GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH

STANDARDS, SPECIFICATIONS AND DETAILS FOR GREEN TECHNOLOGY BMPs TO MINIMIZE STORMWATER IMPACTS FROM LAND DEVELOPMENT

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Prepared For

Delaware Department of Natural Resources
And Environmental Control
Division of Soil And Water Conservation

JUNE 2005

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PREFACE

This Manual is written as the companion document to "Green Technology: The Delaware Urban Runoff Management Approach, a Technical Manual For Designing Nonstructural BMPs to Minimize Stormwater Impacts from Land Development". The intent in this Manual is to provide direct guidance on specific design criteria and standards for Green Technology BMPs, as well as their design details and specifications.

It is recommended that the reader refer to the Technical Manual for background and discussion on the elements addressed in this Manual. In this way, the designer will gain a better appreciation of the issues and the processes underlying these design standards, and thus be better prepared to utilize Green Technology BMPs most effectively.

I would like to express my thanks to Gary Burcham, ASLA, for providing a thorough review of the Chapter on landscaping. I also would like to thank Calvin Ernst for his advice on grasses, and his permission to use his plant pictures. Chris Miller deserves recognition for his advice and guidance on meadow establishment. The Rutgers University Native Meadows short course offered by Dr. Steven Handel also deserves mention as an excellent source for those interested in establishing native landscapes. These individuals provide a wealth of information and their resources are invaluable for anyone involved in the field of native meadow establishment.

CHAPTER 1 CONSTRUCTION AND TESTING SPECIFICATIONS

1.1 INTRODUCTION

It is essential that the proper materials and design standards are applied in constructing the Green Technology BMPs set forth in this Manual. As equally important, proper procedures for testing and installation of the materials must be documented to ensure their long-term function. The following sections set forth the specifications for construction and testing of materials used in BMP construction. Standards and Specifications for Materials, Design and Maintenance for each BMP are addressed specifically in subsequent Sections.

Reference citations have been omitted, since most of the specifications and standards have been derived from many different sources with similar conclusions. Appendix "A" summarizes many of the standards and specifications to be found in the literature, most of which are available over the internet, that were investigated in preparing this Manual.

1.2 CONSTRUCTION AND TESTING SPECIFICATIONS

The following construction specifications set forth the required procedures needed to install Green Technology BMPs. Unless otherwise approved by the delegated review agency in response to submittals prepared by personnel qualified as stated in the Delaware Sediment & Stormwater Regulations, the following construction procedures shall apply to all Green Technology BMPs:

1.2.1 Construction Sequence

In the case of facilities that rely on infiltration such as infiltration trenches, bioretention facilities and dry bioswales, it is essential that all construction equipment and earth disturbance activities be kept away from the site of the BMP during overall site construction. This is particularly important if native soils are to be used for infiltration from bioretention facilities or bioswales. The site of such facilities shall be staked in the field prior to any earth moving, and suitable barrier fence (Amoco Hi-Vu or equivalent) shall be placed around the perimeter at least 10 feet from the site of such facilities.

If possible, construction of these facilities should be staged so that they are installed at the end of the project, when upslope areas have been stabilized. This avoids much of the potential concern about clogging due to sediment-laden runoff. However, since it is rarely practical to delay installation of most BMPs until the end of a project under normal construction practices, the measures set forth below should be followed for BMPs constructed during site disturbance activities.

1.2.2 Runoff Diversion

If Green Technology BMPs are to be installed before the completion of a project, adequate pretreatment measures as specified in the Delaware Erosion and Sediment Control

Handbook must be installed to intercept, divert and/or filter runoff prior to it entering the facility. Until the facility is constructed, runoff from upslope areas should be diverted away from the BMP to keep the work area clean and relatively dry.

In particular, sediment-laden runoff must be kept from the site of any infiltrating facility during construction. Sediments will rapidly clog the open porous soil structure required for such practices to function. Once clogged, the only way to renovate the soils is to remove them completely, and replace with imported soils of suitable characteristics. Even in this event, the properties of the replaced soil will be altered and compacted by its movement, reducing its performance. For this reason, areas for infiltration facilities should not be used for sediment trapping or conveyance unless absolutely necessary, and approved by DNREC.

Where an infiltration facility location is intended for use as a temporary sediment control structure, the bottom elevation of the temporary structure should be at least one foot above the design bottom elevation of the facility. This permits the removal of clogged soils to expose relatively undisturbed soils underneath. In sandy soils where the extent of clogging can extend considerably farther, this distance should be increased to at least two feet. If such infiltration areas are used for sediment trapping or conveyance, it may be necessary to retest the infiltration rates.

1.2.3 Construction Compaction

It is essential to minimize compaction at the base of infiltrating facilities and in their required soil media. Excessive compaction will contribute to design failure. In general, heavy equipment should never traverse areas intended for infiltrating trenches or bioretention facilities. Use of equipment with tracks or tires will cause too much compaction at the base of the facility and is not acceptable. An excavation trackhoe working from outside the footprint of the facility is the only type of equipment acceptable for use in removing the original soil. Areas set aside for infiltrating facilities shall be isolated by barrier fencing before any site disturbance.

1.2.4 Subgrade Preparation and Backfilling

For infiltrating facilities, scarify the subgrade of the facility before backfilling the required sand layer, stone layer, or underdrain gravel. Pump any ponded water and allow the surface to dry before scarifying (rototilling) the base. When backfilling the planting media over the sand layer, first place 3 to 4 inches of media over the sand, then rototill the sand/media to create a gradation zone. Backfill the remaining media to final grade.

When backfilling a bioretention facility, place the media in lifts of approximately 12”. Heavy equipment must not be used on the backfilled media. Place bioretention media with a trackhoe excavator at the perimeter. Heavy equipment can be used only around the perimeter of the basin to supply media and sand.

1.2.5 Geotextile Installation-Drainage Fabric

The manufacturer's recommendations must be followed when installing drainage fabric geotextiles. Its general purpose is to separate the stone reservoir or soil media bed to prevent migration of fine materials. The width of the drainage geotextile must include sufficient material to conform to irregularities in the trench or media bed perimeter. The top must overlap a minimum of 6 inches. Stones or other anchoring objects can be placed on the fabric at the edge of the trench or media bed to prevent displacement during the backfilling operation. When rolls of drainage fabric geotextile need to be joined, the manufacturer's recommendations shall be followed.

1.2.6 Infiltration and Soil Profile Testing

Proper infiltration testing is a key element of infiltration and bioretention facility design. Single-ring infiltrometer tests shall be used for the facilities contemplated in this Manual. Testing and design of Green Technology BMP's that rely on infiltration shall be consistent with current DNREC policies. In the case of bioretention facilities, it is generally recommended that there be at least one infiltrometer test for every 600 square feet of bioretention area. The final field rate calculated by these methods must exceed 1.02 inches per hour for any infiltrating facility, unless underdrains are provided.

It is also necessary that at least one test pit be excavated at each infiltrating BMP location to determine the soil profile through the facility and the depth to seasonal high water table (SHWT). For linear facilities, the test pit shall be located at a point one quarter of the total length from the lowest point. This ensures that results take into account more conservative conditions. Results from the test pit shall be logged by a professional soil scientist, and shall include the following information: depth to SHWT, Standard Penetration Testing every 2 feet, USDA Soil or Unified Soil Classifications, and descriptions of each horizon.

Testing of infiltration facilities should conform to the following specifications:

PROPERTY	BMP TYPE	GENERAL RECOMMENDATION	ADJUSTMENT REQUIREMENT
Infiltrometer Test	Infiltration Trench	Every 200 feet	per DNREC policy
Infiltrometer Test	Bioswale w/Infiltration	Every 400 feet	per DNREC policy
Infiltrometer Test	Bioretention Facility	Every 600 sq. feet	per DNREC policy

CHAPTER 2 DESIGN STANDARDS AND SPECIFICATIONS

2.1 INTRODUCTION

There is considerable variation in the specific design parameters presented in the extensive literature on design standards and specifications adopted in many jurisdictions for Green Technology BMPs. The literature researched for this Manual is summarized in tabular form in Appendix A to facilitate comparison of these standards and specifications. Constructive standards are incorporated into these criteria where appropriate. However, many elements required for comprehensive design are missing from these other sources. Furthermore, as a result of the findings discussed in the Technical Manual, many standards set forth in the other literature differ in important ways from that set forth in this Manual.

In particular, it must be recognized that Green Technology has been formulated to explicitly address site-specific design constraints and thus avoid a “rule of thumb” approach. For this reason, specific “optimal” design standards do not exist, since each situation will have its own best solution. Instead, this Manual establishes certain design standard limits beyond which a redesign is necessary to ensure proper functioning of the BMP involved.

The following Sections set forth the particular design standards to be applied to each Green Technology BMP. The standards followed in this Chapter address design rates, pretreatment measures and volumes, spatial design parameters, and specific maintenance measures for each BMP.

2.2 ACCESS AND MAINTENANCE

Green Technology BMPs must incorporate design standards and specifications that include effective maintenance measures. In particular, the issue of access is most important. Lack of legal and/or physical access to BMP facilities is most often cited by public agencies charged with the responsibility to maintain such facilities after they have been constructed.

For filter strips, access is generally not a major issue, since filter strips are located close to accessways by design, and maintenance is generally limited to landscaping activities that do not require heavy equipment. However, dedicated access to gain entry to locations where sediment accumulates is mandatory for other Green Technology BMPs. As a fundamental element of distributed BMP design, a designed and engineered accessway located within a dedicated easement must be provided to such locations where maintenance would require heavy equipment. An area adequate for sediment disposal must also be included in the overall planning of sites, and access to such an area, whether onsite or offsite, must be incorporated into the plans and supporting legal documents.

A regular institutional program for maintenance is also imperative. An important objective of using Green Technology BMPs is to reduce the extensive measures needed in upkeep of centralized structural BMPs. However, maintenance procedures are still necessary, even though they most often involve activities that are already part of the landscape maintenance obligations of the owner.

The preceding maintenance and access standards are applicable to all BMPs requiring heavy equipment access. Other maintenance procedures specific to each BMP are set forth in the following Sections.

2.3 FILTER STRIPS

While filter strips have relatively few design standards set forth in most literature, they are an extremely important distributed BMP since they are so easily incorporated into the design of projects. Therefore, it is essential that they be designed to handle their hydraulic and pollutant loads properly. This is particularly important where filter strips are incorporated as a pretreatment measure for infiltrating BMPs. In this event, the filter strip should be treated as an independent BMP so its effluent parameters can be adjusted to ensure that they are acceptable for any subsequent infiltrating BMP. If used as pretreatment for infiltrating BMPs, the effluent parameters for TSS should not exceed 15 ppm when modeled using DURMM. (See Section 2.6.3)

2.3.1 Standards for Filter Strip Hydraulic and Spatial Design Parameters

Design standards for filter strips follow the methods set forth in the Technical Manual, in which performance is a function of filter strip width and slope in relation to the anticipated loading rate. Since loading rates and required removal percentages will vary from site to site, specific values or limitations for drainage areas cannot be applied to filter strips. Drainage area runoff volume divided by width of filter strip determines linear hydraulic loading rate as cubic feet per linear foot. While several jurisdictions use hydraulic loading rate based upon runoff volume divided by filter strip area, this is not appropriate since the majority of pollutant removal occurs within the first five feet or so of the filter strip. Therefore, additional length (and area) is only slightly better in terms of further removal and infiltration.

The filter strip's slope and width parameters determine how well it can handle the hydraulic and pollutant loads. Therefore, specific design "removal rates" are not applicable since DURMM provides projected results, which can then be compared to the desired objectives. The following criteria should not be exceeded in designing filter strip BMPs for the quality event:

PROPERTY	MINIMUM REQUIREMENT	MAXIMUM REQUIREMENT
IMPERVIOUS LENGTH	No minimum	100 feet±
LOADING RATE	No minimum	30 cu.ft./lin.ft.
FILTER WIDTH	5 feet	No maximum
FILTER SLOPE	1 percent	25 percent

2.3.2 Standards for Filter Strip Pretreatment Measures

A key component in proper functioning of filter strips is to ensure that runoff from the contributory impervious area occurs as sheet flow. As shown in Detail 2.3.1, the contributory impervious area such as a parking lot can be designed as a plane with a uniform slope that discharges into the filter strip as sheet flow. Where a uniform smooth plane is provided, a separate level spreader is not required so long as the flow path length from such an area is less than 100 feet.

Where the impervious drainage area would discharge in a concentrated flow, as from downspouts, or sag curves in a parking lot, a level spreader must be installed. The level spreader should be constructed per Detail 2.3.3. The length of the level spreader should be equal to the source area divided by 100 so as to distribute the runoff into the filter strip at a hydraulic loading rate similar to that from a uniform plane.

2.3.3 Filter Strip Materials Specifications

The following specifications set forth the required characteristics for materials commonly used in constructing filter strips. Unless otherwise approved by the delegated review agency in response to submittals prepared by personnel qualified as stated in the Regulations, the specifications shall apply to all materials used in filter strips. Specific products mentioned in this Manual are used by way of example, and do not represent an explicit endorsement of the product by DNREC. The submitting designer may substitute different materials if it can be documented that equivalent functioning is provided to meet the performance goals of this Manual.

2.3.3.1 Level Spreader Stone

Level spreader stone is used to intercept the concentrated flows and distribute it along the length of the spreader. It shall be washed free of dust, fines and soil particles. Level spreader stone shall conform to the following specifications:

SIEVE OPENING	0.50 in. to 2.50 in.	Stone shall be clean double-washed bank run gravel or crushed aggregate, free of rock dust, fines or soil particles.
SIZE	clean DE #3	

2.3.3.2 Geotextile

Structural support geotextile is used to line level spreaders to keep the surrounding soil from entering the stone. Its specifications shall match that required under riprap stone. Refer to the Delaware Erosion and Sedimentation Control Handbook for specifications for the appropriate geotextile to be used.

2.3.3.3 Standards for Filter Strip Topsoil

The soil underlying filter strips should be as well aerated and uncompacted as possible. However, by their proximity to impervious surfaces, soils under most filter strips are likely to be completely disturbed and heavily compacted. Such excessive compaction must be alleviated by using a chisel plow, ripper, or subsoiler, as discussed in the Section 1.2.3. Adequate topsoil must also be returned to provide enough organic matter and mycorhizzae necessary for plants to flourish. A minimum of 6 inches of topsoil shall be specified in the plans for filter strips. The topsoil should be disked in to blend it with the subsoil to reduce an abrupt change in soil types and promote infiltration.

If possible, filter strip topsoil should be limed to a neutral pH, fertilized as set forth below, and meet the following gradation recommendations:

PROPERTY	RECOMMENDATION	PROPERTY	RECOMMENDATION
pH	6.0-7.0	Organic Matter	1.0-4.0%
Mg	35 lb./ac.	Sand	30-80%
Po	75 lb./ac.	Silt	30-60%
K	85 lb./ac.	Clay	5-35%
Salts	<500 ppm	Porosity	25-40%

2.3.4 Standards for Filter Strip Vegetation

Filter strips reduce pollutant loads through two mechanisms: filtering through the standing stalks of the vegetation, and infiltration into the soils underneath. Of these two mechanisms, filtering is predominant. While a dense stand of cool season sod-type grasses could be specified in landscaped settings, recent research indicates that a dense native meadow stand can be similarly effective. It is important that the plantings be as dense as possible for the initial 15 feet where filtering is most important. Turf is the obvious choice for many filter strips, since they are lawn areas that happen to be specifically designed to intercept runoff from buildings and parking areas.

However, native warm season grasses have much deeper rooting systems than turf-type cool-season grasses. This greatly promotes infiltration and recharge of runoff into groundwater. There are also several native grasses that form a dense stand at maturity. Where pollutant loads are not excessive and infiltration is desired, native warm season grasses are preferable. See Chapter 3, Landscaping Specifications, for more details on appropriate ground covers.

2.3.5 Standards for Filter Strip Inspection and Maintenance

There should be semi-annual regular inspections of the filter strip; once before new growth emerges in the spring, and once in the fall. The filter strip should also be inspected after severe storm events. Excessive sediments at the lip of the level spreader should be cleaned up by hand with flat shovels every spring and after large storms.

The primary maintenance measure for filter strips involves regular mowing of the turf to maintain a dense stand. In the peak growing season, this occurs every week or so. A mulching mower should be used to ensure that nutrients are recycled, and that excessive clippings do not build up to smother the turf and inhibit infiltration. For warm season grasses, the previous season’s stalks should be cut down to no lower than 12 inches in the early spring (mid March), before new growth emerges.

The soil should be tested annually to ensure proper pH and fertility. If required, fertilizer should only be applied in the fall. Note that most runoff provides all the nutrients normally required, and excessive nutrients can promote aggressive weeds in warm season grass stands. Tilth in sods can also be improved by aerating, particularly if the soils are compacted. Annual dethatching can also improve turf health.

