarbons, such as gas stations or automobile storage and repair facilities. If used for such facilities, extra pre-treatment measures should be taken to remove hydrocarbons prior to discharge to the bioretention facility.

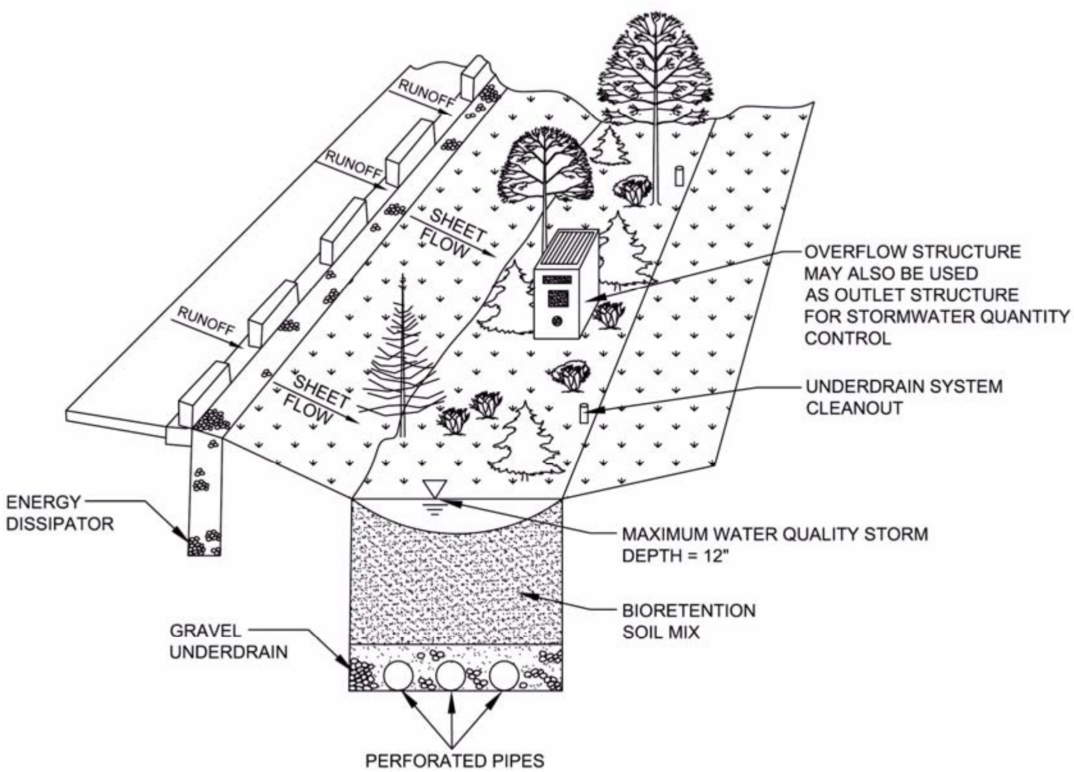
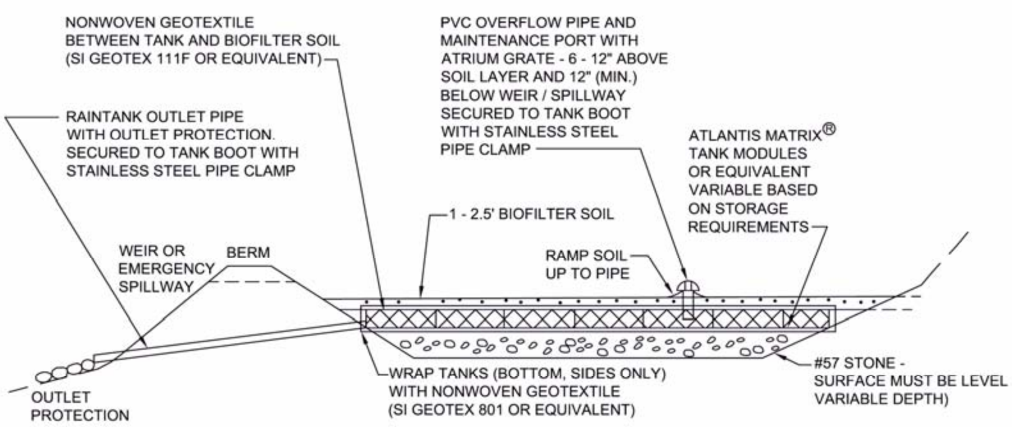


FIGURE 7: BIORETENTION IN DETENTION BASIN
DETAIL NTS

3.7 Bioretention Combined With Detention?

Many sites require both water quantity and quality treatment. Conventionally, bioretention addresses only the latter. Detention basins can be modified to incorporate a bioretention area in the bottom (see **Figure 7**). In fact, this type of design may create fewer nuisance issues than an extended detention basin due to water standing for shorter periods of time and additional landscaping. However, these types of facilities will not have the same aesthetic and landscape benefits as shallow bioretention areas incorporated throughout the site. Also, care must be taken to not hydraulically overload the filter bed by stacking too much water on top of it during storm events. This situation will likely lead to clogging.

Alternately, underground and/or manufactured systems that provide detention storage can be incorporated below the bioretention area. **Figure 8** shows such a system using a proprietary product called RainTanks®. An important design consideration for this type of system is its depth, and whether outlet pipes can have positive drainage to daylight or the storm system. Also, special geotextile fabrics are needed between the soil mix and the tanks to keep soil out of the tanks while allowing water to move through.



NOTES:
1. CLEAN / REPAIR OUTLET WEIR AS NECESSARY.
2. MATRIX TANK MODULES ASSEMBLED AND INSTALLED AS PER MANUFACTURER'S SPECIFICATIONS.
3. BACKFILL TANK PERIMETER WITH FILL OR SAND IN 12" LIFTS AND COMPACT WITH MECHANINCAL COMPACTOR.
4. SECURE OUTLET AND OVERFLOW PIPES INTO TANK BOOTS WITH STAINLESS STEEL PIPE CLAMPS.