2.4 BIOFILTRATION SWALES

Like filter strips, biofiltration swales are a very useful distributed BMP that can be easily incorporated into the design of projects. As an integral feature of the landscape, they can be incorporated into site design with minimal loss of usable ground. Since they simultaneously filter, convey and often detain runoff, they are not only effective in reducing pollutant loads; they also can provide considerable savings over conventional conveyance and detention structures. Often, biofiltration swales and filter strips are the only BMPs needed to reduce pollutant loads to acceptable levels.

As with any BMP, it is essential that biofiltration swales be designed to handle their hydraulic and pollutant loads properly. This is particularly important where biofiltration swales are incorporated as a pretreatment measure for infiltrating BMPs. In this event, the biofiltration swale should be treated as an independent BMP when modeled with DURMM. In this manner, its effluent parameters can be calculated to ensure that they are acceptable for any subsequent infiltrating BMP.

2.4.1 Standards for Biofiltration Swale Hydraulic Parameters

Design standards for biofiltration swales follow the methods set forth in the Technical Manual, in which performance is a function of bioswale geometry in relation to its projected loading rate. Biofiltration swale vegetation, width, slope and length are factors explicitly addressed by the DURMM calculation routines. Based upon the swale design and its loading rates, DURMM calculates hydraulic parameters of residence time, flow velocity and flow depth that affects performance.

These parameters are then used by DURMM to calculate pollutant removal performance. Since loading rates and required removal percentages will vary from site to site, specific design values for these parameters cannot be applied to biofiltration swales. The following parameters should be used as guidelines for biofiltration swale design in the quality event:

PROPERTY	MINIMUM RECOMMENDED	MAXIMUM RECOMMENDED	NOTES
DRAINAGE AREA	No minimum	20 acres	Must be designed according to DURMM procedures to not exceed hydraulic criteria.
RESIDENCE TIME	9 Minutes	No maximum	Studies suggest residence time of 9 minutes for best results.
FLOW VELOCITY	No minimum	1 ft./sec. (0.5 ft/sec preferable)	Higher velocities bend grasses, resuspend sediments and reduce retention times.
FLOW DEPTH	No minimum	The lesser of 6 inches, or one half vegetation height	Can be up to 6" with thick stands of native grasses and sedges.

2.4.2 Standards for Biofiltration Swale Spatial Design Parameters

Biofiltration swale vegetative cover, width, slope and length parameters determine how well it will treat pollutant loads. Therefore, specific design “rules” are not applicable since DURMM provides projected results, which can then be compared to the desired objectives. The hydraulic implications of the spatial design are addressed in DURMM, since spatial design parameters interact to develop the hydraulic results. Increasing width and side slopes and decreasing slope will increase retention time, reduce flow velocities and decrease flow depths, thereby increasing pollutant removal performance.

Detail 2.4.1 shows typical bioswale design parameters. Note that bioswales over 8 feet wide should have a pilot channel deep enough to handle the quality event and more frequent smaller events. Larger storm events should be conveyed using a compound section to keep maximum depths as shallow as possible.

The minimum slope of a biofiltration swale shall be 2 percent, unless the underlying soils meet DNREC’s minimum infiltration rate (1.02”/hr), or an underdrain is provided. If wetland plants are specified, the minimum slope can be as low as 0.50%. However, provisions must be made to prevent the possibility of standing water in excess of 72 hours. If an underdrain is proposed, it should be installed per Detail 2.4.1, using a cross-section of 1.0 feet by 1.0 feet of stone surrounding the piping. In cases where the potential for standing water may exceed 72 hours, alternative practices should be considered. Contact DNREC for current policies and design standards for such practices.

Slopes steeper than 5 percent increase velocities and reduce residence times substantially. While a biofiltration swale can perform adequately with slopes over 5 percent if it is long enough, a grade drop check dam as shown in Detail 2.4.4 should be used to reduce the effective slope and increase performance.

The side slopes should not be steeper than 4:1 unless absolutely necessary to obtain the required volume. Side slopes of 4:1 to 6:1 offer good volume with much simpler maintenance. The effective minimum for side slopes is 10:1. Slopes shallower than this are more effective used as filter strips on their own.

The table below provides guidelines for designing biofiltration swale BMPs. Refer to Details 2.4.1 through 2.4.7 for biofiltration swale and check dam cross-sections and details. The optional infiltration trench design as shown in Detail 2.4.8 is discussed in Section 2.6.

PROPERTY	MINIMUM RECOMMENDED	MAXIMUM RECOMMENDED	NOTES
LENGTH	100 feet	1000 feet	Sized per DURMM for at least 9 minutes of residence time at no more than 1 fps.
WIDTH	2 feet	10 feet, (see note)	With check dams, no more than 16 feet. Install 4 foot pilot channel for wider swales. Size for at least 9 minutes of residence time.
SLOPE	2.0 percent (0.50 percent for wet swales)	5 percent for dry swales	Slopes less than 2% require underdrain unless HSG "A" soils or plants wet tolerant. Size for at least 9 minutes of residence time.
SIDE SLOPE	10:1	3:1	Slopes flatter than 4:1 much preferred since easier to maintain. Size for at least 9 minutes of residence time.

2.4.3 Standards for Biofiltration Swale Pretreatment Measures

Even though they are typically used as conveyance BMP's, biofiltration swales will accumulate sediment. As in the case of filter strips, most of the sediment is deposited at the entrance of the swale where concentrated flow transitions to shallow dispersed flow. Pretreatment is occasionally required, particularly where sediment loads can be extensive. Impervious area runoff should be filtered by overland swales or filter strips to reduce TSS concentration to roughly 30 ppm prior to discharge into a biofiltration swale. The better the pretreatment, the less maintenance is necessary.

Where such filtration is impossible, as at the outlet of pipes, outlet protection should be designed as a sump stilling basin lined with riprap or TRM Geotextile. Although the sump outlet protection design contributes to forebay volume, most of the forebay volume is provided by a stone check dam with weir openings adequate to ensure that no overtopping of the swale occurs.

The forebay should provide for a volume of 2 percent of the runoff volume from the 2-inch quality event. The forebay should create a sump no more than 2 feet deep, and should extend along the swale at a width equivalent to the bottom width for its required length, where the check dam is located. The pipe invert should match the swale invert elevation to ensure that it is not ponded between storm events. See Chapter 4 for details on forebay construction. The following table contains forebay design guidelines for the pretreatment of biofiltration swale BMPs:

PROPERTY	MINIMUM REQUIREMENT	MAXIMUM REQUIREMENT
PRETREATMENT VOLUME	2 percent of quality volume	No maximum
FOREBAY DEPTH	1 foot at quality volume	2 feet at quality volume

2.4.4 Standards for Biofiltration Swale Storage

As an added benefit, bioswales can be designed to operate as detention facilities when properly designed check dams are provided. If pilot channels are used for low flows, sufficient volume to handle 100 year peak reduction can be provided by a wider compound swale section with check dams to detain flows. DURMM estimates the volumes required by the swale design with check dams. These values can then be used in an external routing program to determine the actual flow attenuation provided. Construction specifications for check dams are set forth in Section 2.4.6.1, and details are set forth in Details 2.4.1 through 2.4.7.

The peak flow depth at the check dams should not exceed two feet in the flooding event. If greater depths are involved, such ponding at the deep end of the bioswale becomes hazardous enough that it would be considered a structural BMP. Given the shallow depths and wide widths typically involved in bioswales, a freeboard of 6 inches is required to ensure that overtopping does not occur. This freeboard allows for a safety factor of well over 2 in the extreme event. The following table provides guidelines for designing check dams in biofiltration swale BMPs:

PROPERTY	MINIMUM RECOMMENDED	MAXIMUM RECOMMENDED	NOTES
FLOODING DEPTH	No minimum	2.5 feet	Deeper depths become a hazard.
FREEBOARD	6 inches	No maximum	Design conservative in any event.

2.4.5 Standards for Biofiltration Swale Infiltration Rates

In the case of dry biofiltration swales that are designed to provide infiltration, the infiltration rate shall be determined by the method set forth in Section 1.2.6, along with its required pilot test pit. Where biofiltration swales are designed to provide infiltration, infiltration rates of infiltration facilities should conform to the following specifications:

PROPERTY	BMP TYPE	REQUIREMENT w/o UNDERDRAINS
Min. Field Infiltration Rate	Dry Bioswale	1.02 inches/hour

2.4.6 Biofiltration Swale Materials Specifications

The following specifications set forth the required characteristics for materials commonly used in constructing biofiltration swales. Unless otherwise approved by the delegated review agency in response to submittals prepared by personnel qualified as stated in the Regulations, these specifications shall apply to all materials used in Green Technology BMPs. Specific products mentioned in this Manual are used by way of example, and do not represent an explicit endorsement of the product by DNREC. The submitting designer can substitute different materials if it can be documented that equivalent functioning is provided to meet the performance goals of this Manual.

2.4.6.1 Check Dam Gabions

Check dam gabions are used in biofiltration swales designed to provide storage. They are filled with filter stone to provide retention. The filter stone is surrounded by NSA R-3 face stone to keep the filter stone from being washed through the gabion mesh openings. Typically the gabions used in the lower sections of check dams are 1.5 feet high, and keyed into the proposed grade. This lower section sets the elevation of the 2 year control weir (see Details 2.4.2 and 2.4.3). The upper section, which detains the larger events, is typically 1.0 feet high, and forms the sides of the weir, and/or surrounds or an orifice made from a PVC wye (see Details 2.4.6 and 2.4.7). Gabions are also used to form the dissipater for a grade drop structure (see Details 2.4.4 and 2.4.5).

Gabions shall be made of PVC coated zinc galvanized steel per the following specifications:

<table>
<tr><th>PROPERTY</th><th>STANDARD</th><th>MATERIAL SPECIFICATION</th></tr>
<tr><td>MESH SIZE</td><td>8 x 10 (3.5 in.) per ASTM A975-97</td><td rowspan="2">1. Tensile strength: 75,000 psi per ASTM A641-98,
2. Elongation: shall not be less than 12%, per ASTM A370-97.
3. Zinc coating: meet the requirements of ASTM A641-98
4. Adhesion of zinc: in accordance with ASTM A641-98.</td></tr>
<tr><td>WIRE SIZE</td><td>0.106 in. internal
0.146 in. external</td></tr>
<tr><td>WIRE COATING</td><td>PVC</td><td>1. Specific gravity: 81-84 pcf per ASTM D792
2. Hardness: between 50 and 60 Shore D, per ASTM D 2240;
3. Tensile strength: not less than 2,985 psi per ASTM D412-92;
4. Modulus of elasticity: not less than 2,700 psi perASTM D412-92;
5. Abrasion resistance: weight loss shall be less than 12%, per ASTM D1242-92.</td></tr>
</table>

2.4.6.2 Check Dam Stone

Check dam stone is used in biofiltration swales designed to provide storage. It can also be used to control peak flows from bioretention facilities. NSA R-3 stone can be used for face stone if the smaller fractions are manually removed from the mesh openings, otherwise NSA R-4 shall be used for the face stone. Check dam stone shall conform to the following specifications:

<table>
<tr><th>SIZE USED</th><th>MEDIAN DIAMETER</th><th>MINIMUM DIAMETER</th><th>MAXIMUM DIAMETER</th><th>CLASSIFICATION</th><td rowspan="5">Stone shall be clean double-washed bank run gravel or crushed aggregate free of rock dust, fines or soil particles.</td></tr>
<tr><td>SMALL</td><td>0.50- 0.75 in.</td><td>0.25 in.</td><td>1.50 in.</td><td>DE #57</td></tr>
<tr><td>MEDIUM</td><td>1.50-1.75 in.</td><td>0.50 in.</td><td>2.50 in.</td><td>DE # 3</td></tr>
<tr><td>LARGE</td><td>3.50 in.</td><td>2.00 in.</td><td>5.50 in.</td><td>NSA R-3</td></tr>
<tr><td>FACE</td><td>6.0 in.</td><td>3.0 in.</td><td>9.0 in.</td><td>NSA R-4</td></tr>
</table>

2.4.6.3 Underdrain Piping

Underdrain piping is occasionally used in the bottom of biofiltration swales. Underdrain piping shall conform to the following specifications:

<table>
<tr><td>STANDARD</td><td>MEETS ASTM F810 or F405</td><td rowspan="4">Unless surrounded by stone, the pipe shall be surrounded by a drainage filter geotextile “sock”. If no sock provided, it shall be surrounded by at least 3” of trench stone. 3” pipes acceptable for individual underdrains less than 100 feet long. 4” pipe shall be used where over 100 feet long. 6” pipe shall be used for manifolds.
Individual pipes shall be constructed at same slope as swale. The upstream ends of underdrain collector pipes shall be capped with a cleanout.</td></tr>
<tr><td>SIZE</td><td>3” to 6” SDR 35 PVC or Corrugated Polyethylene</td></tr>
<tr><td>PERFORATION</td><td>3 rows of 5/8” perf. @ 6” on center,</td></tr>
<tr><td>COVER</td><td>minimum of 3” of gravel over pipes</td></tr>
</table>

2.4.6.4 Underdrain Gravel

Underdrain gravel is occasionally used in the bottom of biofiltration swales. It shall be double-washed and free of dust, fines and soil particles. Underdrain gravel shall conform to the following specifications:

<table>
<tr><td>SIEVE OPENING</td><td>0.25 in. to 1.50 in.</td><td rowspan="2">Stone shall be clean double-washed crushed aggregate, free of rock dust, fines or soil particles.</td></tr>
<tr><td>SIZE</td><td>DE #57</td></tr>
</table>

2.4.6.5 Drainage Filter Geotextile

Drainage filter geotextile is used for lining underdrains and under check dams to keep the surrounding soil from entering the stone, while letting water exfiltrate into the soils. Refer to the Delaware Erosion and Sediment Control Handbook for more information on filter fabric. The most important element in specifying drainage fabric is the permeability, which should be at least 110 gal/min/sq.ft.. Woven geotextiles should be used in preference to nonwoven geotextiles, as they are less subject to formation of biofilms that could clog the pores.

A drainage filter fabric shall meet the following Minimum Average Roll Value (MARV) specifications across the weave. Alternative fabrics must be supported by design calculations showing its suitability for the design use:

PROPERTY	TEST METHOD	REQUIREMENT	PROPERTY	TEST METHOD	REQUIREMENT
Grab Tensile Strength	ASTM D-4632	200 lb.	Apparent opening	ASTM-D-4751	#70 sieve
Grab Elongation	ASTM D-4632	15 percent	Percent Open Area	COE-022150-86	4 percent
Mullen Burst Strength	ASTM D-3786	420 psi.	Permittivity	ASTM-D-4491	0.28/sec.
Puncture Strength	ASTM D-4833	50 lb	Flow rate	ASTM D-4491	0.010 cm/sec
UV Resistance	ASTM D-4335	70 per cent at 500 hrs	Permeability	ASTM D-4491	110 gal/min/ft.^{2}

2.4.6.6 Channel Protection Geotextiles

Channel protection geotextiles are required to line bioswales to ensure that they can convey extreme events without degradation. Depending upon the peak flow rate and shear stresses, either temporary rolled erosion control products (RECPs) or permanent turf reinforcement matting (TRMs) are required. The forebays will need to be lined with riprap or a heavy TRM. Refer to the Delaware Erosion and Sediment Control Handbook for specifications for the geotextile to be used in the particular situation for each swale segment.

2.4.6.7 Biofiltration Swale Topsoil Specifications

As is the case for all Green Technology BMPs, the soil profile under biofiltration swales should be as well aerated and uncompacted as possible. However, soils under many bioswales are likely to be completely disturbed and heavily compacted. Such excessive compaction must be alleviated by using a chisel plow, ripper, or subsoiler, as discussed in the Section 1.2.3. Adequate topsoil must also be returned to provide enough organic matter and mycorhizzae necessary for plants to flourish. A minimum of 6 inches of topsoil shall be specified in the plans for bioswales. The topsoil should be disked in to blend it with the subsoil to reduce an abrupt change in soil types and promote infiltration.

If possible, bioswale topsoil should be limed to a neutral Ph, fertilized as set forth below, and meet the following gradation recommendations:

PROPERTY	RECOMMENDATION	PROPERTY	RECOMMENDATION
pH	6.0-7.0	Organic Matter	1.0-4.0%
Mg	35 lb./ac.	Sand	40-80%
Po	75 lb./ac.	Silt	20-40%
K	85 lb./ac.	Clay	5-15%
Salts	<500 ppm	Porosity	25-50%

2.4.6.8 Standards for Biofiltration Swale Vegetation

The extensive length of bioswales permits considerable flexibility in vegetation selection. Although a dense stand of cool season turf-type grasses may have the highest blade density, such grasses have a short rooting depth, which inhibits development of the infiltration potential of the swale.