FIGURE 8: BIORETENTION / RAINTANK® CONCEPT
INCORPORATING DETENTION BELOW BIORETENTION CELL
DETAIL NTS

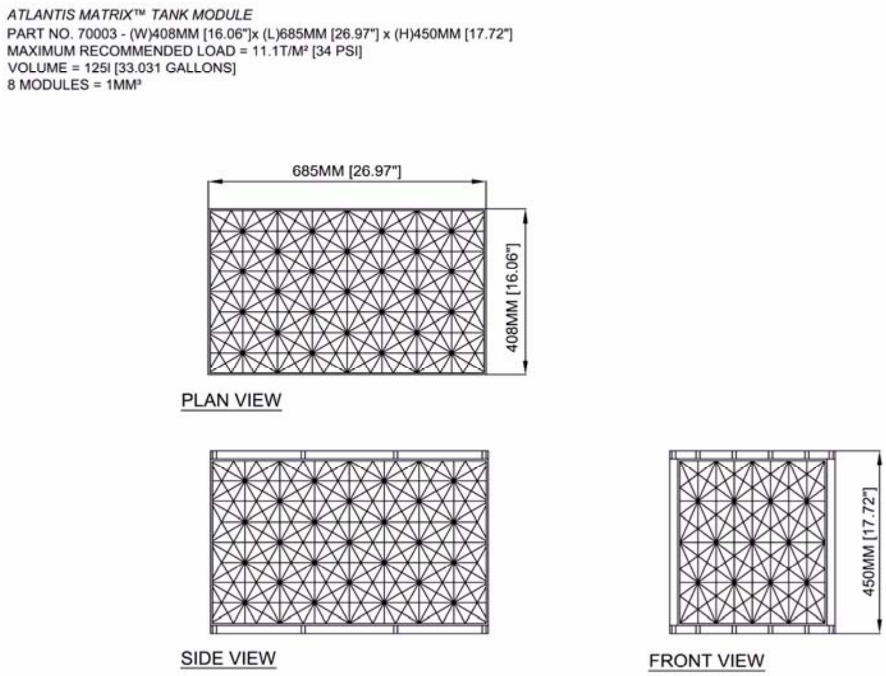


FIGURE 8: CONTINUED
BIORETENTION / RAINTANK® CONCEPT
(OR EQUIVALENT UNDERGROUND STORAGE STRUCTURE)
DETAIL NTS

3.8 Aesthetics

The designer should strive to incorporate bioretention facilities into the overall landscape setting of the site. Early planning and allowing sufficient surface area for bioretention during the concept stage are important principles. Also, the landscape plan for each bioretention facility can be adapted to particular site conditions. For instance, some bioretention areas may have a mulch bed with annuals and perennials, while others may consist of mowed turf with trees or a wildflower meadow (see Section 4.6).

4.0 Design Considerations

The following section outlines the major design parameters for bioretention facilities.

4.1 Sizing The Bioretention Area

The sizing criteria for bioretention areas are based on the computation procedures for Water Quality Volume (WQv) in the Lake County Stormwater Management Department Rules and Regulations or applicable community equivalent (hereafter referred to as the "Rules and Regulations").

Once the WQv is calculated for a particular site, the following sizing computations apply in general, and for each Design Concept.

V(total) = V(storage) + V(soil) + V(underdrain);

Where:
V(total) = total storage in the bioretention facility
V(storage) = storage above the soil layer to the elevation of an overflow
V(soil) = temporary storage within the soil layers
V(underdrain) = temporary storage in the underdrain gravel below the pipe.

All units are in cubic feet. V(total) is a combination of detention and retention storage.

Design Concept #1 – Underdrain System

SA = surface area of bioretention in square feet

V(storage) = 0.5xSA (assumes 0.5 feet of storage between soil and overflow device)
V(soil) = 0.2x2.5xSA (assumes 2.5 feet of soil mix with a void ratio of 0.2)
V(underdrain) = 0

V(total) = 1.0xSA

Design Concept #2 – Shallow System With Drain Cell

V(storage) = 0.5xSA (assumes 0.5 feet of storage between soil and overflow device)
V(soil) = 0.2x0.67xSA (assumes 8" of soil mix with a void ratio of 0.2)
V(underdrain) = 0

V(total) = 0.63xSA

Design Concept #3 – Infiltration Below Underdrain Pipe

V(storage) = 0.5xSA (assumes 0.5 feet of storage between soil and overflow device)
V(soil) = 0.2x2.5xSA (assumes 2.5 feet of soil mix with a void ratio of 0.2)
V(underdrain) = 0.4x2.0xSAx0.5 (assumes 2 feet of underdrain gravel below the underdrain pipe with a void ratio of 0.4. The 0.5 multiplier is for surface area reduction at the underdrain elevation due to side slopes).

V(total) = 1.4xSA

Design Concept #4 – Water Quality Swale

The Water Quality Swale concept can be applied to any of the above design concepts. However, storage is only provided behind check dams for facilities that have a longitudinal slope. Therefore, storage is dependent on slope and the number, spacing, and height of check dams.

The computations listed above for each design concept can be used, but the surface area used should be the collective area of storage behind check dams. Also, since V(storage) will be a series of "wedges" rather than a rectangle, that factor should be adjusted for actual design conditions.

Unified Sizing of Bioretention Using WQv

The following chart represents sizing of bioretention facilities for each Design Concept and Land Use, based on the assumptions listed above and the WQv computation procedures in the rules and regulations.

Land Use	Concept 1 -- % of DA	Concept 2 -- % of DA	Concept 3 -- % of DA
Industrial/Commercial	5.0%	7.9%	3.6%
High Density Residential (> 8 DUs/ac)	3.1%	5.0%	2.2%
Medium Density Residential (4-8 DUs/ac)	2.5%	4.0%	1.8%
Low Density Residential (<4 DUs/ac)	1.9%	3.0%	1.3%

The chart simplifies the bioretention sizing criteria. Each bioretention facility is sized based on a percentage of the drainage area that contributes runoff to the facility. *The size obtained using this method is for the floor, or filter area, of the bioretention facility. It does not include adjacent side slopes.*

4.2 Ponding Depth

The sizing method above assumes a ponding depth of 0.5 feet. However, bioretention facilities can be designed with a maximum ponding depth of 1.0 foot, especially for Design Concepts 1 and 3 (underdrain system). The 0.5 foot depth is recommended in areas in close proximity to buildings and residential neighborhoods.

4.3 Inlet and Outlet Options (on-line or off-line)

Bioretention facilities can be designed as "on-line", meaning that entire range of storms enters the facility and larger storms exit through an overflow device or weir. Alternately, they can be designed as "off-line" facilities, in which case only the design storm (the storm that generates the WQv) enters the facility and larger flows are by-passed.

Several important inlet considerations are listed below:

- *Pretreatment:* Pretreatment is an important element to extend the longevity of bioretention facilities and prevent clogging. Pretreatment can consist of a grass swale, grass filter strip, stone energy dissipater, or a manufactured BMP effective at removing sediment loads from incoming stormwater. Care must be taken that incoming velocities are reduced to the point that grass pretreatment areas do not erode.

- *Inlet Options:* Water can enter the bioretention facility through curb cuts, trench drains, ditches, or pipes. Concentrated flow into a bioretention facility must have adequate energy dissipation and pretreatment to prevent erosion of the filter media and to spread the flow across the filter surface to the extent possible. Flow splitters can also be used within the upstream conveyance system to divert only the first-flush design flow to the bioretention area (off-line design).

- *Curb cuts:* One curb cut should be provided for every 20 feet of curb associated with each bioretention cell, or a minimum of 2 curb cuts per cell (whichever is greater).