On the other hand, native grasses and forbs have root systems that penetrate deeply into the soil profile, promoting soil tilth and the development of macropores that increase infiltration rates, particularly in compacted soils. There are also several native grasses that form a dense stand. Taller native plants can handle deeper flow depths, and have a greater retardance value, providing better performance for a given bioswale geometry. Native grasses and forbs also require minimal maintenance compared to turf, and are much more effective in conserving ecology and energy.

For these reasons, native herbaceous plant materials are the preferred choice for bioswales. The choice of vegetation is ultimately a matter of preference though, provided that the BMP performance characteristics are met by the design. While turf may be less desirable for the reasons cited above, it may be appropriate in formal landscaped settings.

Woody vegetation should not be specified for the bottom of bioswales, since woody plants provide minimal filtering, and will eventually shade out the herbaceous plants. For this reason, taller shrubs and trees should be specified only on the northerly side slopes of bioswales. Only small shrubs less than 5 feet high at maturity can be placed on the southerly side slopes.

Regardless of the type of plant material, it is still necessary that the material be suited for the conditions. Saturation tolerance, flooding tolerance, drought tolerance and shade tolerance differ substantially among plant species, and the appropriate species must be selected for each planting zone in the bioswales. See Chapter 3, Landscaping Specifications, for more details on the particular characteristics of plant material for bioswales.

In bioswales sloped over 2 percent without check dams, there is no standing water, so saturation tolerance and flooding tolerance are less important. On the other hand, drought tolerance becomes more important during dry periods, because less runoff is infiltrated in the bioswale. Where slopes are milder or check dams are provided, greater tolerance of saturation and flooding is required in plants located within the area saturated by the quality event. Some flooding tolerance is also required along the balance of the swale. Plants that are occasionally flood tolerant and generally drought tolerant should be selected for the side slopes.

2.4.6.9 Standards for Biofiltration Swale Inspection and Maintenance

There should be semi-annual regular inspections of the facility: once before new growth emerges in the spring, and once at seed dispersal. The bioswale should also be inspected after severe storm events. Where sediment forebays are provided, remove sediments accumulated in the forebay once they are half filled. If forebays are not provided, remove visible accumulations of sediment with a flat shovel. Stabilize eroded areas with RECP or TRM and replant as required.

If a turf cover is used, the bioswales should be mowed regularly to maintain a dense stand. Mow no lower than 6 inches, or twice the quality storm event flow depth. A mulching mower should be used to ensure that nutrients are recycled, and that excessive clippings do not build up.

If native plants are used, cut down standing stalks to 12 inches in spring, just before new growth emerges. To eliminate competition from invasive plants and undesirable woody vegetation, selectively hand-apply an appropriate herbicide with a cut stump applicator or directed foliar sprays. See Chapter 3, Landscaping Specifications, for more details on herbicides. Reseed and/or replant as required based upon inspection findings.

The soil should be tested annually to ensure proper pH and fertility. If required, fertilizer should only be applied in the fall. Note that most runoff provides all the nutrients normally required, and excessive nutrients can promote aggressive weeds in warm season grass stands. Tilth in sods can also be improved by aerating, particularly if the soils are compacted. Annual dethatching can also improve turf health.

Check dams should be inspected annually in the spring for debris and silt accumulation, and vegetative growth. Materials that accumulate on the outside of the check dam shall be removed. All vegetation that extends roots within the check dams shall be manually removed, and herbicides may be necessary to eliminate herbaceous species with persistent roots. All silt deposits that build up outside the check dam shall be removed, and the area regraded and seeded.

If fines have accumulated within the filter stone, power-washing or pressure jet equipment shall be used to remove the fines. The nozzle of such equipment shall be inserted between the rear face stones of the check dam to force the accumulated fines back out the front of the check dam. If the accumulation is extensive, it may be necessary to open up the gabion top, remove the face stone and enough of the filter stone to permit access by pressure washing equipment.

2.5 BIORETENTION FACILITIES

Bioretention facilities are the most effective distributed BMP for sites with high pollutant concentrations. As with bioswales and filter strips, they can be easily incorporated into the design of projects with minimal loss of usable ground. Since they simultaneously filter and infiltrate runoff, they are not only very effective in reducing pollutant loads; they can also provide considerable recharge. Although they require less space than bioswales, they are more expensive to construct for the same volume of treatment. Therefore, bioretention facilities should be specified where pollutant loads are relatively high and space is not available for bioswales. Bioretention facilities are particularly effective for high density commercial areas dominated by pavement.

2.5.1 Standards for Bioretention Facility Hydraulic Parameters

As with all BMPs, bioretention facilities must be designed to handle their hydraulic and pollutant loads properly. Like other filtering BMPs, the design standard for bioretention facility sizing is a function of bioretention facility geometry in relation to its projected loading rate. The design infiltration rate shall be at least 0.5 inches per hour (i.e., a field measured rate of 1.02 inches per hour), unless underdrains are provided. Bioretention facility width and length determine the bioretention area. Runoff volume is divided by the design infiltration rate over a period of 36 hours to arrive at the area required. This period represents a 24 hour interval after rainfall ends, to which is added the 12 hour period after the onset of runoff during the storm event.

Loading depth relates the total volume of runoff, the surface area of the bioretention facility and a design removal rate, in lieu of a formal hydrograph routing process. At a minimum design infiltration rate of 0.5 inch/hour, a 48 hour period results in a maximum loading depth of 18 inches for one inch of runoff in a properly designed bioretention facility. Even though a loading depth of 18 inches is much higher than the ponding depth of 6 inches usually recommended, a hydraulic loading ratio of 18:1 results in the bioretention area being 5.6% percent of the impervious area. This value closely corresponds to the 5 to 7 percent bioretention area percentage recommended in the literature. When an underdrain is provided, a higher loading depth can be used. Current estimates indicate that the biosoil media has a permeability of approximately 2.83 in/hr. This would allow a hydraulic depth of 2.75' (33 in.) for design purposes. If quantity management must be more accurately determined, a routing procedure can be performed on bioretention facilities. Routing procedures shall be consistent with current DNREC policies.

Unlike other filtering BMPs, pollutant removal efficiency is not dependent upon design parameters. Since the required media depth provides as much removal as is possible, there are no design-dependent adjustments to performance. However, loading concentrations vary from site to site, so overall performance will vary accordingly per DURMM routines. The following parameters should not be exceeded by a bioretention facility designed for the quality event:

PROPERTY	MINIMUM RECOMMENDED	MAXIMUM RECOMMENDED	NOTES
DRAINAGE AREA	No minimum, but one half acre suggested	10 acres	To be designed according to hydraulic criteria. Large facilities are not recommended.
DRAWDOWN TIME	No minimum, but 24 hours suggested	48 hour drawdown after hydrograph peak	Facility must have no surface water ponding 24 hours after end of 24 hour design storm of 2.0".
HYDRAULIC LOADING DEPTH	No minimum, but 12" suggested	18" w/infiltration; 33" w/underdrain.	Value based on min. design infiltration rate by regulation or max. permeability rate of biosoil media.
INFILTRATION RATE (FIELD)	1.02 inches/hour*	No maximum	*No minimum requirement if underdrains are provided

2.5.2 Standards for Bioretention Facility Spatial Design Parameters

As indicated above, for a given infiltration rate, the bioretention facility's area is the only parameter that determines how well it can handle hydraulic loads. Where phosphorus loading is a problem, the specific design standard requires a minimum 3.0 foot depth of bioretention media, since phosphorus removal performance begins to diminish at depths below this value. If phosphorus loading is not an issue, the minimum depth can be reduced to 2.0 feet if there are site limitations that warrant the granting of a variance. Research suggests that a three foot deep media has a useful life of 50 years, or longer if mulch is maintained properly. As a practical matter, the maximum depth should thus not exceed 4 feet.

Bioretention facilities should be "footprinted" into the available landscape, so maximum flexibility is encouraged in design, and specific standards for length and width are not mandated. However, practical considerations limit the range of standards. Side slopes should not be steeper than 4:1 unless necessary to obtain the required bioretention area. Side slopes of 4:1 to 6:1 offer adequate volume with much simpler maintenance. The effective minimum for side slopes is 10:1. Slopes shallower than this are more effective used as filter strips on their own. The following plan values should not be exceeded in designing bioretention facility BMPs:

PROPERTY	MINIMUM REQUIREMENT	MAXIMUM REQUIREMENT	NOTES
MEDIA DEPTH	3 feet (2.0 feet by variance)	4.0 feet	Good phosphorus removal by 3.0 feet. Deeper depths provide minimal additional benefit.
LENGTH	~20 feet	~100 feet	No absolute standard, values are recommendations
WIDTH	~4 feet	20 feet, or one half length, unless at grade	Maximum determined by reach of excavator, unless built at grade.
SIDE SLOPE	10:1	3:1	Slopes over 4:1 much preferred since easier to maintain.
DEPTH TO SHWT	3.0 feet	No maximum	No minimum required if underdrain provided, but bottom of facility must be above SHWT.

2.5.3 Standards for Bioretention Facility Pretreatment Measures

As a highly effective Green Technology BMP, bioretention facilities will accumulate sediment where TSS levels are elevated in the entering runoff. As in the case of bioswales, if concentrated flow is present at the entrance of the facility, most of the sediment will be deposited there as it transitions to shallow dispersed flow through the facility and ponding builds up. Therefore, pretreatment is required, particularly where entering sediment loads will be high. Impervious area runoff should be filtered by overland swales or filter strips to reduce TSS concentration to roughly 20 ppm prior to discharge into a bioretention facility. The better the pretreatment, the less maintenance will be necessary.

For this reason, most bioretention details call for a filter strips and level spreaders to filter runoff from impervious source areas. This approach is endorsed in this Manual. If loads are expected to be high, DURMM should be run on the filter strip as a separate BMP to ensure that its performance will meet this objective.

However, there are many other possible locations for bioretention facilities, such as the outlets of overland swales, enclosed pipes or at curb cuts. In the case of the former, DURMM should be run for the swale geometry and loading to see if it can reduce TSS to the required level. If such filtration is inadequate, or where pipes or curb cuts are involved, outlet protection and a forebay must be provided. The outlet protection should be designed as a sumped stilling basin lined with landscape stone or TRM Geotextile. The sump outlet protection should be designed to provide the required forebay volume.

The forebay should provide for a volume of 5 percent of the runoff volume from the 2 inch quality event. This volume can be reduced by the extent of swale pretreatment, if present. The forebay should be no deeper than 2 feet at design flows See Detail 2.5.5 for details on forebay construction. The following values should not be exceeded in designing bioretention facility BMPs:

PROPERTY	MINIMUM REQUIREMENT	MAXIMUM RECOMMENDATION
PRETREATMENT VOLUME	5 percent of quality volume	No maximum
FOREBAY DEPTH	No minimum	2 feet at quality volume

2.5.4 Standards for Bioretention Facility Storage

While bioretention facilities can be designed to operate as detention facilities, they typically have insufficient volume to handle 100 year peak reduction. However, they can be very effective in reducing the increase in runoff of the 2 year event. Bioretention volumes can be treated in DURMM as if they were infiltrated or routed to the outlet as surface flow.

In any event, the peak flooding depth in the forebay should not exceed 2.0 feet in the flooding event. If greater depths are involved, ponding at the deep end of the bioretention facility becomes hazardous enough that the bioretention facility would to be considered a structural BMP. Given the shallow depths and wide widths typically involved in bioretention facilities, a freeboard of 6 inches is required to ensure that overtopping does not occur. The following table provides recommendations for designing forebays used for pretreatment of bioretention BMPs:

PROPERTY	MINIMUM RECOMMENDED	MAXIMUM RECOMMENDED	NOTES
FLOODING DEPTH	No minimum	2.0 feet	Deeper depths become a hazard.
FREEBOARD	6 inches	No maximum	Design conservative in any event.

2.5.5 Standards for Bioretention Facility Infiltration Rates

In the case of bioretention facilities that rely on the underlying soils for drainage, the infiltration rate shall be determined by the method set forth in Section 1.2.6, along with its required pilot test pit. Infiltration rates of bioretention facilities should conform to the following specifications:

PROPERTY	REQUIREMENT w/o UNDERDRAINS	REQUIREMENT w/ UNDERDRAINS
Min. Field Infiltration Rate	1.02 inches/hour	No minimum

2.5.6 Standards for Bioretention Facility Location

If the textural class of the existing soil is appropriate per the specifications set forth in Section 2.5.7.9 below, a well developed soil profile undisturbed by construction activity may provide adquate results. This requires that the designer carefully grade the site to direct runoff from adjacent graded areas into the facility. However if this is the case, sediments will also be directed to the facility, which will require that the sediments and underlying topsoil be removed to restore infiltration capabilities.

Even though they are not intended as a conveyance structure, many bioretention facilities end up being located on-line. Although many literature sources recommend off-line designs, very few designs actually end up that way. Most facilities directly absorb runoff from all events, with overflow entering a catch basin located inside the facility. The only “off-line” aspect is the fact that ponding directs the majority of peak flows directly to the outlet through the facility. While these larger flows may be controlled by the catch basin geometry, they can exert considerable stress on the facility as they pass through it.

Therefore, the outlet protection measures described in Section 2.5.3 are mandatory. In addition, the flow path from inlet to outlet under peak flow conditions should be investigated to ensure that peak flows do not detach the mulch or erode the underlying media. In either event, the flow path geometry should be redesigned to disperse flows as much as possible. Only as a last resort should landscape stone be used to stabilize flow paths in undersized facilities, since stone is ineffective in removing pollutants compared to mulch.

2.5.7 Specifications for Bioretention Facility Materials

The following specifications set forth the required characteristics for materials used in bioretention facilities. Unless otherwise approved by the delegated review agency in response to submittals prepared by personnel qualified as stated in the Regulations, the specifications shall apply to all materials used in Green Technology BMPs. Specific products mentioned in this Manual are used by way of example, and do not represent an explicit endorsement of the product by DNREC. The submitting designer can substitute different materials if it can be documented that equivalent functioning is provided to meet the performance goals of this Manual.

2.5.7.1 Sand

Sand is the fundamental component of the bioretention media that ensures its permeability. Sand shall conform to the following specifications:

<table>
<tr><td>SIEVE OPENING</td><td>0.02 in. to 0.25 in.</td><td rowspan="2">Sand shall be silica based. Calcium carbonated or dolomitic sand substitutes are not acceptable. Sand substitutes such as Diabase and Graystone #10 are not acceptable.</td></tr>
<tr><td>SIZE</td><td>Clean ASTM C-33 concrete sand; fineness modulus of 2.75 or greater</td></tr>
</table>

2.5.7.2 Sphagnum Peat Moss

Sphagnum peat moss is used as part of the organic component in formulating the soil media for bioretention facilities to improve tilth, permeability, and cation exchange capacity (CEC). However, peat moss has a low pH, so it should not be used in such high proportions that the media exceeds the pH specification in Section 2.5.7.9. If necessary, a buffering agent such as powdered limestone can be provided. Since peat moss decomposes rapidly, it releases nutrients, and needs to be replaced often. Therefore, peat shall not be used to provide the entire organic component of bioretention media discussed in Section 2.5.7.9.

2.5.7.3 Mulch

Mulch is used as the other organic component of the soil media. It can also be used on the surface of bioretention facilities. Only triple-shredded aged hardwood mulch shall be used in the soil media mix. If desired, a top dressing of 2”-3” of straight hardwood mulch can be applied for aesthetic purposes. However, it has been observed that the larger pieces can be prone to flotation and displacement during storm events.

2.5.7.4 Underdrain Gravel

Underdrain gravel is used in the bottom of many bioretention facilities. When an underdrain is provided, the gravel layer shall extend across the entire length and width of the facility. Underdrain gravel shall conform to the following specifications:

<table>
<tr><td>SIEVE OPENING</td><td>0.25 in. to 1.50 in.</td><td rowspan="2">Stone shall be clean double-washed crushed aggregate, free of rock dust, fines or soil particles.</td></tr>
<tr><td>SIZE</td><td>DE #57</td></tr>
</table>

2.5.7.5 Underdrain Piping

Underdrain piping is used in the bottom of many bioretention facilities. Underdrain piping shall conform to the following specifications:

<table>
<tr><td>STANDARD</td><td>MEETS ASTM F810 or F405</td><td rowspan="4">The pipe shall be bedded and covered with min 1” gravel layer. 4” pipe may be used for laterals; 6” pipe shall be used for mains and manifolds.

Individual pipes may be constructed at 0% slope within the facility, but should have a minimum slope of 0.5% once exiting the facility. The terminal ends of underdrain collector pipes shall be capped with a cleanout which can also act as the observation port.</td></tr>
<tr><td>SIZE</td><td>4” to 6” Sch. 40 PVC or SDR 35</td></tr>
<tr><td>PERFORATION</td><td>3 rows of 5/8” perf. @ 6” on center,</td></tr>
<tr><td>BED & COVER</td><td>minimum of 1” of gravel both over and under pipes</td></tr>
</table>

2.5.7.6 Drainage Fabric Geotextile

When an underdrain is provided, a drainage-type geotextile fabric is used as a separation layer to prevent the soil media mix from migrating into the underlying gravel layer. Refer to the Delaware Erosion and Sediment Control Handbook for more information on geotextiles. The most important element in specifying drainage fabric is the permeability, which should be at least 110 gal/min/sq.ft.;. Woven geotextiles should be used in preference to nonwoven geotextiles, as they are less subject to formation of biofilms that could clog the pores.

A drainage filter fabric shall meet the following Minimum Average Roll Value (MARV) specifications across the weave. Alternative fabrics must be supported by design calculations showing its suitability for the design use:

PROPERTY	TEST METHOD	REQUIREMENT	PROPERTY	TEST METHOD	REQUIREMENT
Grab Tensile Strength	ASTM D-4632	80 lb. min.	Puncture Strength	ASTM D-4833	45 lb. min.
Grab Tensile Elongation	ASTM D-4632	50% max.	UV Resistance	ASTM D-4335	70% at 500 hrs min.
Trapezoidal Tear Strength	ASTM D-4533	35 lb. min.	Apparent opening	ASTM-D-4751	40-80 US Sieve
Mullen Burst Strength	ASTM D-3786	160 psi. min.	Permeability	ASTM D-4491	110 gal/min/ft.^{2} min.

2.5.7.7 Channel Protection

Channel protection is often required at the entrance into bioretention facilities to ensure that they can convey extreme events without degradation. Depending upon the peak flow rate and shear stresses, either permanent turf reinforcement matting (TRMs) or riprap may be required in the forebay. Refer to the Delaware Erosion and Sedimentation Control Handbook for specifications for the geotextile or riprap to be used in the particular situation for each bioretention facility.

2.5.7.8 Bioretention Media

The proper composition of the bioretention media is the key component in determining bioretention performance. The media must have adequate infiltration capability to percolate the design flows within a period of 48 hours. Many designs have failed due to the presence of fines in the mixed media. Under its high hydraulic load, the media can compact tightly so that there are relatively few voids, and permeability decreases to low levels. Therefore, the mixed media must contain an adequate percentage of sand.

However, if a mixed media is necessary, the media must be able to adsorb the pollutants in runoff without becoming saturated over the design life of the facility. Therefore, the media should not be overly dominated by sands that have a low CEC of only around 2 cmol/kg. With very few CEC binding sites and much less retention time, pure sands result in substandard removal performance once its CEC sites are saturated.

On the other hand, organic matter has a CEC in the range of 200 cmol/kg or more. Its high CEC is the reason for including organic matter in the soil media mix. However, the pH of the media should be tested, and adjusted with limestone if it is determined to be too acidic. It is also necessary to avoid too high a percentage of organic matter, since it is associated with poorly draining soils. Research also appears to indicate that other soil amendments such as Zeolites or gypsum that can be added to increase CEC.

The bioretention planting media shall be a uniform mix consisting of equal parts, by volume, of sand, sphagnum peat moss, and mulch, as specified in previous sections. It shall be free of stones, stumps, roots or other similar objects larger than one inch. No other materials or substances shall be mixed or dumped within the bioretention media that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations. The planting media shall be free of noxious weeds.

Until a material standard and specification is developed by DNREC, the soil media for all bioretention facilities shall only be provided by an approved supplier, based on criteria established by DNREC. A textural analysis and/or permeability test of the mixed media may be required to verify that the mix meets the standard and specification. All testing results shall come from the same testing facility.

The soil media shall be mechanically mixed until a homogenous mixture is obtained. The media shall be placed in lifts of approximately one foot, and spread out by means of an excavator to minimize compaction. Placement of the media should only occur when it is optimally moist (not wet or dry), and only when there is no precipitation present. There shall be no abrupt changes in textural class between layers, as this will inhibit infiltration. The media should be left to settle for at least one storm event before the final lift so that it can be adjusted in the field to correspond to the plan elevations. A topdressing of mulch may then be placed in a 3 inch thickness and plantings installed. If blowing of material is a concern, a biodegradable netting can be spread over the surface until the facility has gone through several wetting cycles.

2.5.7.9 Standards for Bioretention Facility Vegetation

While bioretention media absorption and filtering are the predominant mechanisms of pollutant removal in bioretention facilities, vegetation will augment pollutant uptake and promote infiltration. However, the variation of ponding depth within a facility requires careful consideration in selecting vegetation. Note that turf grasses are not acceptable, since such grasses typically have short rooting depths and are incompatible with mulch.

Because of this, clump-forming herbaceous plants and woody plants with root systems that penetrate deeply into the soil profile and develop macropores are recommended. Native grasses forbs, shrubs, and trees also require relatively minimal maintenance, and are more effective than non-natives in conserving ecology. For these reasons, native plant materials are the preferred choice for bioretention facilities. Non-native plants with similar characteristics are also acceptable, provided that they are specified by qualified landscape designers familiar with the properties required. In this event, the properties shall be documented as part of the design.

The choice of vegetation is ultimately a matter of preference, provided that the BMP performance objectives are met by the design. If herbaceous plants are desired as the permanent community, taller shrubs and trees should not be specified for the southerly side or bottom of bioretention facilities, since they will eventually shade out the herbaceous plants.

Regardless of the type of plant material, each plant must be suited for the conditions in which it is placed. Saturation, flooding, drought, and shade tolerances differ substantially among plant species, and the appropriate species must be selected for each planting zone in the bioretention facilities. Refer to Chapter 3, Landscaping Specifications, for more details on the particular planting zone characteristics of plant material for bioretention facilities.

At the floor of the facility, greater tolerance of saturation and flooding is required for the plants. Selection for shade tolerance should take into account the initial and final conditions desired. On side slopes of bioretention facilities, there is no standing water, so saturation tolerance is not required, and flooding tolerance is less important. However, drought tolerance becomes more important during dry periods, because less runoff is infiltrated in the bioretention facility.

Plantings within the bioretention facility should not be so dense so as to inhibit surface permeability. Spacing of individual plantings within the planting areas should be based on recommendations for the individual species selected. A good rule of thumb is to ensure that the plants themselves occupy no more than about 50% of the total surface area at maturity. Trees should be planted around the perimeter of the facility in the native soils due to the light nature of the bioretention soil media mix.

2.5.8 Standards for Bioretention Facility Inspection and Maintenance

There should be semi-annual regular inspections of the facility; once before new growth emerges in the spring, and once at seed dispersal in the fall. The bioretention facility should also be inspected after severe storm events. Where sediment forebays are provided, remove sediments accumulated in the forebay once it is half filled. Remove all visible accumulations of sediment on top of the mulch layer with a flat shovel. Stabilize eroded areas with appropriate geotextile and replant as required

Just before new growth emerges in spring, cut down standing stalks of herbaceous material to 12 inches. To eliminate competition from invasive plants and undesirable woody vegetation, selectively apply appropriate herbicide with a cut stump applicator or directed foliar sprays. See Chapter 3, Landscaping Specifications, for more details on herbicides. Reseed and/or replant as required based upon inspection findings. For woody material, inspect for pests and ice damage. Trees and shrubs should be pruned as needed every fall. The soil should be tested annually to ensure proper pH, and fertilizer should only be applied in the fall. Add mulch every spring for systems with a mulch topdressing.

2.6 INFILTRATION TRENCHES

Given their ability to reduce surface runoff, infiltration trenches are a very effective Green Technology BMP. However, infiltration trenches can provide minimal benefits in terms of reducing concentrations of pollutants such as nitrate, since they are located below the root zone and surface soil profile, where most filtering occurs in other Green Technology BMPs. In fact, infiltration trenches can introduce dissolved pollutants such as nitrates and dissolved metals into groundwater. Furthermore, excess sediments easily clog infiltration trenches. For these reasons, infiltration trenches are only applicable in situations where extensive pretreatment is provided.

Infiltration trenches can be easily incorporated below bioswales and filter strips, which can provide the required pretreatment with minimal loss of usable ground. Since they provide recharge at considerable cost compared to overland systems, they are best specified where recharge is deemed an important objective and space is limited. Therefore, infiltration trenches should be specified where pollutant loads are relatively low and space is not available for other infiltration BMPs such as bioswales.

2.6.1 Standards for Infiltration Trench Hydraulic Parameters

As with all BMPs, infiltration trenches must be designed to handle their hydraulic and pollutant loads properly. Like bioretention BMPs, the design standard for infiltration trench sizing is a function of infiltration trench geometry and infiltration rate in relation to the projected loading rate. Infiltration trench length, width and depth determine the infiltration surface area.

The Technical Manual notes that the relation between infiltration trench width and depth to SHWT affect design infiltration rate due to groundwater mounding. Trenches that are long and narrow will have higher rates than those that are wider, given the same depth to SHWT. Runoff volume is divided by the design infiltration rate multiplied by a period of 36 hours to arrive at the area required. Like bioretention facilities, infiltration trenches are sized for a maximum of 1.0 inches of runoff.

Given infiltration trench geometry and infiltration rate, DURMM calculates the wetted area involved. To calculate overall infiltration volume, DURMM multiplies the wetted area of the bottom and the sides, times the design infiltration rate.

The following table contains recommendations for infiltration trenches designed for up to 1.0 inch of runoff from the quality event:

PROPERTY	MINIMUM RECOMMENDED	MAXIMUM RECOMMENDED	NOTES
DRAINAGE AREA	No minimum	2 acres	To be designed according to hydraulic criteria. Large facilities are not recommended.
HYDRAULIC LOADING RATE	No minimum	48 hour drawdown after max. design storm	Facility must be completely drained 24 hours after end of 24 hour design storm of 1.0” runoff.
HYDRAULIC LOADING DEPTH	No minimum	18 Inches for 1.0” runoff	Value based on min. design infiltration rate of 0.50 inches per hour for 36 hours.
INFILTRATION RATE (FIELD)	1.02 inches/hour	no maximum	

2.6.2 Standards for Infiltration Trench Spatial Design Parameters

Since infiltration trenches should be as narrow as possible to reduce mounding effects, maximum flexibility is encouraged in design, and specific standards for length and width are not mandated. However, practical considerations limit the range of standards. The maximum length should be 150 feet, the width should be less than 6 feet, and depth should not exceed 6 feet. The slope should be flat, except for trenches located in bioswales with a longitudinal slope. In that event, the trench should be interrupted when its fall is no greater than 1 foot. In this way, its storage volume is not lost at the upper end, and water will not bypass all the way to the end. See Detail 2.4.8 for details on trenches located in bioswales.

The following recommended values should be used in designing infiltration trench BMPs:

PROPERTY	MINIMUM RECOMMENDED	MAXIMUM RECOMMENDED
DEPTH	~2 feet	~6 feet
LENGTH	~20 feet	~150 feet
WIDTH	~2 feet	~6 feet

2.6.3 Standards for Infiltration Trench Pretreatment Measures

As discussed above, extensive pretreatment is required, particularly where entering sediment loads or dissolved pollutant loads will be high. Impervious area runoff should be filtered by overland swales or filter strips to reduce TSS concentration to roughly 10 ppm prior to discharge into the facility. For this reason, most infiltration trench details call for bioswales or filter strips with level spreaders to filter runoff from impervious source areas. This approach is endorsed in this Manual. DURMM should be run on the bioswale or filter strip as a separate BMP to ensure that its performance will meet this objective. Settling forebays are inadequate by themselves, and therefore, unacceptable.

The following pretreatment values should not be exceeded in designing infiltration trench BMPs:

PROPERTY	MAXIMUM RECOMMENDATION
TSS CONCENTRATION	10 ppm
NO_3 CONCENTRATION	5 ppm
ZN^- CONCENTRATION	20 ppb

2.6.4 Standards for Infiltration Trench Infiltration Rates

In the case of infiltration trenches, the infiltration rate shall be determined by the method set forth in Section 1.2.6, along with its required pilot test pit. Infiltration rates of infiltration facilities should conform to the following specifications.

PROPERTY	REQUIREMENT
Min. Field Infiltration Rate	1.02 inches/hour

2.6.5 Standards for Infiltration Trench Location

Infiltration trenches should be located where adequate pretreatment can be provided, while still being fairly high in the landscape where the soil conditions are better suited for infiltration. Often, they can be located under biofiltration swales or below filter strips. In either case, the choice of whether a topsoil cover is provided depends upon the quality of the incoming runoff. It is recommended that topsoil cover be provided for at least the first 100 feet of a bioswale before exposing stone at the surface.

2.6.6 Infiltration Trench Materials Specifications

The following specifications set forth the required characteristics for materials commonly used in constructing infiltration trenches. Unless otherwise approved by the delegated review agency in response to submittals prepared by personnel qualified as stated in the Regulations, the specifications shall apply to all materials used in infiltration trenches. Specific products mentioned in this Manual are used by way of example, and do not represent an explicit endorsement of the product by DNREC. The submitting designer can substitute different materials if it can be documented that equivalent functioning is provided to meet the performance goals of this Manual.

2.6.6.1 Infiltration Trench Stone

Infiltration trench stone is used as the storage media for infiltration trenches. It shall be washed free of dust, fines and soil particles. Infiltration trench stone shall conform to the following specifications:

SIEVE OPENING	0.50 in. to 2.50 in.	Stone shall be clean double-washed bank run gravel or crushed aggregate, free of rock dust, fines or soil particles. Crushed limestone aggregate is not acceptable.
CLASSIFICATION	DE #3	

2.6.6.2 Infiltration Trench Cover Pea Gravel (Optional)

As an option, an infiltration trench cover consisting of pea gravel can be used for filtering between the cover stone and infiltration stone. It shall be washed free of dust, fines and soil particles. Infiltration trench stone shall conform to the following specifications:

SIEVE OPENING	0.125 in. to 0.50 in.	Stone shall be clean double-washed bank run gravel or crushed aggregate, free of rock dust, fines or soil particles. Crushed limestone aggregate is not acceptable.
CLASSIFICATION	DE #8	

2.6.6.3 Infiltration Trench Cover Stone

Infiltration trench cover stone is a large aggregate used to cover the surface of infiltration trenches, resistant to dislodging by peak flows. It shall be washed free of dust, fines and soil particles. Infiltration trench stone shall conform to the following specifications:

SIEVE OPENING	1.50 in. to 4.0 in.	Stone shall be clean double-washed bank run gravel or crushed aggregate, free of rock dust, fines or soil particles. Crushed limestone aggregate is not acceptable.
CLASSIFICATION	DE #1	

2.6.6.4 Drainage Fabric Geotextile

Drainage fabric geotextile is used for lining infiltration trenches to keep the surrounding soil from entering the stone, while letting water exfiltrate into the soils. Refer to the Delaware Erosion and Sediment Control Handbook for more information on filter fabric. The most important element in specifying drainage fabric is the permeability rate, which should be at least 110 gal/min/sq.ft.. A drainage filter fabric shall meet the following Minimum Average Roll Value (MARV) specifications across the weave. Woven geotextiles should be used in preference to nonwoven geotextiles, as they are less subject to formation of biofilms that could clog the pores. Alternative fabrics must be supported by design calculations showing its suitability for the design use:

PROPERTY	TEST METHOD	REQUIREMENT	PROPERTY	TEST METHOD	REQUIREMENT
Grab Tensile Strength	ASTM D-4632	80 lb. min.	Puncture Strength	ASTM D-4833	45 lb. min.
Grab Elongation	ASTM D-4632	50% max.	UV Resistance	ASTM D-4355	70 % at 500 hrs. min.
Trapezoidal Tear Strength	ASTM D-4533	35 lb. min.	Apparent opening	ASTM-D-4751	40-80 US Sieve
Mullen Burst Strength	ASTM D-3786	160 psi. min.	Permeability	ASTM D-4491	≥ 110 gal/min/ft.^{2}

2.6.6.5 Standards for Infiltration Trench Soils

As with all Green Technology BMPs, the soil profile under infiltration trenches should be as undisturbed as possible. However, if close to construction activities, the soil profile under infiltration trenches can be extensively disturbed, and probably compacted as well. If excessive, compaction must be alleviated by using a chisel plow, ripper, or subsoiler, as discussed in Section 1.2.3.

2.6.7 Standards for Infiltration Trench Inspection and Maintenance

All infiltration trenches should have an observation port installed at the low point. Detail 2.6.1 displays how the observation port should be installed. These observation ports should be inspected semi-annually in the spring and fall and 48 hours after major storms. A log should be kept of the water level remaining after each event observed. If the topsoil cover is eroded, the geotextile should be repaired as needed, topsoil replaced and turf cover reseeded.