Curb cuts are particularly susceptible to erosion and clogging. Curb inlets require appropriately sized stone or other erosion protection (reinforced turf) to prevent erosion at the curb openings. The top of the stone should be approximately 4 inches below the pavement height to prevent clogging of the curb cuts with debris and vegetation. The impervious area draining to the curb cuts must be graded so as to (1) evenly distribute water into and across the bioretention surface; (2) prevent runoff from by-passing the filter; and (3) prevent the concentration of runoff at the outlet structure. Site grading must be carefully examined during both design and construction.

- *Outlet Options:* The outlet system often determines whether a facility is on-line or off-line. A common approach is for the facility to fill to the design depth, at which point the flow is diverted to inlet structures in the curb. Other outlet options include an outlet structure in or at the edge of the bioretention facility or an overflow weir, with the overflow elevation set at the design depth.

When outlet structures are located in the bioretention area, the area where filter material meets the structure is prone to scouring. In these cases, the filter media should be ramped up to the crest of the overflow structure, or other provisions made to prevent erosion and scouring (see **Figure 9**). For weir systems, the design must incorporate provisions for overland relief, in accordance with the Comprehensive Storm Water Management Ordinance (Chagrin River Watershed Partners, Inc., Performance Standards, Section B.7). For all designs, the embankment around the bioretention area must be high enough so that peak discharge from the 10-year storm is confined without overtopping the embankment.

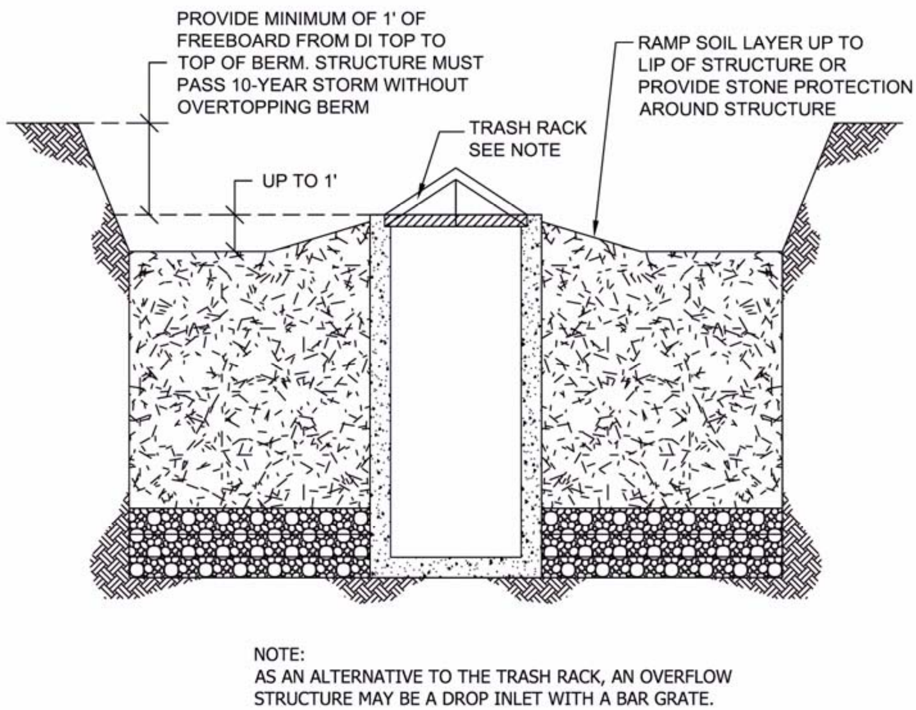


FIGURE 9:
OUTLET STRUCTURES IN BIORETENTION
DETAIL NTS

4.4 Vertical control (design elevations)

Since design elevations are critical to bioretention success, the plan should include a plan view detail, profile detail, an appropriate number of cross-sections, with elevations shown for the:

- Top of curb (if applicable)
- Top of the embankments
- Tops and inverts of the inlet/outlet structures
- Top of the soil mix
- Top and bottom of the under-drain layer
- Cleanouts

4.5 Materials

Materials for bioretention facilities shall be in accordance with the following chart, unless otherwise approved by the Stormwater Management Department.

Material	**Specification**
Pea Gravel	Clean, preferably double-washed #7, #8, or #78 stone
Stone Diaphragm	Depends on velocities. Generally stone 2 inches - 5 inches
Underdrain Gravel	Clean, preferably double-washed #57 stone
Underdrain Pipe	4 inches or 6 inches rigid schedule 40 PVC. For perforated sections, use 3/8 inch perforations @ 6 inches o.c., 4 holes per row. Alternately, score pipe with circular saw or use 20-slot well screen pipe.
Soil Mix	• 50% sand (ASTM C33 Fine), • 30% topsoil (see below), • 20% composted organic (leaf compost), • Or mix available from vendor approved by Stormwater Management Department.
Topsoil (30% component of Soil Mix specified above)	USDA textural classification of loamy sand or sandy loam. Topsoil component of soil mix must be tested and approved for use by the Stormwater Management Department. The testing criteria are listed in the table below.
Geotextile	Nonwoven polypropylene geotextile with flow rate > 110 gal/min/sf. (Geotex 351, Geotex 601, or equivalent).
Drain Cell	52mm cell, 2 inches thick, or equivalent.
Mulch	Shredded hardwood mulch (3" min).
Plants	Site-specific. Conform to standards of the current edition of *American Standards for Nursery Stock* **Appendix A – Plant List**.

The following criteria apply to the topsoil component (30%) of the Biofilter Soil Mix.

Soil Testing Criteria for Topsoil	
Item	**Criteria**
Corrected pH	5.5 -- 7.0
Organic matter	1.5 -- 10%
Magnesium	32 ppm minimum.
Phosphorus (P205)	Not to exceed 69 ppm
Potassium (K20)	78 ppm minimum.
Soluble Salts	Not to exceed 500 ppm

- Soil that falls outside of the acceptable range for pH may be modified with lime (to raise) or iron sulfate plus sulfur (to lower) the pH.
- Soil that does not meet the minimum requirement for organic matter may increase the organic component of the Soil Mix (e.g., from 20% to 25%).
- Soil that does not meet the minimum requirement for magnesium may be modified with magnesium sulfate.
- Soil that does not meet the minimum requirement for potassium may be modified with potash.

The lime, iron sulfate, magnesium sulfate, and/or potash must be mixed uniformly into the topsoil.

4.6 Landscape Planting

The landscape plan should reflect the appropriate landscape setting for the bioretention area. These settings may include:

- Landscape bed with native trees, shrubs, and herbaceous layer and mulch.
- Turf cover with native trees and shrubs, intended to be mowed.
- Low-maintenance native herbaceous cover, resembling a wet meadow.