CHAPTER 3 LANDSCAPING STANDARDS AND SPECIFICATIONS

3.1 INTRODUCTION

Surface flow filtering BMPs depend on a dense vegetative cover to provide the proper filtering. This is particularly important for filter strips and biofiltration swales. Relying on infiltration, bioretention facilities are less dependent upon the density of vegetative cover at the ground level, but their location in a developed setting requires that their landscaping be viable and attractive. It is also important that maintenance measures for Green Technology BMPs require as little effort and energy consumption as possible. This objective can be attained by designing and installing diverse plantings such as meadows, which require relatively low maintenance, once they are established.

Therefore, it is essential that the proper plants are specified for use in Green Technology BMPs, and that methods for their establishment and maintenance be properly documented. It is now recognized that native plant material is preferable to plant material derived from foreign sources. This is due to the fact that native material is better adapted to local conditions, providing for greater vigor. Native plants are also less susceptible to diseases. These factors result in much less maintenance in the long run.

Even more important, noninvasive native plants are the basis for a healthy ecosystem. (Note that there are native species that are invasive.) Restricting the planting plan to noninvasive native species reduces the threat of colonization by invasive plants, exotic or native. Dominance of formerly diverse ecosystems by monocultures of invasive plants is now recognized as one of the most pervasive threats to the natural ecosystem throughout Delaware.

Delaware's native fauna are also far better adapted to the food and cover provided by native plants. This is particularly important in riparian areas where many Green Technology BMPs are constructed. The plant lists set forth in Tables 1 through 4 indicate the relative wildlife values of the individual plants. By using native material, Green Technology BMPs can thus be as closely integrated into the natural landscape as possible.

For these reasons, the intent of this Manual is to focus the choice of plants on noninvasive native species. While there may be acceptable exotic plants, there are so many superior native plants suited for these purposes that there is no point in discussing imported plant material. In high maintenance landscapes such as in heavily landscaped commercial sites where the potential for colonization is remote, exotic plants or turf grasses can be specified. However, it is essential that they do not pose a threat to the ecosystem. Any such noxious plants as listed by DNREC shall not be approved, and other plants may be specified only if their capabilities match the demands of the site, as documented by a qualified plant expert.

The following Sections present the Landscaping Standards to be applied to Green Technology BMPs.

3.2 PLANT SELECTION BY STRUCTURAL ATTRIBUTES

In designing a typical landscape, texture and color aspects such as leaf shape and hue, bloom timing, texture and color, fall color and fruiting, and winter habit are important elements involved in plant selection. Complementing texture and color, structural elements of the landscape such as growth rate, height, and mature form determine the overall massing of the design. Diverse landscape plantings incorporate an herbaceous layer, a shrub layer, an understory tree layer, and a canopy tree layer.

The herbaceous layer is differentiated into grasses, sedges, rushes, perennials, and ferns. Grasses are further differentiated into cool season and warm season species. This distinction is important: cool season grasses retain their leaf blades over the winter months when warm season grasses have died back to the ground, while warm season grasses will thrive in the hot summer months when cool season grasses go dormant. Some grasses and sedges also form a sod, instead of the clumping habit typical to most warm season grasses. These are identified as such in the comment column of Table 3-1. For filter strips, a sod forming grass would appear to be more desirable, since the flow path is relatively short. However, research has shown that even a short warm season grass filter strip can be very effective in filtering runoff.

In a study of grass and forest riparian buffer under high nutrient loading situations, warm season grasses accumulated biomass at up to twice the rate of pasture grasses. Root biomass in the warm season grasses was found to be up to ten times that of the cool season turf. In fact, the grasses had a greater root biomass and uptake than the forest portion. This study confirms the efficacy of using warm season grasses in filtering BMPs.

For biofiltration swales with a longer flow path, cool season grasses could be included with warm season grasses to provide a diverse mixture with year round effectiveness. However, since turf-type cool season grasses generally out-compete warm season grasses until the latter are established, they should be only a small proportion of the overall planting mixture. An exception is Red Top, a sod-forming cool season grass that is eventually dominated by more vigorous warm season grasses. Germinating very rapidly, it eventually gives way to the slower establishing warm season grasses. The Wild Ryes also tend to give way to warm season grasses. These grasses are very useful as a nurse crop to keep out invasive plants while warm season grasses become established.

Outside of filter strips, turf-forming native or exotic grasses are not at all appropriate for Green Technology BMPs. These grasses will dominate to the exclusion of any other plants included in the planting plan, resulting in a sterile monoculture. Furthermore, fescues have substantial adverse effects upon wildlife. Tall Fescue, Kentucky Bluegrass and other similar turf-forming cold season grasses thus have been purposely excluded from Table 3-1. Unless the designer/owner is willing to stipulate the much higher maintenance responsibilities involved in mowing these grasses on a regular basis, they shall not be specified. Turf forming grasses are only acceptable for filter strips used in landscaped locations next to buildings and parking areas.

Determined by the myriad different plants available, elements of texture, color, and structure outline the landscaper's palette. Delaware is fortunate in having a temperate climate and fertile soils that support many different native plants. Since there are relatively few site limitations in the landscape setting, the general practice in landscape design is thus to select plants based upon their ability to display those particular features desired by the designer, and alter the setting as needed for the plant to become established.

However, in distributed BMPs where maintenance and watering would be minimal or absent compared to a landscaped setting, selecting plants for texture and color attributes is much less important than long-term practicality and viability. On the other hand, selecting plants for structural aspects is essential in designing Green Technology BMPs. In many filtering BMPs, a dense cover of grasses, sedges, and rushes are required in the herbaceous layer where most of the filtering takes place. Herbaceous perennials and ferns can be blended with these grass-like plants to provide a diverse meadow ecosystem.

More structure can be provided along the edges of a bioswale or in a bioretention facility by adding shrubs and understory trees. These plants provide greater ecological diversity and some shade. Shrubs, understory and canopy trees are not only an excellent choice for bioretention facilities; they are also essential in riparian restoration as well as street tree and open space plantings. Canopy trees can also be planted on the north side of bioswales where they cast less shade on the filtering channel. Tables 3-1 through 3-4 list suitable native plants according to their structural classification.

3.3 PLANT SELECTION BY TOLERANCE FACTORS

Regardless of the structural classification, plant selection for long-term viability is the single most essential aspect of landscaping design for Green Technology BMPs. If a plant is placed where site conditions are stressful, it will not thrive, and eventually it will die out, to be replaced by invasive plants. On the other hand, site conditions that stress some plants may be ideal for others. Some plants prefer saturated soils where others will drown. Some plants prefer to be in dry upland locations where others would wilt. Some plants can tolerate occasional flooding, while others do not. Some plants prefer shaded sites where other plants will not grow.

Therefore, understanding how the variation in these conditions is distributed over the site is the first step in developing a planting plan. The site plan must be methodically evaluated to delineate planting zones defined by these conditions. This is the basis of the planting zone concept that underlies all properly designed plantings for Green Technology BMPs. It should be emphasized that planting zones grade into each other, and the concept is to be used a design tool. For this reason, discrete planting zones should not be specified on the Plans.

Through careful analysis of the location, surroundings, local hydrogeology, slope, aspect, and hydrology of the intended design, the designer can delineate the different planting zones that comprise the site. These zones are differentiated according to the factors discussed below. For every native plant listed in each of the structural types discussed above, the respective tolerance is presented in Tables 3-1 through 3-4 to assist the designer in selecting the most appropriate plant available for the condition specified. As an Excel™ spreadsheet, this list can be sorted by tolerance factor to assist in plant selection. This approach is similar to the sculptured seeding method used in prairie restoration seeding projects.

At the opposite pole from site tolerance, some plants can be very competitive. It is important to recognize this aspect in certain plants, since they can dominate a planting if they are specified as a high proportion of the plant mix. While these plants are not necessarily invasive or nonnative, they will tend to crowd out the other plants during establishment, resulting in a less diverse mix. For tough sites where these plants may be the only ones to thrive, they should be specified in a higher proportion to ensure decent stand cover to keep out the invasive plants and weeds. For typical sites, such species should be specified at no greater than five percent of the total mix, or they can dominate the mix eventually. Such plants are indicated with an "A" in Tables 3-1 through 3-4.

3.3.1 Moisture Tolerance

The most fundamental condition that determines lasting plant viability is the moisture regime. By their very nature as stormwater facilities, Green Technology BMPs provide a wide range of moisture regimes. The extent and duration of moisture in the bottom of a bioswale is very different from that on top of the side slopes. The moisture regime involves three different parameters, permanent saturation (saturation tolerance), temporary saturation (flooding tolerance), and temporary wilting (drought tolerance). It should be noted that most plants native to Delaware do well in moist conditions, so this is not included as a separate category.

Saturation tolerance is the ability of the plant to withstand extended periods of wet conditions during the growing season. It is analogous to wetland status. Plants can be obligate, requiring saturated conditions to grow, or facultative, in which drier conditions can be tolerated. Saturated conditions are likely in the bottom of bioswales that have flat slopes located on poorly drained soils. If such conditions are called for in the design, plants in this area must have a high saturation tolerance. If soil and/or design conditions promote better drainage, but still quite moist conditions, the plants with an average saturation tolerance should prosper.

By definition, zones that are saturated will also be flooded after storms. While flooding tolerance is similar to saturation tolerance, the saturated condition occurs for a shorter period of at most several days. In Green Technology BMPs, locations above the saturated zone will dry out between storm events, while flooding conditions will occur in every storm. Flooding tolerance is thus mandatory for plants located within the flow line and ponded areas of the BMP. The difference between these factors is important, as many plants exhibit better flooding tolerance than saturation tolerance. This permits greater flexibility in the design. Plants with low flooding tolerance are suitable only for the upper side slopes of the BMP.

As the opposite pole from saturation tolerance, drought tolerance is required for plants in these drier locations. While it seems odd that drought tolerance would be important in a stormwater BMP, recent rainfall patterns in Delaware emphasize that very dry conditions can occur for extended periods of time during the growing season. Drought tolerant plants have deep roots that obtain moisture that has infiltrated into the soil from the flow channel.

Based upon the preceding criteria, it is possible to delineate the zones in the BMP facility according to their relative moisture conditions, as discussed in Section 3.4.

3.3.2 Shade Tolerance

The other fundamental condition in plant selection is light level. Many plants will only thrive in full sun, while others prefer deep shade. Shade tolerance is thus a key factor for plants proposed for shady sites. Most filtering BMPs are dominated by sunny conditions, so shade tolerance is generally less important than the moisture tolerances. However, in bioretention facility design and riparian restoration, shady conditions predominate. Close attention must be paid to shade tolerance for plants specified for the herbaceous, shrub and understory layers of such areas. Although there are few shade tolerant grasses or rushes, there are many shade tolerant sedges, ferns and perennials suitable for such locations.

Plants to be placed in a dense forest setting should have a higher shade tolerance than plants in a bioretention facility where sunlight from the extensive edges will reduce overall shade levels. At the other extreme, plants in unshaded BMPs such as filter strips should have a high sun tolerance. Sun tolerance can be just as important for plants placed in such sunny locations. While most plants prefer full sun, there are a few plants such as ferns that tolerate exposure to full sun only under moist soil conditions. Other plants will not thrive even under these circumstances. Since most Green Technology BMPs rely on filtration by plants, the planting plan should support sunny conditions that promote a dense vegetative layer. Sun tolerance thus becomes an important factor to consider in specifying these plants. Based upon the preceding criteria, it is possible to delineate the zones in the BMP facility according to their relative shade level. Shade conditions are considered a modifier to the moisture regime.

3.4 PLANT SELECTION BY TOLERANCE ZONE

The following discussion proposes zones according to saturation, flooding, and drought. Since flooding is common to all but the droughty locations, saturated/flooded is listed as S, moist (unsaturated) flooded is M, and droughty is listed as D. Shade modifiers are listed as A for shaded sites and U for sunny sites. While defined in the plan as a discrete boundary for design purposes, the extent of these zones is more appropriately treated as a continuum across the boundaries between regimes.

Within the flooded zone, plants selected for the lower areas should have greater saturation and flooding tolerance than plants selected for higher areas. Likewise plants outside of the flooding zone selected for the higher areas should have greater drought tolerance than plants selected for lower areas. Similarly, plants to be placed in a dense forest setting should have a higher shade tolerance than plants in a bioretention facility where sunlight from the edges reduces overall shade levels. At the other extreme, plants in unshaded BMPs such as filter strips should have a high sun tolerance. In this manner, the planting selection can best respond to the variations in regimes found across the boundaries delineated for each zone of a distributed BMP.

Based upon these three moisture regimes and two shade regimes, up to six different zones could be found in a complex riparian buffer BMP. However, most filtering BMPs would have only the first three moisture regimes, all of which are sunny. It should be noted that most plants that tolerate saturation also do well in moist conditions. The following discussion illustrates how Tables 3-1 through 3-4 would be used in selecting plant material.

3.4.1 Zone SA

Zone S is the saturated area most subject to flooding. The A modifier indicates a shaded forest setting typical of a riparian forest buffer. While south and west oriented edges have more solar exposure, it will be reduced in north facing edges, where fewer species will tolerate the shadier conditions.

Canopy species with good tolerance to the wetland conditions are listed in Table 3-4. Due to their fast growth rate, pioneer species such as Sycamore, Black Willow and Eastern Cottonwood are established relatively easily, and rapidly reach canopy closure. However, there are many other trees that are also suitable, although they may grow less rapidly or not as high. If slower growing wetland trees are selected, they should have a higher shade tolerance where pioneer trees could eventually shade them. Pin Oak, River Birch, Black Gum and Red Maple are excellent plants for these conditions.

The canopy trees will shade the smaller plants in the forest understory. Shade tolerant understory trees and shrubs that handle flooding and wet soils should be interplanted among canopy species to provide additional complexity to the ecosystem. A wetland understory of Alder, Black Haw, Possumhaw, and Sweet Bay will provide additional structure. Shade tolerant wetland shrub species such as Winterberry, Elderberry, Arrowwood, Virginia Sweetspire and Silky Dogwood will further shade the forest floor, inhibiting competition from intolerant edge species. Information on these and other suitable shrubs are listed in Table 3-3.

In the herbaceous layer, shade tolerant wetland plants include the wild ryes, Slender Mannagrass, several sedges and many perennials. High Meadow Sedge is the only sod-forming shade tolerant plant, but it is only available in plugs. Most of the ferns are also excellent for these conditions. Since ferns can be invasive, it is recommended that they be planted after other plants in the herbaceous layer are established. These and other suitable herbaceous plants are listed in Tables 3-1 and 3-2. Designed as coherent whole, this plant community can be designed to eventually replicate a native terrestrial forest ecosystem.

3.4.2 Zone SU

Like Zone SA, Zone SU is saturated, but it is a sunny site with few or no canopy trees. The shade cast by narrow plantings of understory trees is generally filtered enough to that shade intolerant species can be selected in the shrub and herbaceous layers. In addition to the shade tolerant understory trees listed above, intolerant species such as Box Elder and Rough Alder can also be chosen. Likewise, intolerant wetland shrubs such as Bayberry, Pussy Willow, Buttonbush or Sweet Pepperbush can be selected.

The herbaceous layer in zone SU is the most important layer in filtering BMPs. Since a dense stem density is preferred, intolerant grasses and sedges should be included, preferably with some of the sod-forming grasses. A good base mixture would include Coastal Panicgrass, Prairie Cordgrass, Switchgrass and Wood Reedgrass. Red Top and/or Virginia Wild Rye can be used as a nurse crop that will eventually give way to these grasses as they become established. Sedges, rushes and wetland plants can be included for wetter sites. If a meadow mix is desired, many Asters, Goldenrods, butterfly Milkweed, Boneset, Turtlehead, Ironweed, Cardinal Flower, and Blue Vervain are excellent choices. There are many other species that will also thrive in the SU zone. Royal Fern and Sensitive Fern are the only ferns that have the sun tolerance suitable for these conditions, but they can be invasive. These and other suitable herbaceous plants are listed in Tables 3-1 and 3-2. Designed as coherent whole, this plant community eventually replicates a native wet meadow ecosystem.

3.4.3 Zone MA

Since it is not saturated and floods less frequently, a greater number of plants can be specified for Zone M sites. The A modifier indicates a shaded forest setting typical to a riparian forest buffer. As in the case of the SA zone, the pioneer canopy trees do not have to have the shade tolerance that slower growing trees would need. In addition to the trees suitable for Zone SA, Ashes, Oaks, Basswood, Walnut and Slippery Elm all would do well in this setting. Likewise, Hornbeam and Redbud can be added to the understory Zone SA plants that tolerate shade. Shadblow and Dogwood can be planted where flooding is less frequent. For the shrub layer, Witch Hazel can be added to the wetland plants suitable for Zone SA. Spicebush often dominates upland sites since it is highly resistant to deer herbivory. However, it and Mapleleaf Viburnum are good choices in upland areas where heavy deer herbivory precludes the use of other species.

In the herbaceous layer, shade tolerant upland plants include the riverbank and Virginia Wild Ryes, Broomsedge, most of the sedges and many perennials. High Meadow Sedge is the only sod-forming shade tolerant plant for moist conditions. Most of the ferns are also excellent for these conditions. These and other suitable herbaceous plants are listed in Tables 3-1 and 3-2. Designed in concert with the plants for the SA zone, this plant community eventually replicates a native terrestrial forest ecosystem.

3.4.4 Zone MU

As a moist, sunny site with few, if any, canopy trees, the MU zone is the most common zone for filtering BMPs. In addition to the shade tolerant understory trees listed above, intolerant species such as Sassafras and Bladdernut can also be used. Likewise, intolerant shrubs such as the Chokeberries and upland Viburnum species can be selected.

As with the SU Zone, the herbaceous layer in zone MU is the most important layer in filtering BMPs. For a dense stem density, intolerant grasses and sedges should be included, preferably with some of the sod-forming grasses. In addition to the Zone SU grass mixture, Indiangrass, Eastern Gamagrass, Big Bluestem and Switchgrass are excellent choices.

Purple Top and Broom Sedge are particularly common in this setting, and will colonize the planting if a seed source is nearby. For this reason, they should be included in the mix, but only at low proportions since they will be established very easily. Red Top and Canada Wild Rye should be used as cover crop. Sedges, rushes and wetland plants can be included for these sites. For a meadow mix in addition to the Zone SU perennials, Joe Pye Weed, False Indigo and Bee Balm are excellent choices, although the latter will dominate the plantings if too much is used. Most of the other species will also thrive in the MU Zone. As in the SU Zone, Royal Fern and Sensitive Fern are the only ferns that have suitable sun tolerance. These and other suitable herbaceous plants are listed in Tables 3-1 and 3-2. This plant community eventually replicates a native meadow ecosystem.

3.4.5 Zone DA

The DA Zone is the driest part of a shaded BMP. Instead of flooding and saturation tolerance, drought tolerance becomes the most important factor. Persimmon is listed as the most drought tolerant canopy tree that tolerates shade. Since they are located close to a watercourse, less drought tolerant species such as Hackberry, Black Ash, Black Gum, and Bald Cypress are also suitable. Walnut, Red Cedar, Willow Oak and Pin Oak are suitable where there is less shade or if they are established as pioneer species in the beginning. Understory trees that are most suitable include Fringe Tree, Ironwood, Witch Hazel and Redbud. New Jersey Tea, Grey Dogwood, Fragrant Sumac and the Blueberries are drought tolerant shrubs that grow in the shade.

In the shaded herbaceous layer, drought tolerant plants include the Wild Ryes, Broomsedge, a few of the sedges and many perennials. There is no sod-forming shade tolerant grass or sedge for droughty conditions. The only fern that will tolerate these conditions is Sensitive Fern. These and other suitable herbaceous plants are listed in Tables 3-1 and 3-2. Designed in concert with the plants for the MA Zone, this plant community eventually replicates the upland margins of a native terrestrial forest ecosystem.

3.4.6 Zone DU

The DU Zone is the driest part of a BMP. Exposed to full sun with little or no shade, it requires plants that can handle such conditions. The understory trees listed for the MA Zone also have a high drought tolerance. For the shrub layer, the Sumacs, Blueberries and Sheep Laurel are the most drought tolerant species that thrive in full sun.

In the exposed herbaceous layer, drought tolerant plants include Canada Wild Rye, Side Oats Grama, Little Bluestem, and Switchgrass. Indiangrass and Eastern GamaGrass are good plants for droughty conditions. A few of the sedges and perennials such as Milkweed, Coreopsis, Ox Eye Sunflower and the Coneflowers are well adapted to droughty conditions. No Fern will tolerate these conditions. These and other suitable herbaceous plants are listed in Tables 3-1 and 3-2. Designed in concert with the plants for the MA Zone, this plant community eventually replicates a native upland meadow ecosystem.

3.5 PLANT SELECTION BY SOURCES

Complementing the planting zone selection criteria discussed above, the source of plant material is the factor remaining in specifying the appropriate species. Material originating in the vicinity of the BMP location is most appropriate. This is due to the fact that local biotypes have better vigor and hardiness, and are thus better able to compete. Wildlife value for forage, shelter and corridor movement may be higher for local species. Most plant material will have to be obtained from available nursery stock. In recognition of the merits of native material, many nurseries now stock native plants, some from local sources. Also, since Delaware comprises both the Coastal Plain and Piedmont physiographic provinces, plants from both these areas are included in Tables 3-1 through 3-4. Most plants are adaptable to either zone; where certain woody species have either a marked preference or would seem out of place in the wrong region, their common names are indicated with (C) for coastal Plain plants and a (P) for Piedmont plants.

Where available, local stock should be used, although much of the plant material may have to come from more distant genetic sources. Nursery stock from large or distant suppliers often comes from a biotype far removed from the site of installation. Stock from remote sources is a less desirable option, even though its cost may be slightly more competitive. Local sources may be slightly more expensive, but the better quality control and reduced shipping and handling costs can offset initial price disadvantages. The designer must weigh the merits of the available sources when it comes to the final plant list specification.

Even if they are remote, large suppliers can assist in locating and/or contract growing locally adapted plant material, so they should be contacted. The local NCRS office and local landscapers should be contacted to ensure that potential sources are not overlooked. Sources are then evaluated as to size, price and availability of the remaining plants. Often, certain species are unavailable or expensive, while others may be abundant in the trade, and relatively inexpensive. In this manner, the plants listed in Tables 3-1 through 3-4 will be narrowed down to appropriate species available in the proper sizes. This forms the basis of the plant list to be used in the BMP.

Note that this plant list is not exhaustive. Delaware has a list of native plants that are acceptable alternatives. See also those plants listed as natives in "National List of Plant Species That Occur in Wetlands: Northeast (Region 1)" by the Fish & Wildlife Service. Note also that certain plants, such as black ash (Fraxinus nigra) is very rare in Delaware, and only found in New Castle County. This is because New Castle County and northern Cecil County Maryland represent the southern limit of its native range. Conversely, bald cypress (Taxodium distichum) is a southern plant native to the gulf coast, and the southeastern coastal plain as far north as Sussex County, DE. Since Green Technology BMPs, should attempt to replicate the original community, the designer is encouraged to plants native to the location, be it Coastal Plain or Piedmont.

TABLE 3-1: Grasses, Sedges, Rushes and Wetland Plants for Green Technology BMPs
(Photographs provided by permission from Ernst Seeds Inc.)

BOTANICAL NAME	COMMON NAME	WET TOLER.	FLOOD TOLER.	DROUGHT TOLER.	SHADE TOLER.	SUN TOLER.	HEIGHT	WILDLIFE VALUE	P=plateau A=aggress. V=volunt.
COOL SEASON GRASSES									
Agrostis alba	Red Top	◆◆◆◆	◆◆◆	◆◆	◆◆	◆◆◆	◆	◆◆	[[P]]
Elymus canadensis	Canada wild rye	◆◆	◆◆	◆◆	◆	◆◆◆	◆◆	◆◆	
Elymus hystrix	Bottlebrush Grass	◆◆	◆◆	◆	◆◆◆	◆	◆	◆	
Elymus riparius	Riverbank wild rye	◆◆◆	◆◆◆	◆◆	◆◆	◆◆	◆◆	◆◆	
Elymus villosus	Eastern Wild Rye	◆◆	◆◆◆	◆◆	◆◆	◆◆◆	◆◆	◆◆	
Elymus virginicus	Virginia Wild Rye	◆◆◆	◆◆◆	◆◆	◆◆◆	◆◆	◆◆	◆◆	(P)
WARM SEASON GRASSES									
Andropogon gerardii	Big Bluestem	◆	◆◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆◆	P
Andropogon virginicus	Broom Sedge	◆	◆◆◆	◆◆◆	◆◆	◆◆◆	◆◆	◆◆	P,V
Bouteloua curtipendula	Side Oats Grama	◆	◆◆	◆◆	◆	◆◆◆	◆	◆◆	P
Calamagrostis canadensis	Canada Bluejoint	◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆◆	◆◆	A
Chasmanthium latifolium	River Oats	◆◆	◆◆◆	◆◆	◆◆	◆◆◆	◆	◆◆	
Cinna arundinacea	Wood Reedgrass	◆◆◆	◆◆◆	◆	◆◆◆	◆◆	◆◆	◆◆	
Glyceria canadensis	Rattlesnake Grass	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆	◆◆◆	
Glyceria Striata	Manna Grass	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆◆◆	
Panicum amarum	Coastal Panicgrass	◆◆◆	◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆	
Panicum virgatum	Switchgrass	◆◆◆	◆◆◆	◆◆◆	◆	◆◆◆	◆◆	◆◆◆	[[P]]
Schizachyrium Scoparium	Little Bluestem	◆	◆	◆◆◆	◆	◆◆◆	◆	◆◆◆	P
Sorghastrum nutans	Indiangrass	◆◆	◆◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆	P
Spartina pectinata	Prairie Cord Grass	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆◆	◆◆	(P)
Tridens flavus	Purpletop	◆◆◆	◆◆◆	◆◆◆	◆◆	◆◆	◆◆	◆◆	V
Tripsacum dactyloides	E. Gamagrass	◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆◆	◆◆◆	P
SEDGES									
Carex Annectens	Yellow Fruited Sedge	◆◆◆	◆◆◆	◆◆◆	◆	◆◆◆	◆◆	◆	
Carex communis	Colonial Sedge	◆◆	◆◆	◆◆	◆◆◆	◆◆◆	◆	◆	
Carex crinita var. crinita	Fringed sedge	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆◆	
Carex emoryi	Emory's Sedge	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆	◆	
Carex gracillima	Graceful Sedge	◆◆	◆◆	◆◆	◆◆	◆◆	◆	◆◆	
Carex grayi	Gray's Sedge	◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆	◆	
Carex intumescens	Bladder Sedge	◆◆◆	◆◆	◆	◆◆	◆◆◆	◆◆	◆◆	
Carex lupulina	Hop Sedge	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆◆	
Carex Lurida	Shallow Sedge/Lurid Sedge	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆◆	
Carex pensylvanica	High meadow sedge	◆◆	◆◆	◆	◆◆◆	◆◆	◆	◆	
Carex scoparia	Blunt Broomsedge	◆◆◆	◆◆◆	◆◆	◆	◆◆◆	◆	◆◆	
Carex stipata	Awl/Stalk-grain Sedge	◆◆◆	◆◆◆	◆◆	◆	◆◆◆	◆	◆◆	
Carex stricta	Tussock Sedge	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆	◆◆◆	
Carex tribuloides	Bristlebract Sedge	◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆	◆◆	
Carex vulpinoidea	Fox Sedge	◆◆◆◆	◆◆◆	◆◆◆	◆◆	◆◆◆	◆◆	◆◆	
RUSHES AND WETLAND PLANTS									
Acorus Calamus	Sweet Flag	◆◆◆◆	◆◆◆	◆◆	◆	◆◆◆	◆◆	◆	
Caltha palustris	Marsh Marigold	◆◆◆◆	◆◆◆	-	◆	◆◆◆	◆◆	◆	
Iris Pseudacorus	Yellow Iris	◆◆◆◆	◆◆◆	-	◆	◆◆◆	◆◆	◆	
Iris versicolor	Blue Flag	◆◆◆◆	◆◆◆	-	◆◆	◆◆◆	◆	◆	
Eleocharis obtusa palustris	Blunt Spike Rush	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆	◆◆	
Juncus canadensis	Canadian Rush	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆	◆◆	
Juncus effusus	Soft Rush	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆◆	◆◆	
Juncus tenuis	Path Rush	◆◆	◆◆	◆◆	◆◆	◆◆◆	◆	◆	
Juncus torreyi	Torrey's Rush	◆◆◆	◆◆◆	◆◆	◆	◆◆◆	◆	◆◆	
Scirpus Cyperinus	Woolgrass	◆◆◆	◆◆◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆	
Scirpus Fluviatilis	River Bulrush	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆◆	◆	
Scirpus pungens/americanus	Common 3 Square	◆◆◆◆	◆◆◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆◆	
Scirpus Tabernaemontanii	Soft-Stem Bulrush	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆	◆	
Polygonum Pensylvanicum	PA Smartweed	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆	◆◆	

TABLE 3-2: Herbaceous Perennials for Green Technology BMPs
(Photographs provided by permission from Ernst Seeds Inc.)

BOTANICAL NAME	COMMON NAME	SATUR. TOLER.	FLOOD TOLER.	DROUGHT TOLER.	SHADE TOLER.	SUN TOLER.	HEIGHT	WILDLIFE VALUE	P=plateau A=aggress. V=volunt.
PERENNIALS									
Asclepias incarnata	Swamp Milkweed	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆◆	◆◆◆	
Asclepias tuberosa	Butterflyweed	◆	◆	◆◆◆	◆	◆◆◆	◆◆	◆◆	
Aster divaricatus	Wood Aster	◆	◆	◆◆◆	◆◆◆	◆◆	◆◆	◆◆	
Aster firmus	Shining Aster	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆	◆	
Aster laevis	Smooth or Blue Bird Aster	◆	◆◆	◆◆	◆◆	◆◆◆	◆◆	◆◆	
Aster lanceolatus	Panicled Aster	◆◆◆	◆◆◆	◆	◆	◆◆	◆	◆	
Aster novae-angliae	New England Aster	◆◆◆	◆◆◆	◆◆	◆◆	◆◆◆	◆◆	◆◆	P
Aster novi-belgii	New York Aster	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆	◆◆	
Aster prenanthoides	Swamp Aster	◆◆◆	◆◆◆	◆◆	◆◆◆	◆◆	◆	◆	
Aster puniceus	Purple Stemmed Aster	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆◆	◆	
Aster umbellatus	Flat Topped-White Aster	◆◆◆	◆◆◆	◆	◆◆	◆◆	◆◆	◆	
Baptisia australis	Blue False Indigo	◆◆	◆◆◆	◆◆◆	◆◆	◆◆	◆◆	◆	P
Bidens aristosa	Tickseed Sunflower	◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆	◆	
Bidens cernua	Nodding Bur-Marigold	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆	◆◆	
Boltonia asteroides	Boltonia	◆◆	◆◆◆	◆	◆	◆◆◆	◆◆◆	◆	
Chelone glabra	Turtlehead	◆◆◆◆	◆◆◆	◆	◆◆	◆◆	◆◆	◆◆	
Chelone obliqua	Rose Turtlehead	◆◆◆	◆◆◆	◆	◆	◆◆	◆◆	◆◆	
Chrysanthemum leucanthemu	Ox-Eye Daisy	◆	◆	◆◆◆	◆	◆◆◆	◆	◆◆	P
Coreopsis lanceolata	Threadleaf Coreopsis	◆	◆	◆◆◆	◆	◆◆◆	◆	◆	P
Echinacea purpurea	Purple Coneflower	◆	◆	◆◆◆	◆	◆◆◆	◆◆	◆	P
Eupatorium fistulosum	Joe Pye Weed	◆◆◆	◆◆◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆	
Eupatorium maculatum	Spotted Joe Pye Weed	◆◆◆◆	◆◆◆	◆◆	◆◆	◆◆◆	◆◆	◆◆	
Eupatorium perfoliatum	Boneset	◆◆◆◆	◆◆◆	◆◆	◆◆◆	◆◆	◆◆	◆◆	
Eupatorium Purpureum	Purple Joe Pye Weed	◆◆	◆◆	◆◆	◆◆	◆◆◆	◆◆	◆	
Eupatorium rugosum	White Snakeroot	◆	◆	◆◆	◆◆	◆◆◆	◆◆	-	
Heliopsis helianthoides	Ox- eye Sunflower	◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆◆	A
Hibiscus moscheutos	Swamp Rose-mallow	◆◆◆◆	◆◆◆	-	◆	◆◆◆	◆◆◆	◆◆	
Hypericum pyramidatum	Great St. John's-Wort	◆◆	◆◆◆	◆◆	◆◆◆	◆◆	◆◆	◆	
Liatris spicata	Marsh Blazing Star	◆◆	◆◆◆	◆	◆	◆◆◆	◆◆	◆	
Lobelia cardinalis	Cardinal Flower	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆◆	
Lobelia siphilitica	Blue Cardinal Flower	◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆	
Mentha Arvenis	Wild Mint/Field Mint	◆◆◆	◆◆	◆◆	◆	◆◆◆	◆	◆	
Mertensia virginica	Virginia Bluebells	◆◆◆	◆◆	-	◆◆◆	◆	◆	◆	
Monarda didyma	Bee Balm	◆◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆	◆◆	A
Monarda fistulosa	Wild Bergamot	◆	◆	◆◆◆	◆	◆◆◆	◆◆	◆◆	A
Osmorhiza claytonii	Hairy Sweet Cicely	◆◆	◆◆	◆	◆◆◆	◆	◆	◆	
Penstemon digitalis	Foxglove Beardtongue	◆	◆	◆	◆◆	◆◆◆	◆◆	◆	
Physostegia virginiana	Obedient Plant	◆◆	◆◆	◆	◆	◆◆◆	◆◆	◆◆	
Polemonium reptans	Greek Valerian/Jacobs Ladde	◆	◆◆	◆◆	◆◆◆	◆◆	◆	◆	
Rudbeckia fulgida	Orange Coneflower	◆	◆◆	◆◆◆	◆	◆◆◆	◆	◆◆	
Rudbeckia hirta	Black-eyed Susan	◆	◆	◆◆◆	◆	◆◆◆	◆	◆◆	P
Rudbeckia laciniata	Greenheaded/Tall Coneflowe	◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆◆	◆◆	
Rudbeckia triloba	Three-lobed or Branched Cor	◆	◆◆	◆◆◆	◆	◆◆◆	◆◆	◆◆	
Solidago graminifolia	Grass-Leaved Goldenrod	◆◆◆	◆◆◆	◆◆	◆	◆◆◆	◆◆	◆◆	A
Solidago rugosa	Wrinkle-Leaf Goldenrod	◆◆	◆◆◆	◆◆◆	◆◆	◆◆◆	◆◆◆	◆◆	
Solidago speciosa	Showy Goldenrod	◆◆	◆◆◆	◆◆	◆◆	◆◆◆	◆◆	◆	
Solidago sphacelata	Goldenrod	◆	◆◆	◆◆	◆	◆◆◆	◆◆	◆◆	
Thalictrum pubescens	Tall Meadow-Rue	◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆	
Tradescantia virginiana	Spiderwort	◆◆	◆◆	◆◆	◆◆◆	◆◆◆	◆◆	◆	
Verbena hastata	Blue Vervain	◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆	
Vernonia noveboracensis	New York Ironweed	◆◆◆	◆◆◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆	V