See **Figure 10** for vegetative cover options. In general, the planting plan should strive for as much surface area coverage as possible. In this regard, the herbaceous layer will have many more plants than either the tree or shrub layer.

In general, plants should be selected from the Bioretention Plant List in **Appendix A**, or as advised by Ohio State University Cooperative Extension Office.

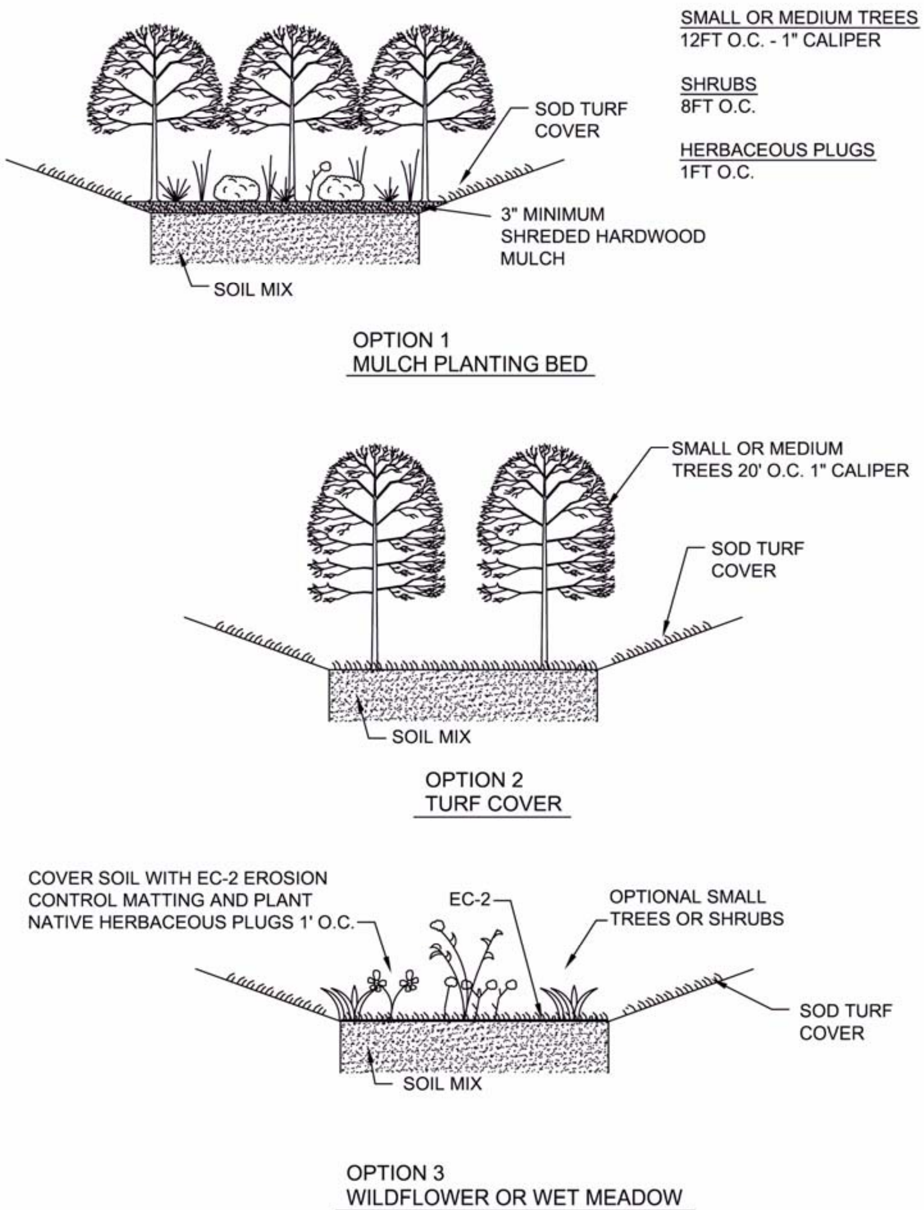


FIGURE 10: VEGETATIVE COVER OPTIONS

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4.7 Cold Weather & Snow Considerations

The main considerations for cold weather and snow are as follows:

- Freezing of the filter media and pipes, leading to wintertime clogging.
- Snow plows running over/through the bioretention area, especially in parking lot island designs without curbs.
- Snow being piled on top of the bioretentention cells, freezing, and compacting the filter media and damaging/killing plants.
- Large loads of sand or salt being washed into bioretention cells, leading to clogging and/or plant damage and mortality.

While it may be desirable to have melting snow drain towards bioretention areas to realize the water quality filtering benefits, the design should incorporate some precautions to avoid the problems listed above. Several design options include:

- Use larger diameter underdrain pipes (e.g., 6-inch instead of 4-inch) to promote drainage.
- Incorporate a designated snow storage area in the grass filter strip that is large enough to accommodate snow from the adjacent parking lot/travelway (for instance, 3 inches of filter strip width for each parking space).
- Use curbs with curb cuts in parking lot island bioretention areas to provide a cleaner line to keep plows away.
- Place signage in the bioretention area (at least during the winter months) to keep plows away.
- Specify that snow fence should be placed around the perimeter of the filter bed during snow season.

5.0 Construction Specifications

5.1 Protection During Construction

The following points are critical during the construction process:

- Bioretention facilities must not be installed until the contributing drainage area is stabilized to the satisfaction of the Stormwater Management Department. Even small amounts of construction runoff with silt and clay will clog the filter.
- For sites using Design Concept #3 (infiltration), the area designated for infiltration must be protected during construction. The area cannot be compacted or receive any construction runoff.
- Secondary erosion control measures shall be employed during installation of the bioretention facility. These may include silt fence around the perimeter of the filter area, diversion dikes, blocking/diverting all inlets into the facility, and/or installing sod or erosion control matting on the side slopes of the facility itself . The objective is to keep all sediment runoff, including from disturbed side slopes of the bioretention area, from entering the filter area.

5.2 Co-Location With Erosion & Sediment Control Measures

Sites using Design Concept #3 (infiltration) are discouraged from co-locating temporary erosion control measures with permanent bioretention facilities. The exception to this would be if the stone "sump" layer of the bioretention area is excavated below the sediment trap invert, and all construction sediment accumulated in the trap is carefully removed from bioretention construction area.

For Design Concepts #1 and #2, measures may be co-located, as approved by the Stormwater Management Department.

5.3 Testing the Bioretention Soil Mix

The soil shall be a uniform mix, free of stones, stumps, roots or other similar objects larger than two inches. No other materials or substances shall be mixed or dumped within the bioretention area that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations. The planting soil shall be free of noxious weeds.

When soil is mixed by the contractor, the mix shall be tested according to specifications in Section 4.5. A textural analysis is required from the site stockpiled topsoil. If topsoil is imported, then a texture analysis shall be performed for each location where the topsoil was excavated. Since different labs calibrate their testing equipment differently, all testing results shall come from the same testing facility.