TABLE 3-3: Woody Shrubs For Green Technology BMPs

BOTANICAL NAME	COMMON NAME	SATUR. TOLER.	FLOOD TOLER.	DROUGHT TOLER.	SHADE TOLER.	GROWTH RATE	HEIGHT	WILDLIFE VALUE
SHRUBS (5' to 15' high)								
Aronia arbutifolia	Red chokeberry	◆◆◆	◆◆◆	◆◆	◆◆	◆◆	◆◆	◆◆
Aronia melanocarpa	Black Chokeberry	◆◆◆	◆◆◆	◆◆	◆◆	◆◆	◆◆	◆◆
Aronia prunifolia	Purple Chokeberry	◆◆◆◆	◆◆◆	◆	◆◆	◆◆	◆◆◆	◆
Ceanothus americanus	New Jersey Tea	◆◆	◆	◆◆◆	◆◆	◆	◆◆	◆
Cephalanthus occidentalis	Buttonbush	◆◆◆◆	◆◆◆	◆	◆	◆◆	◆◆	◆
Clethra alnifolia	Sweet pepperbush	◆◆◆◆	◆◆◆	◆	◆◆◆	◆◆	◆◆	◆
Comptonia Peregrina	Sweet-fern	◆	◆	◆◆	◆	◆	◆	◆
Cornus ammomum	Silky dogwood	◆◆◆	◆◆	◆◆	◆◆◆◆	◆◆◆	◆◆	◆◆◆
Cornus racemosa	Grey dogwood	◆◆◆	◆◆	◆◆◆	◆◆◆	◆◆	◆◆	◆◆◆
Cornus sericia	Red/Red Osier dogwood	◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆◆
Gaultheria procumbens	Wintergreen or Teaberry	◆	◆	◆◆	◆	◆	◆	◆
Gaylussacia baccata	Black Huckleberry	◆	◆	◆◆	◆	◆	◆◆	◆◆
Hamamellis virginiana	Witch hazel	◆◆	◆	◆◆	◆◆◆◆	◆◆	◆◆◆	◆
Hypericum densiflorum	St John's Wort	◆◆◆	◆◆	◆◆	◆	◆	◆	◆
Ilex glabra	Inkberry	◆◆◆	◆◆◆	◆	◆◆	◆	◆◆	◆
Ilex verticellata	Winterberry	◆◆◆◆	◆◆◆	◆	◆◆	◆◆	◆◆◆	◆◆
Itea virginica	Virgina sweetspire	◆◆◆◆	◆◆◆	◆	◆◆◆	◆◆	◆◆	◆
Kalmia angustifolia	Sheep Laurel	◆	◆	◆◆◆	◆	◆	◆	◆
Leucothoe racemosa	Fetterbush	◆◆◆◆	◆◆◆	◆	◆◆◆◆	◆	◆◆	◆
Lindera benzoin	Spicebush	◆◆◆	◆◆	◆	◆◆◆◆	◆◆	◆◆	◆◆◆
Myrica gale	Sweetgale	◆◆	◆◆	◆◆	◆	◆	◆	◆
Myrica pensylvanica	Bayberry	◆◆◆	◆◆◆	◆◆	◆	◆◆	◆◆	◆◆
Physocarpus opulofolius	Common ninebark	◆◆◆◆	◆◆◆	◆◆	◆◆	◆◆◆	◆◆	◆
R. periclymenoides	Pinxterbloom Azalea	◆◆◆	◆◆◆	◆	◆◆	◆	◆◆	◆
Rhododendron canescens	Sweet Azalea	◆◆	◆	◆	◆◆	◆	◆◆	◆
Rhododendron maximum	Rosebay Rhododendron	◆◆◆	◆	◆	◆◆◆◆	◆	◆◆◆	◆
Rhododendron viscosum	Swamp Azalea	◆◆◆◆	◆◆◆	◆◆	◆◆	◆	◆◆	◆
Rhus aromatica	Fragrant Sumac	◆	◆	◆◆◆	◆◆	◆◆◆	◆◆	◆
Rhus copallina	Shining Sumac/Dwarf Sumac	◆	◆	◆◆◆	◆	◆◆◆	◆◆◆	◆
Rhus glabra	Smooth Sumac	◆	◆	◆◆◆	◆	◆◆◆	◆◆◆	◆
Rhus typhina	Staghorn Sumac	◆	◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆
Rosa palustris	Swamp Rose	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆	◆◆
Salix discolor	Pussy willow	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆◆	◆◆
Sambucus canadensis	Elderberry	◆◆◆◆	◆◆◆	◆◆	◆◆◆	◆◆◆	◆◆◆	◆◆◆
Spiraea latifolia	Meadowsweet/Steeplebush	◆◆	◆	◆	◆◆	◆◆	◆	◆
Vaccinium angustifolium	Low Blueberry	◆◆	◆◆	◆◆◆	◆◆	◆	◆	◆◆◆
Vaccinium corymbosum	Highbush Blueberry	◆◆◆◆	◆◆◆	◆◆◆	◆◆	◆	◆◆◆	◆◆◆
Viburnum acerifolium	Maple-leaved Viburnum	◆◆	◆	◆◆	◆◆◆◆	◆◆	◆◆	◆◆
Viburnum cassinoides	Witherod Viburnum	◆◆	◆	◆	◆◆	◆◆	◆◆	◆◆
Viburnum dentatum	Arrowwood	◆◆◆	◆◆◆	◆◆	◆◆◆	◆◆◆	◆◆	◆◆◆
Viburnum lentago	Nannyberry	◆◆◆	◆◆	◆◆	◆◆	◆◆	◆◆◆	◆◆
Viburnum trilobum	CranberryBush Viburnum	◆◆	◆◆	◆	◆◆◆◆	◆◆	◆◆◆	◆◆

TABLE 3-4: Understory and Canopy Trees For Green Technology BMPs

BOTANICAL NAME	COMMON NAME	SATUR. TOLER.	FLOOD TOLER.	DROUGHT TOLER.	SHADE TOLER.	GROWTH RATE	HEIGHT	WILDLIFE VALUE
CANOPY TREES- (50' to 100' high)								
Acer rubrum	Red Maple	◆◆◆	◆◆◆	◆◆	◆◆	◆◆◆	◆◆	◆◆◆
Acer saccharinum	Silver Maple (P)	◆◆	◆◆◆	◆	◆	◆◆◆◆	◆◆	◆◆
Betula nigra	River birch	◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆◆	◆◆◆
Celtis occidentalis	Hackberry	◆◆◆	◆◆	◆◆	◆◆	◆◆◆	◆◆◆	◆◆◆
Chamaecyparis thyoides	Swamp white Cedar (C)	◆◆◆◆	◆◆◆		◆	◆◆	◆◆	◆◆
Diospyris virginiana	Persimmon	◆◆	◆◆	◆◆◆	◆◆	◆	◆	◆◆
Fagus grandifolia	American beech	◆◆	◆	◆	◆◆◆◆	◆◆	◆◆◆	◆◆
Fraxinus americana	White Ash	◆◆	◆◆	◆	◆◆◆	◆◆	◆◆◆	◆
Fraxinus Nigra	Black Ash (P)	◆◆	◆◆	◆◆	◆◆	◆◆◆	◆◆◆	◆
Fraxinus pennsylvanica	Green ash	◆◆◆	◆◆◆	◆◆	◆◆	◆◆◆◆	◆◆◆	◆
Juglans nigra	Black walnut	◆◆	◆◆	◆◆◆	◆	◆◆◆	◆◆◆	◆
Juniperus virginiana	Eastern Red Cedar	◆	◆	◆◆◆	◆	◆◆	◆◆	◆◆
Liquidamber styraciflua	Sweetgum	◆◆◆	◆◆◆	◆	◆	◆◆	◆◆	◆
Liriodendron tulipfera	Tulip poplar	◆	◆	◆	◆◆	◆◆◆	◆◆◆	◆
Nyssa sylvatica	Blackgum	◆◆◆◆	◆◆◆	◆◆	◆◆	◆	◆◆	◆
Platanus acerifolia	London Plane Tree	◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆◆	◆
Platanus occidentalis	Sycamore	◆◆◆	◆◆◆	◆	◆◆	◆◆◆◆	◆◆◆	◆
Populus deltoides	E. Cottonwood (P)	◆◆◆◆	◆◆◆	◆	◆	◆◆◆	◆◆◆	◆
Quercus alba	White Oak	◆◆	◆	◆◆	◆◆	◆	◆◆◆	◆◆
Quercus bicolor	Swamp White Oak	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆◆◆	◆◆
Quercus borealis	Red Oak	◆◆	◆	◆	◆◆	◆◆	◆◆◆	◆◆
Quercus nigra	Water Oak	◆◆◆	◆◆◆	◆	◆◆◆◆	◆◆	◆◆	◆◆
Quercus palustris	Pin Oak	◆◆◆	◆◆◆	◆◆	◆	◆◆◆	◆◆◆	◆◆
Quercus phellos	Willow oak	◆◆◆	◆◆◆	◆◆◆	◆	◆◆◆	◆◆◆	◆◆
Salix nigra	Black willow	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆◆	◆◆	◆
Taxodium distichum	Bald cypress (C)	◆◆◆◆	◆◆◆	◆◆	◆◆	◆◆	◆◆◆	◆
Thuja occidentalis	Arborvitae	◆◆	◆	◆	◆◆	◆	◆◆	◆
Tilia americana	Basswood	◆◆	◆	◆	◆◆◆	◆◆	◆◆	◆◆
Ulmus Rubra	Slippery Elm	◆◆	◆◆◆	◆◆	◆◆◆◆	◆◆◆◆	◆◆◆	◆◆
UNDERSTORY TREES- (15' to 40' high)								
Acer negundo	Box elder (P)	◆◆◆◆	◆◆◆	◆◆	◆	◆◆◆◆	◆◆◆	◆◆◆
Alnus Rugosa	Rough Alder	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆	◆	◆◆
Alnus serrulata	Common alder	◆◆◆◆	◆◆◆	◆	◆◆	◆◆◆◆	◆	◆◆
Amelanchier arboreas	Downy Serviceberry	◆◆	◆◆	◆	◆◆◆	◆◆	◆◆	◆◆
Amelanchier canadensis	Shadbush/Serviceberry	◆◆◆	◆	◆	◆◆◆◆	◆	◆◆◆	◆◆
Asimina triloba	Paw Paw	◆◆	◆	◆	◆◆	◆	◆◆	◆◆◆
Carpinus carolina/carolineana	Hornbeam or Ironwood	◆◆	◆◆	◆◆	◆◆◆◆	◆	◆◆	◆◆◆
Cercis canadensis	Redbud (P)	◆◆	◆◆	◆◆	◆◆◆	◆◆	◆◆	◆
Chionanthus virginicus	Fringetree	◆	◆	◆◆◆	◆◆◆	◆	◆◆	◆
Cornus Florida	Flowering/White Dogwood	◆	◆	◆	◆◆	◆	◆◆	◆◆◆
Crataegus viridis	Green Hawthorn	◆	◆	◆	◆◆◆	◆◆	◆◆	◆◆
Franklinia alatamaha	Franklinia	◆◆	◆◆	◆	◆◆◆	◆	◆◆	◆
Ilex decidua	Possumhaw (C)	◆◆◆	◆◆◆	◆	◆◆	◆◆	◆	◆◆
Ilex opaca	American Holly	◆◆	◆◆	◆	◆◆◆	◆	◆◆◆	◆◆
Magnolia virginiana	Sweet bay	◆◆◆◆	◆◆◆	◆	◆◆	◆◆	◆◆	◆◆
Sassafras Albidum	Sassafras	◆◆	◆	◆	◆	◆◆◆	◆◆	◆◆
Staphylea trifolia	Bladdernut (P)	◆◆◆	◆	◆	◆◆	◆◆	◆	◆◆
Viburnum prunifolium	Black Haw	◆◆◆◆	◆◆◆	◆◆	◆◆◆	◆	◆◆	◆◆

3.6 PLANTING PLAN

The first step in developing a planting plan is to generate the plant list based upon the zones and material availability discussed in the preceding sections. This plant list should take price variation into account, so as to ensure the greatest potential for the BMP. Least expensive material can be widely used, while the most expensive material will be used sparingly in high visibility locations where it will be most appreciated. Where cost differential is not a factor, plants on the list should be used in roughly equal proportions within each combination of physical conditions to provide the greatest diversity and resistance to plant diseases.

This Manual includes a spreadsheet incorporating the plants listed in Tables 3-1 through 3-4 that is intended to be used as a blank plant list. This plant list includes information on planting density for herbaceous plants. After eliminating rows containing those plants that are not even considered, the remaining rows are filled out with the costs and sizes from individual suppliers to assist in comparison. After selecting the size of the plantings and the delivered cost, this list becomes the basis for the planting schedule.

Given a conceptual plant list, formulation of the planting plan is straightforward. Canopy plantings should be delineated with graphic symbols of a diameter representing their size at maturity, and arranged randomly throughout the BMP. Individual species are allocated to each symbol from the conceptual plant list. Note that many plant species have a wide degree of tolerance in soil moisture, pH, and shade tolerance. Therefore, these species can be used effectively in many locations through the BMP. Where site conditions permit a wide choice of material, the individual species selection is not as important as the overall mix in a particular area. In essence, the planting plan should appear random; the crucial issue being that all plants are located where they will thrive.

Understory plants are similarly arranged, using symbols of a smaller diameter. Typically, there should be at least one understory tree for every two or three canopy trees. This will provide structural diversity similar to mature forests. In riparian forests, shrub species are most intensively arranged at the margins, where edge effects are the greatest. In bioretention facilities, shrubs are placed throughout. More shade tolerant species are used on the north facing margins. To avoid clutter and provide graphic clarity in the dense plantings of a BMP, complete names should be omitted from the plan. Instead, initials representing the genus and species should specify each plant or grouping of identical species. A key to relate the identifying initials to the proper names is listed in the plant list.

For the herbaceous layer, the planting plan delineates the extent of various mixes. The precise composition of the various mixes is specified in the plant list. The plan and list should differentiate between seed and plugs when herbaceous plantings are installed, as discussed in more detail below. Mixes should be delineated with generic terms such as wet meadow, meadow or upland meadow, with shade or sun modifiers. “Edge islands” of different groupings can be integrated into the plan to provide for more diversity and a natural appearance.

Once the planting plan is complete, the quantity of each plant or mixture is calculated from the Plan and entered into the plant list. Since the list is a spreadsheet, it is simple matter to use it to determine the cost by species. A column for installation by plant is included to permit estimation of the installed cost by species. Adding up the individual species costs then generates a close estimate of project costs prior to letting the project out for bid.

In this manner, the designer can rapidly examine the cost implications of alternate planting densities and sizes. By simply excluding the cost columns, the final plant list chosen has now become the plant schedule, listing plant species by symbol, botanical name, common name, cultivar (if applicable), size, type of material (container, balled and burlapped, etc.) and quantity.