Should the pH fall out of the acceptable range, it may be modified (higher) with lime or (lower) with iron sulfate plus sulfur. Should the mix not meet the minimum requirement for magnesium, it may be modified with magnesium sulfate. Likewise, should it not meet the minimum requirement for potassium, it may be modified with potash. Magnesium sulfate and potash must be mixed uniformly into the soil mix prior to use in bioretention facilities.

For pre-mixed bioretention soils available from vendors, the mix shall first be approved by the Stormwater Management Department.

5.4 Testing Soils for Infiltration Designs

For Design Concept #3, relying on infiltration from the bottom of the bioretention facility, a minimum field infiltration rate (fc) of 0.5 inches per hour is recommended; areas yielding a lower rate may preclude these practices. Testing is done in two phases, (1) Initial Feasibility, and (2) Concept Design Testing. Testing is to be conducted by a qualified professional: either a registered professional engineer in the State of Ohio, or a soil scientist or geologist also licensed in the State of Ohio.

Feasibility testing is conducted to determine whether full-scale testing is necessary, and is meant to screen unsuitable sites, and reduce testing costs. The designer should first consult the NRCS Soil Survey for Lake County to determine the soil unit and series, hydrologic group, permeability, and USDA texture. Based on the Soil Survey information, the designer may elect to proceed to site-specific testing.

Initial testing involves either one field test per facility, regardless of type or size, or previous testing data, such as the following:

- Septic percolation testing on-site, within 200 feet of the proposed facility, and on the same contour (this can establish initial rate, water table and/or depth to bedrock).
- Previous written geotechnical reporting on the site location as prepared by a qualified geotechnical consultant

If the results of initial feasibility testing as determined by a qualified professional show that an infiltration rate of greater than 0.5 inches per hour is probable, then *concept design test* pits shall be per the following: 1 infiltration test and 1 test pit per 200 square feet of filter area. An encased soil boring may be substituted for a test pit, if desired.

The testing procedure for concept design testing is specified in Appendix E.

5.5 Excavation

The bioretention facility shall be excavated to the dimensions, side slopes, and elevations shown on the Plans. The method of excavation shall minimize the compaction of the bottom of the bioretention facility. Excavators and backhoes, operating on the ground adjacent to the bioretention facility, shall be used to excavate the facility if possible. Low ground-contact pressure equipment may also be used for excavation. 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 storage volumes and is not acceptable (especially for Design Concept #3). Excavated materials shall be removed from the bioretention facility site.

5.6 Tilling/Ripping Base for Infiltration Designs

For Design Concept #3, compaction can be alleviated at the base of the bioretention facility by using a primary tilling operation such as a chisel plow, ripper, or subsoiler. These tilling operations are to refracture the soil profile through the 12 inch compaction zone. Substitute methods must be approved by the Stormwater Management Department. Rototillers typically do not till deep enough to reduce the effects of compaction from heavy equipment. Till 2 to 3 inches of sand into the base of the bioretention facility before back filling the stone layer. Pump any ponded water before tilling the base. The soil must be friable before tilling.

5.7 Underdrain Installation

Place the underdrain according to the Plan. When installing perforated underdrain pipe, ensure a minimum of 3 inches of gravel (No. 57) over the pipe, plus the additional 3 inches of pea gravel (No. 8 or 78). Underdrains shall be placed across the entire bottom of the bioretention facility, with approximate spacing of 20 feet on-center and with a minimum slope of 1%.

Observation wells/cleanouts of non-perforated pipe shall be placed vertically in the bioretention facility. The wells/cleanouts shall be connected to the perforated underdrain with the appropriate manufactured connections, using 45 degree connections at the junction to aid clean-out. The wells/cleanouts shall extend roughly 6 inches above the top elevation of the bioretention facility, and shall be capped with a screw cap. The ends of underdrain pipes not terminating in an observation well/cleanout shall be capped.

For Design Concept #2 (shallow system), the drain cell and geotextile shall be placed according to the manufacturers specifications.

5.8. Placing The Soil Mix

The Bioretention Soil Mix shall be placed and graded using excavators and/or backhoes operating on the ground adjacent to the bioretention facility. If equipment must operate within the filter area itself, it must be light equipment that will not compact the soil to any appreciable degree (e.g., small loader with wide tracks or marsh tracks). No heavy equipment and/or equipment with narrow tracks, narrow tires, rubber tires, or high pressure tires shall be used within the immediate filter area during or after the placement of the soil mix.

The mix shall be placed in horizontal layers not to exceed 12 inches for the entire area of the bioretention facility. Grade bioretention materials by hand or with light equipment such as a compact loader or a dozer/loader with marsh tracks. The soil mix can be expected to settle, especially after becoming saturated. For this reason, the elevation of the mix should be a couple of inches higher at installation than the design elevation in anticipation of settling.

5.9 Plant Installation

After placing the soil mix and approval, trees, shrubs and herbs shall be planted. Planting shall be conducted between May 1 and June 15 or September 15 and November 1. Root stock of the plant material should be kept moist during transport, from the source, to the job site and until planted.

Bioretention facilities should be planted in accordance with the planting plan and plant schedule on the plans which provides specific spacing requirements. Prior to planting the entire area, the Stormwater Management Department or their representative should inspect and approve plant spacing and planting techniques before proceeding.

All planting pits shall be dug by hand and excavated to $1^1/_2$ times the width of the root mass. The planting pit shall be deep enough to allow the first lateral root of the root mass to be flush with the existing grade. Remove all non-organic debris from the pit and tamp loose soil in the bottom of the pit by hand.

Remove the plant from its container either by cutting or inverting the container. Do not handle the plant by the branches, leaves, trunk or stem. Place the plant straight in the center of the planting pit, carrying the plant by the root mass. Never lift or carry a plant by the trunk or branches.

Mix a minimum of 500 spores of endomycorrhizal fungi and 30 million spores of ectomycorrhizal fungi to each cubic foot of backfill for trees and shrub planting. Backfill planting pit with existing soil and hand tamp as pit is being backfilled to completely fill all voids and air pockets. Do not over compact soil. Make sure plant remains straight during backfilling/tamping procedure. Do not cover the top of the root mass with soil.

An 18 inch diameter area of well aged (6 to 12 months) shredded hardwood mulch shall be placed around each plant 2-3 inches thick. Mulch shall NOT be placed directly against the stem of the plant. Pine mulch and wood chips will float and move to the perimeter of the bioretention area during a storm event and are not acceptable. Water plant thoroughly immediately after planting, unless otherwise directed by Stormwater Management Department. The topsoil specifications provide enough organic material to adequately supply nutrients from natural cycling. The primary function of the bioretention structure is to improve water quality. Adding fertilizers defeats, or at a minimum, impedes this goal.

6.0 Inspection & Maintenance

6.1. Construction Inspection

There are several critical milestones during construction. It is recommended that inspections take place at the following points:

- Site is stabilized adequately to begin installation of bioretention.
- Runoff diverted around bioretention area and secondary erosion control measures in place.
- Inspection/testing of bioretention soil mix.
- Inspection/testing of underlying soil for infiltration designs (Design Concept #3).
- Excavation and installation of underdrain system.
- Placement of soil mix.
- Planting and completion. Ensure that any sediment from construction is removed. If filtration rate is poor, till in 2 inches of sand to top layer.

A construction inspection checklist is provided in **Appendix C**.

6.2. As-Built Certification

After vegetation has been established in the bioretention area, an as-built drawing and certification shall be provided to the Stormwater Management Department.

6.3. Maintenance Inspection

Long-term maintenance inspection consists of inspecting the following elements:

- Filter bed functions and drains at a proper rate. Standing water is not an issue between storms. The filter has not settled in pockets, or "piping" created through filter media. The filter bed is not eroding.
- Vegetation is maintained. Dead or diseased plants are removed and replaced. Mulch is replaced as necessary. Vegetation is pruned as needed.
- Pretreatment is functioning properly and is not more than 50% full of sediment.
- Inlets are not eroding, by-passing flow, or clogged.
- Outlet structures are not eroding, by-passing flow, or clogged.
- Underdrains do not appear to be clogged and flow after a storm event.
- No evidence of contamination with oil, grease, or other contaminants from drainage area.
- The cell continues to have a concave shape rather than being mounded up.
- Snow load is not an issue during the winter. There are designated areas for snow to be piled (not on the filter itself, but in the grass filter strip or other adjacent area). If deemed necessary, snow fence is installed during the winter around the perimeter of the actual filter bed.

  A maintenance inspection checklist is provided in the Appedix D.

7.0 References

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8.0 Appendices

APPENDIX A: BIORETENTION PLANT LISTS

Plant List 1

The following is a composite list of suitable plants bioretention facilities compiled from the following on-line plant lists. The first two links are to interactive sites from the Wisconsin Department of Natural Resources. The third link is from a watershed group in Minnesota that promotes rain gardens. The Minnesota list is included Plant List 2.

http://dnr.wi.gov/org/water/wm/nps/rg/plants/PlantListing.htm
http://dnr.wi.gov/org/water/wm/nps/rg/RaingardenPlantList.pdf
http://www.mninter.net/%7Estack/rain/

TREES

	Scientific Name	Common Name
•	Acer rubrum	Red Maple
•	Betula nigra	River Birch
•	Fraxinus americana	White Ash
•	Fraxinus pennsylvanicum	Green Ash
•	Gleditsia treacanthas	Honeylocust
•	Juniperus virginiana	Eastern Red Cedar
•	Liquidambar styraciflua	Sweet Gum
•	Nyssa sylvatica	Black Gum
•	Platanus occidentalis	Sycamore
•	Populus deltoides	Eastern Cottonwood
•	Quercus bicolor	Swamp White Oak
•	Quercus coccinea	Scarlet Oak
•	Quercus palustris	Pin Oak

SHRUBS

Scientific Name	Common Name
Cornus racemosa	Gray Dogwood
Cornus Stolonifera	Red Osier Dogwood
Ilex glabra	Inkberry
Amelanchier canadensis	Shad Bush
Clethra alnifolia	Sweet Pepperbush
Hammamelis virginiana	Witch Hazel
Hypernicum densiflorum	Bushy St. John's Wort
Ilex verticillata	Winterberry
Lindera benzoin	Spicebush
Viburnum cassinoides	Wilthe Rod
Viburnum dentatum	Arrow-Wood
Viburnum lentago	Nannyberry

HERBACEOUS

Scientific Name	Common Name
Agastache foeniculum	Blue Giant Hyssop
Allium cernuum	Nodding Wild Onion
allium stellatum	Prairie Wild Onion
Amorpha canescens	Leadplant
Andropogon gerardii	Big Bluestem
Andropogon scoparius	Little Bluestem
Anemone candensis	Canada Anemone
Angelica atropurpurea	Angelica
Apocynum androsaemifolium	Dogbane
Aquilegia canadensis	Columbine
Arisaema triphyllum	Jack in the Pulpit
Artemisia ludoviciana	Prairie Sage
Asclepias incarnata	Red Milkweed
Asclepias syriaca	Common Milkweed
Asclepias syriaca spp.	Butterfly Weed
Asclepias tuberosa	Butterfly Milkweed
Aster azureus	Sky Blue Aster
Aster ericoides	Heath Aster
Aster laevis	Smooth Aster
Aster macrophyllus	Bigleaf Aster
Aster novae-angliae	New England Aster
Aster novae-belgis	New York Aster
Aster pilosus	Frost Aster
Aster puniceus	Red-stemmed Aster

HERBACEOUS (continued)

Scientific Name	Common Name
Aster sericeus	Silky Aster
Astragalus canadensis	Canada Milk Vetch
Bidens polyepis	Tickseed Sunflower
Bouteloua curtipendula	Side-oats Grama
Bromus ciliatus	Fringed Brome
Campanula rotundifolia	Harebell
Carex comosa	Bottlebrus Sedge
Carex crinita	Caterpillar Sedge
Carex hystericina	Porcupine Sedge
Carex vulpinoidea	Fox Sedge
Cassia hebecarpa	Wild Senna
Ceanothus americanus	New Jersey Tea
Chelone glabra	Turtlehead
Cirsium discolor	Native Field Thistle
Crataegus viridis	Winter King
Desmodium canadense	Showy Tick-trefoil
Desmodium illinoense	Illinois tick-trefoil
Echinacea pallida	Pale Purple Coneflower
Echinacea purpurea	Purple Coneflower
Epilobium angustifolium	Fireweed
Equisetum fluviatile	Horsetail
Eryngium yuccifolium	Rattlesnake Master
Eupatorium maculatum	Spotted Joe Pye
Eupatorium perfoliatum	Boneset
Eupatorium purpureum	Savanna Joe Pye
Galium boreale	Northern Bedstraw
Gentiana andrewsli	Bottle Gentian
Geum triflorum	Prairie Smoke
Glyceria striata	Fowl Manna Grass
Helenium autumnale	Sneezeweed
Helianthus laetiflorus	Showy Sunflower
Helianthus mollis	Downy Sunflower
Helianthus occidentalis	Ox-eye Sunflower
Heliopsis helianthoides	False Sunflower
Heuchera richardsonii	Prairie Alumroot
Iris shrevei	Wild Iris
Iris versicolor	Blueflag
Juncus effusus	Soft Rush
Lespedeza capitata	Roundhead Bush Clover
Liatris aspera	Rough Blazing Star
Liatris ligulistylis	Meadow Blazing Star
Liatris pycnostachya	Prairie Blazing Star
Liatris spicata	Blazing Star
Lilium superbum	Turk's-cap Lily

HERBACEOUS (continued)

Scientific Name	Common Name
• Lobelia cardinalis	Cardinal Flower
• Matteuccia struthiopteris	Ostrich Fern
• Mertensia virginica	Virginia Bluebells
• Monarda fistulosa	Bergamot
• Oenothera biennis	Evening Primrose
• Onoclea sensibilis	Sensitive Fern
• Osmunda regalis	Royal Fern
• Panicum virgatum	Switch Grass
• Penstemon digitalis	Bearded Foxglove
• Petalostemum purpureum	Purple Prairie Clover
• Phlox divaricata	Woodland Phlox
• Phlox pilosa	Downy Prairie Phlox
• Physostegia virginiana	Obedient Plant
• Pteridium aquilinum	Bracken Fern
• Pycnanthemum virginianum	Mountain Mint
• Ratibida pinnata	Yellow Coneflower
• Rudbeckia hirta	Black-eyed Susan
• Rudbeckia subtomentosa	Brown-eyed Susan
• Rudbeckia triloba	Brown-eyed Susan
• Ruellia humilis	Wild Petunia
• Schizachyrium scoparium	Little Bluestem
• Scirpus cyperinus	Woolgrass
• Scutterlaria lateriflora	Mad-dog Skullcap
• Silphium integrifolium	Rosin Weed
• Silphium laciniatum	Compass Plant
• Silphium perfoliatum	Cup Plant
• Silphium terebinthinaceum	Prairie Dock
• Smilacina racemosa	False Solomon's Seal
• Solidago flexicaulis	Zig-zag goldenrod
• Solidago reddellii	Reddell's goldenrod
• Solidago rigida	Stiff Goldenrod
• Solidago speciosa	Showy Goldenrod
• Sorghastrum nutans	Indian Grass
• Spartina pectinata	Prairie Cord Grass
• Sporobolus heterolepis	Prairie Dropseed
• Thalicitrum dasycarpum	Tall Meadowrue
• Tradescantia ohiensis	Spiderwort
• Verbena hastata	Blue Vervain
• Verbena stricta	Hoary Vervain
• Vernonia fasciculata	Ironweed
• Veronicastrum virginicum	Culver's Root
• Viola papilionacea	Common Wood Violet
• Viola pedata	Birdsfoot Violet
• Zizia aptera	Heartleaved Golden Alexander
• Zizia aurea	Divided Golden Alexander

Plant List 2

The following plant list highlights plants with their associated environments. It is adapted from a watershed group in Minnesota that promotes rain gardens.

http://www.mninter.net/%7Estack/rain/

Native Plants for Wet Soils --- Sunny Areas

- Sweet Flag……………..Acorus calamus
- Giant Hyssop*……….. .Agastache foeniculum
- Canada Anemone………Anemone canadensis
- Marsh Milkweed*…….. Asclepias incarnata
- New England Aster*…..Aster novae-angliae
- Marsh Marigold………..Caltha palustis
- Tussock Sedge…………Carex stricta
- Turtlehead*…………….Chelone glabra
- Joe Pye Weed*…………Eupatorium maculatum
- Boneset…………………Eupatorium perfoliatum
- Queen of the Prairie* Filipendula rubra -
- Sneezeweed…………….Helenium autumnale
- Blueflag Iris…………….Iris versicolor
- Soft Rush……………….Juncus effusus
- Great Blue Lobelia……..Lobelia siphilitica
- Switchgrass*…………...Panicum virgatum
- Prairie Phlox……………Phlox pilosa
- Mountain Mint………….Pycnanthemum virginianum
- River Bulrush…………..Scirpus fluviatilis
- Softstem Bulrush……….Scirpus validus
- Riddell's Goldenrod…….Solidago riddellii
- Tall Meadow Rue*……..Thalictrum dasycarpum
- Culvers Root*………….Veronicastrum virginicum
- Golden Alexander………Zizia aurea

*Likely to grow taller than three feet

Native Plants for Wet Soils --- Shady Areas

- Caterpiller Sedge……… Carex crinita
- Cardinal Flower*…………Lobelia cardinalis
- Ostrich Fern*…………….Matteuccia struthiopteris
- Virginia Bluebells………..Mertensia virginica
- Sensitive Fern…………….Onoclea sensibilis

Shrubs --- Sunny or Shady Areas

- Black Chokeberry ………...Aronia melanocarpa
- Red Osier Dogwood………Cornus serecia
- Low Bush Honeysuckle….Diervilla lonicera)
- Pussy Willow……………..Salix caprea
- Blue Arctic Willow……….Salix purpurea 'Nanna')

Shrubs --- Sunny Areas Only

- Meadow Sweet…………….Spiraea alba
- Steeplebush………………..Spiraea tomentosa
- High Bush Cranberry……...Viburnum trilobum

APPENDIX B: BIORETENTION PLAN REVIEW CHECKLIST

DATE:________________ REVIEWER:__________________________

PLAN NAME & #:___________________PREPARED BY:________________________

- □ Design Concept matches site conditions. Soil Survey is checked for soil types, texture, permeability, and hydrologic group. Site is examined for clay soils, shallow water table, shallow to bedrock, and other constraints. Site checked for baseflows, chlorinated flows, and hot spots.
- □ Drainage area to each facility is one acre or less for commercial/industrial, and 5 acres or less for residential. If not, "off-line" designs are employed.
- □ Each facility sized according to criteria. Sizing applies to filter bed and not side slopes.
- □ Ponding depth is 0.5 feet – 1 foot .
- □ Adequate pretreatment provided. Inlets velocities will not erode grass inlets, curb cuts, etc. Area is specified for snow storage NOT on the filter surface.
- □ Site is graded so that flow will be distributed as evenly as possible throughout facility, will not by-pass, and will not concentrate at the outlet structure.
- □ Stable outlet structures provided. Soil is ramped up to overflow structure within filter area. Confining berm will not overtop for 10-year storm. Weirs have overland relief.
- □ Vertical elevation shown on plan for: curb, embankments, inlet and outlet structures, soil mix, underdrain, and clean-outs.
- □ Materials are specified as per design guidelines or equivalent approved by County. Soil testing is specified for soil to be mixed by contractor. Infiltration testing is specified for Design Concept #3.
- □ Landscape setting is specified. Plantings as per plant list or qualified professional.
- □ Secondary erosion control measures specified during bioretention installation.
- □ Construction sequence specified in erosion control plan to protect bioretention area from construction runoff, compaction, and disturbance (unless co-located with erosion control measures).
- □ Construction sequence specified for installation of bioretention components. Inspection milestones are outlined.

APPENDIX C: BIORETENTION CONSTRUCTION CHECKLIST

PROJECT:____

FACILITY:__________________________

DATE:______________ **INSPECTOR:**________________

SITE STATUS:____

- □ Construction sequence followed to protect bioretention location and underlying soils (for Design Concept #3).
- □ Site/drainage area is stabilized adequately to begin bioretention installation.
- □ Site will drain evenly to bioretention. Curb cuts will receive runoff water as evenly as possible. Water will not concentrate at outlet.
- □ Runoff is diverted/by-passed away from bioretention construction area. Curb cuts are blocked (if applicable).
- □ Soil mix testing conducted if mixed by contractor. Soil mix uniformly mixed and does not have unacceptable objects (e.g., stones, stumps, roots, weeds).
- □ Soil/infiltration testing conducted for Design Concept #3 facilities.
- □ Facility excavated to property size and in proper location. Secondary erosion control measures installed.
- □ For Design Concept #3, bottom of facility is tilled or ripped and sand is tilled in.
- □ Underdrain system installed property and at design elevation.
- □ Soil mix installed in lifts and lightly compacted using proper procedure (no heavy equipment on filter bed). Top of filter is at design elevation or approximately 2 inches higher.
- □ Bioretention dimensions and slopes as per plans.
- □ Inlets and pretreatment are stable.
- □ Outlet structure as per plans. Soil ramped up to outlet structure if within filter bed.
- □ Weirs have overland relief.
- □ Landscaping installed as per plans. Plant substitutions approved. Mulch or EC-2 installed properly.

- □ Runoff diverted back into bioretention area after approximately 2 storms. Drainage area is fully stabilized with vegetative cover.
- □ Filter appears to function properly after storm. Filter drains within 48 hours of storm.
- □ No erosion evident at inlets, outlet, or in filter bed. Underdrains flow during/after storm.
- □ If filter is not draining properly, and construction silt or sediment removed from surface and 2 inches of sand tilled into top layer.
- □ As-built plans submitted and reflect field conditions.

COMMENTS:

ACTIONS TO BE TAKEN:

APPENDIX D: BIORETENTION MAINTENANCE CHECKLIST

PROJECT:____

FACILITY:____________________________

DATE:____________ **INSPECTOR:**______________

SITE STATUS:____

□ Bioretention area and drainage area clean of debris, yard waste, litter, etc.

□ Bioretention area and drainage area do not have erosion that is causing operational issues with bioretention.

□ Bioretention appears to drain properly. No excessive settling of filter bed, standing water, piping through filter bed, by-passing, etc. The filter maintains a concave shape and is not mounded with soil or debris.

□ Pretreatment and inlets are stable. Pretreatment is not more than 50% full of sediment. Inlets are not clogged or blocking flow.

□ Oultet structure or weir is in good condition, is not eroding or blocked, and does not appear to be by-passing flow.

□ Mulch and/or ground cover adequate.

□ Plants are in good condition. Dead or diseased plants replaced. Plant composition is similar to plans or has been improved with additional plantings.

□ Underdrain outlet is clear. No standing water in underdrain clean-outs 48 hours after storm.

□ Downstream channel is stable, not eroding.

□ Snow load is properly handled. Snow is not piled on the filter bed (although it can be piled on the adjacent grass filter strip). Snow plows are not running through or across the bioretention area. Snow fence is installed during the winter around the perimeter of the filter bed if necessary.

COMMENTS:

ACTIONS TO BE TAKEN:

APPENDIX E: CONCEPT DESIGN TESTING REQUIREMENTS FOR INFILTRATION DESIGNS

As stated in Section 5.4, if the results of initial feasibility testing as determined by a qualified professional show that an infiltration rate of greater than 0.5 inches per hour is probable, then *concept design test* pits shall be per the following: 1 infiltration test and 1 test pit per 200 square feet of filter area. An encased soil boring may be substituted for a test pit, if desired. The testing procedure is outlined below, unless an alternative method is approved by the Stormwater Management Department.

Test Pit/Boring Requirements

a. Excavate a test pit or dig a standard soil boring to a minimum depth of 4 feet below the proposed facility bottom elevation.

b. Determine depth to groundwater table (if within 4 feet of proposed bottom) upon initial digging or drilling, and again 24 hours later.

c. Conduct Standard Penetration Testing (SPT) every 2 feet to a depth of 4 feet below the facility bottom.

d. Determine USDA or Unified Soil Classification System textures at the proposed bottom and 4 feet below the bottom of the facility.

e. Determine depth to bedrock (if within 4 feet of proposed bottom).

f. The soil description should include all soil horizons.

g. The location of the test pit or boring shall correspond to the bioretention location; test pit/soil boring stakes are to be left in the field for inspection purposes and shall be clearly labeled as such.

Infiltration Testing Requirements

a. Install casing (solid 4-6 inch diameter, 30 inch length) to 24 inches below proposed facility bottom (see **Figure 11**).

b. Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate. Remove all loose material from the casing. Upon the tester's discretion, a 2 inch layer of coarse sand or fine gravel may be placed to protect the bottom from scouring and sediment. Fill casing with clean water to a depth of 24 inches and allow to pre-soak for twenty-four hours.

c. Twenty-four hours later, refill casing with another 24 inches of clean water and monitor water level (measured drop from the top of the casing) for 1 hour. Repeat this procedure (filling the casing each time) three additional times, for a total of four observations. Upon the tester's discretion, the final field rate may either be the average of the four observations, or the value of the last observation. The final rate shall be reported in inches per hour.

d. The test may be done through a boring or open excavation.

e. The location of the test shall correspond to the Stormwater Management Pond (SMP) location.

f. Upon completion of the testing, the casings shall be immediately pulled, and the test pit shall be back-filled.

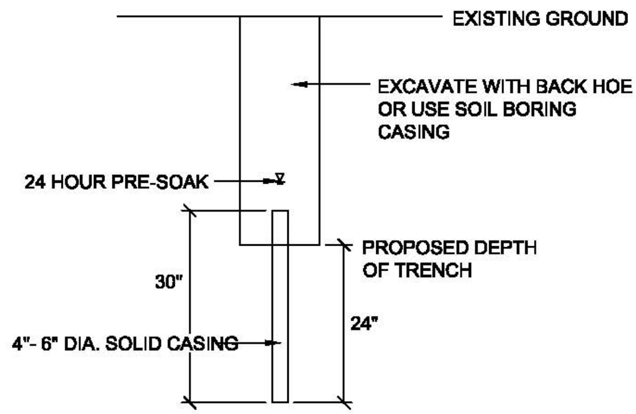

FIGURE 11: INFILTRATION TESTING
DETAIL NTS

Laboratory Testing

a. Grain-size sieve analysis and hydrometer tests where appropriate may be used to determine USDA soils classification and textural analysis. Visual field inspection by a qualified professional may also be used, provided it is documented. The use of lab testing to establish infiltration rates is prohibited.