A very important element of the plant list is the selection and composition of the temporary nurse crops. As discussed below in Section 3.9.8, seed planting often requires a carrier such as Oats, Winter Wheat or Barley to be mixed with the chaffy seeds of native grasses in order for them to be dispersed effectively. These carriers also provide a temporary cover for the first year after seeding while the grasses become established. Note that Annual Rye should not be used since it can reseed itself and become invasive.

However, even when nurse crops are used, it takes several years for warm season grasses to become established. For cover during the succeeding years after the initial nurse crop has died, a cold season native grass such as Red Top, Canada wild rye, or Virginia Wild rye should be planted. These grasses will provide an attractive dense cover while the warm season grasses establish their root systems, dominating the planting by the third year. By having a dense cover during this time, few, if any, annuals or perennial weeds will become established from seed blown in by the wind or dropped in by birds since the ground is so well covered. This is very important in ensuring that the planting does not get overrun by weeds.

3.7 PLANT ORDERING

While formulating the plan, the designer should identify the most likely sources of plant material. Local sources should not only be contacted, but also visited, to see the material specified. Designers should examine the size, condition and health of the plants to be ordered. Such visits can be an invaluable educational tool, as nursery managers take pride in their material and will take the time to discuss details such as the best planting methods.

Specimen material can be tagged at this time, and arrangements for delivery, payment and guarantee conditions are drawn up. Discounts are often available for government-sponsored projects such as riparian restoration projects. When ordering plants, it is important to provide as much lead time as possible to ensure the best selection. Prior to early spring is the best time to place orders, as the best trees are shipped first.

3.8 PLANT MATERIAL SPECIFICATIONS

In most cases, plants should not be paid for until delivery and unloading. This ensures that delivered material meets the specifications stipulated, and that the plants arrive in good condition. Plants that do not meet specifications should not be accepted, and sent back to the supplier with arrangements for replacement or refund. At delivery, woody material should be examined to ensure that it meets the following specifications:

- Size. The plants should meet the dimensions specified in the Planting Schedule.

- Form. The plants should not have broken branches, misshapen crowns, poor crotch angles or other defects in growth habit that may preclude long-term viability. This is particularly important for larger material.

- Vigor. The plants should have well developed branches and adequate buds. Bark should be pliable and green when scratched, without shriveling or discoloring. Leaves should not be discolored or desiccated, or show spotting indicative of potential disease or nutrient stress.

- Roots. B&B plants should have the specified root ball size. The root ball should be securely wrapped and competent without any signs of looseness, or the roots are likely to be damaged and/or desiccated. The ball should be moist. Container plants should be upright and firmly rooted. Inspect for circling, kinked or "J" roots that may girdle the tree. Rootbound plants that have roots protruding above the surface or through the drain holes, a leggy appearance, and/or are unusually large for the container shall not be accepted.

- Wounds and Diseases. The trunk should be free of abrasions, cuts, scars, knots and/or sunscald injury. There should be no insect egg masses or fungi on the branches or trunk.

At delivery, herbaceous material should be examined to ensure that it meets following specifications:

- Size. The plants should meet the dimensions specified in the Planting Schedule.

- Vigor. The plants should have well developed branches. Leaves should not be discolored or desiccated, or show spotting indicative of potential disease or nutrient stress.

3.9 PLANTING PRACTICES

Planting practices include site preparation, planting layout, storage of material prior to planting, planting timing, and planting procedures. These planting specifications are very important. Planting specifications should detail these aspects, and the maintenance practices to be followed. These specifications should be amended as required by the type of material and method of installation chosen by the designer and incorporated into the plan drawings as notes so that all parties are clear as to their responsibilities.

3.9.1 Site Preparation

Proper site preparation is perhaps the most important aspect of successful seed establishment. Chapters 1 and 2 detail the proper composition and construction procedures for soils in Green Technology BMPs. The site must be prepared to meet the specifications as discussed in those sections.

In addition to the soil specifications, seeds and rootstocks of noxious weeds and plants lying in the soils must be controlled. Generally, the best way to achieve this is by a preplanting application of the appropriate herbicide. This is best accomplished by having the BMP graded to final grades and left dormant to allow weeds in the topsoil to grow up to height of at least 6 inches. A nonspecific herbicide with a low toxicity and high adsorbance to soils, such as Round-Up™, can then be applied to control these weeds.

If particularly persistent broad leaf woody plants are present, a broad-spectrum herbicide with residual ground activity such as Transline™, Stinger™ or 2,4,D may be required. Herbicides are most effective if repeatedly applied during an entire year before planting, however, this regimen is unlikely for most BMPs. It cannot be overemphasized that every noxious plant rootstock must be eliminated, since those that may remain will seriously outcompete any planting in short order.

As a broad spectrum nonspecific herbicide that is quite nontoxic, Round-Up™ is most suitable for BMPs where it could be transported into receiving streams if washed off before it is absorbed by the plants. Rodeo™ is glyphosate formulation specifically formulated for wetland use. If properly applied, it is effective on annuals, perennials and turf grasses. For best results on turf grasses, Roundup™ should be applied in the fall after mowing the grass low and allowing it to regrow several inches. Even better results are obtained by adding Plateau™, a targeted herbicide with residual postemergent activity that does not kill many of the herbaceous species listed in Tables 3-1 and 3-2. Plateau™ can also be applied after emergence to control many noxious weeds. Very good results have recently been achieved using Plateau™ in meadow establishment projects. More specific information on listed plants should be obtained from the manufacturer. Any herbicide must be applied by trained and certified personnel following the manufacturer's label specifications.

As an alternative to herbicides, repeated mowing can exhaust the root stores of carbohydrates in many noxious species. However, it is rarely as effective as herbicides. Where a total eradication is required, as in the case of meadow establishment, repeated mowing should be used to weaken the target weeds before a final herbicide application. This uses less herbicide, and is most effective.

3.9.2 Planting Layout

After final site preparation prior to planting, the site must be marked so the planting crew can put the right plant in the right place. In laying out the site, it is not necessary to conform rigidly to geometry set forth in the planting plan. Plants should not be placed where roots, stumps, hummocks, depressions and gullies will interfere or create less than optimal conditions.

Usually, a specific marker is used to delineate each plant at each location. This approach is necessary for high visibility sites. A variety of markers can be used. Spray paint can be rapidly applied to the ground, but this method has minimal ability to convey species selection. Prelabeled for species, flagged wires color coded to the plant list can be individually placed by the designer.

3.9.3 Storage of plant material

After delivery, plant material should be stored on site in a moist shaded location prior to and during planting. The root balls of B&B stock should be thoroughly watered, and kept moist with a covering of peat moss, straw or sawdust. Container material is less susceptible to moisture stress and will store well if properly watered.

3.9.4 Timing of Planting

Deciduous trees and shrubs are best planted in the early spring before bud break in April. This ensures the longest season for root growth and gives the plant a chance to establish feeder roots prior to the moisture demands of the summer growing season. While less than optimal, planting can extend into late May in the moist conditions found in BMPs. Evergreens can be planted with good results before the new growth is fully extended in May. Planting later in the growing season will subject plants to moisture stress, unless proper care is taken to ensure adequate moisture in the root zone.

Warm season grasses should be planted in the spring well after all threat of frost has passed, and weeds can be controlled with a final preplant herbicide application. In Delaware, the month of May is considered the best for warm season grasses. Warm season grasses can also be planted in the fall and early winter after any threat of a warm spell germinating the seed has passed. While this better stratifies the seed, it precludes weed control in the spring when the seedlings emerge. This can result in more weed problems in the initial stand, although Plateau™ can control many weeds after germination. Fall planting is considered better for forbs.

Evergreens can be planted early in the fall after the heat of summer is past. Most deciduous trees can be planted later in the fall after leaf drop, since their roots will continue to grow until the soil temperature falls below 45 degrees. However, the ground must have adequate moisture, or a severe winter will kill the trees. Many oaks are listed as fall hazard plants, so they should be planted only in the spring. Winter transplanting is possible if the soil around the tree to be transplanted is not frozen, and the planting area is mulched enough to prevent freezing through the winter.

3.9.5 B&B Tree Planting Procedures

Balled and burlapped (B&B) stock should never be picked up by the trunk or dropped, as this will damage the root ball. To move B&B stock during planting, the root ball should firmly cradled. The planting hole should be twice the width of the root ball, and no deeper than the diameter of the root ball. To dig the planting holes, a tractor mounted augur can be used to drill a 24 inch diameter hole, which can then be expanded to the proper width in a saucer shape. The bottom must be loosened up to eliminate smearing by the augur. It is better to dig to a shallow depth, and hand dig to the depth required in proportion to the root ball. Soil amendments are not recommended, since few roots will grow beyond the amended soils. All sod should be discarded.

The root collar should be placed at the same level as the original soil; if the hole is overdug and backfill is necessary, the tree should be placed at least an inch or two higher to allow for settlement. After placement of the tree, completely remove any wire baskets and twine. Remove as much burlap as possible without damaging the root ball by cutting it down to where the root ball rests on the native soil.

Work the backfill around the root ball, firmly compacting in place to avoid any air pockets. Fill up to original grade with the balance of the soil, compact and water. Fill in any spots that settle, and place excess soil in a ring around the tree to retain water. A mulch of wood chips and/or geotextile fabric should be placed in a 3 to 4 foot diameter circle around the tree to inhibit grass and herbaceous competition. Avoid placing organic mulch directly against the trunk, as this will harbor insects and rodents that may damage the tree. Broken and diseased branches should be pruned.

3.9.6 Container Planting Procedures

For container material, the planting hole should be twice as wide and deep as the soil in the container. A portable or tractor mounted augur can be used to drill the planting hole, or it can be hand dug. Carefully cut the container away from the plant to expose the roots. Where size, soil texture and rooting density permits, plants can be removed from the container by turning it upside down and pulling the container off in an upward direction. (This is appropriate only if the soil remains firmly attached to the root system.) Where the soil is very loose, the container can be cut away after placing it in the hole, and the bottom slid out from under the plant.

After exposing the roots, look for circling roots. Where small, they can be teased apart and spread out in the planting hole. Where large and extensive, the roots will have to be cut in several vertical cuts to prevent girdling the plant, setting them back substantially. These plants should be rejected, as cutting roots introduces soil borne diseases. Backfill the planting hole, water and mulch as in B&B plants.

3.9.7 Herbaceous Plug Planting Procedures

Herbaceous plants can be planted by two methods, plugs and seed. Plugs are small seedling plants that are inserted individually into the desired location. Plugs are typically planted in a hole some 3 to 6 inches deep, depending upon the root length. Plugs can be rapidly planted by untrained volunteers using a trowel or dibble bar to open the planting hole and pushing the dirt back behind the trowel. Plugs are quite hardy and will become well established rapidly, provided that adequate moisture is provided during the root establishment period.

The only drawback with plugs is their cost, which ranges from $0.25 to $1.50 each, depending upon size, species and supplier. At a planting density of 1 to 4 plugs per square yard, the installed cost of a dense herbaceous cover can exceed $0.50 per square foot, or $20,000 per acre. This can be a large sum in a long bioswale. Plugs are most effective for perennials used to provide diversity in a grass planting. However, since plugs of herbaceous forbs will not be able to compete if the grasses are well established, plugs should only be used during grass establishment.

3.9.8 Herbaceous Seed Planting Procedures

The far more cost-effective method is to plant seed. First and foremost, good seed quality is required. Seeding rates are based upon Pure Live Seed (PLS), so certified seed should be used, and its certification should be current. Year old seed can be used in certain cases if it has been stored properly and has no musty odor.

Seeds can be planted by broadcast methods, an air seeder, a hydroseeder, or a grain drill specially adapted for grasses. Broadcasting is the easiest and least expensive method, but because the seeds often lie on the surface, germination rates are much lower than optimal. This can require twice the seed compared to using a properly adapted grain drill. It is most appropriate in situations where access for other methods is less feasible. Since seeds differ so much in weight, size and density, the lighter chaffier seeds do not travel nearly as far as heavier seeds. Adjusting the end gate for proper seeding rate can thus be very difficult. Therefore, broadcasting should be done in two passes, one perpendicular to the other.

A more reliable method is to use an air seeder that uses forced air to distribute the seed through booms. For best results with either of these methods, the ground should be prepared by roughening it up with rakes or cultivators. Following broadcasting, a cultipacker is used to compact the loose dirt around the seeds. The planting depth should not be deeper than one-quarter inch.

For either method, a carrier must be used to move the seed through the equipment. For air seeders, use potash or pelletized lime at a rate of 60 to 100 pounds per acre. For broadcast seeding, wheat at 40 to 60 pounds per acre in the fall, or oats at 32 pounds per acre in the spring works well. Care must be exercised in not using too much of these annuals, as they can take over the planting if not controlled by mowing after germination of the grasses. Annual Rye is not recommended since it crowds out the seedlings and may not winter kill in Delaware. Barley is also recommended as a nurse crop that does not compete with the grasses.

Hydroseeding adds a mulch and tackifier to the seed, promoting germination. Proper ground preparation as for broadcasting is necessary for hydroseeding. It is still less effective than drilling, since many seeds are still too shallow for optimal growth. Therefore, the planting rate should be higher than that required for grain drills. A recent innovation in hydroseeding called terraseeding adds compost to the mixture. This substantially increases cover, germination and seedling vigor, but it requires substantial amounts of compost and is considerably more expensive. It has been used very effectively for cool season grass plantings in tough situations.

The most effective method is the use of a grain drill specially designed for warm season grasses. Truax™ manufactures a drill specifically for warm season grasses, but it is not commonly available. One can rent a Truax™ drill from the County Conservation Service, but it may be difficult to find at seeding time if there are many projects occurring simultaneously. Other grain drills can be adapted by changing the coulter discs and seed wheels. However, even an adapted drill cannot plant all of the many different types of grass seed, even when debearded seed is used (which is expensive). If a cracked corn carrier is used at a 2:1 ratio, such drills can be used with some success, but two passes are required since the carrier lowers the seeding rate. There is also still the problem with “float” of the lighter seeds in the seed box, so the seed must be agitated frequently to prevent stratification. These drills must also be carefully calibrated to ensure that the seed is applied at the proper depth and planting rate.

3.10 ESTABLISHMENT AND MAINTENANCE MEASURES

The most critical period during BMP installation is the time from when plant material is newly planted until it is well established. Ongoing establishment and maintenance practices are necessary to ensure establishment of a thriving material, particularly where herbaceous plant material is seeded. Even where large plants are involved, herbivory, invasion by exotic species, and competition by undesired herbaceous forbs and grasses will be a continuing problem. Therefore, maintenance practices are necessary to ensure the long-term effectiveness of a BMP.

3.10.1 Woody Plant Maintenance

In the early stages of tree establishment, competition for nutrients by adjacent grasses and forbs can substantially inhibit growth. Release from herbaceous competition has been demonstrated as a most cost effective method to accelerate the growth of woody plants. An alternative to mowing is the use of mulches to control weed and forb growth. A well-aged hardwood mulch will not compete for nutrients, and will retain moisture in the root zone of plantings.

However, annuals and perennials easily root within such organic mulches as they decompose, increasing herbaceous competition. Geotextile fabrics reduce the rooting ability under organic mulches. However, plants in the humid east thrive in organic mulches, and their feeder roots can penetrate the underlying geotextile to obtain required nutrients and moisture. Using exposed geotextile fabric without mulch solves this problem, but then the uncovered fabric must be stapled down to prevent being entangled in mowers, blown away, or be washed away during floods.

Herbicides can control herbaceous competition without the preceding drawbacks, particularly where tree shelters are present to isolate seedlings from control measures. Post emergent application of a mixture of Oust™ and Accord™ controls grasses and broadleaf annuals and perennials. A clear zone 4 feet in diameter will substantially promote the vigor of the seedlings compared to no treatment. Two to three years of control will successfully release the seedlings from grass and forb competition.

Outside of the clear zone, selective control of broadleaves by Escort™ will direct succession to warm season grasses, which have a high wildlife value, and pose less competition for desired woody species. Herbicide application is less expensive and more flexible over the establishment period than repeated mowing, and will result in more rapid establishment of the woody plants.

3.10.2 Herbaceous Plant Maintenance

Herbaceous plant maintenance measures can be divided into two general categories, normal annual procedures, and specific practices during and after establishment to ensure that invasive plants are controlled and that the plants specified remain vigorous.

3.10.2.1 Herbaceous Plant Annual Practices

For cold season turf grasses, regular mowing is required to maintain vigor and promote a dense stand. Fertilizer applications should not be required; if they are, it should only be applied in the fall. Since turf is not recommended for Green Technology BMPs and there is a substantial literature of turf maintenance, this literature should be consulted for more specific details.

In the case of warm season grasses and perennials, annual practices comprise mowing or cutting the herbaceous perennials and grasses in the springtime just before new growth appears. This ensures that a continual stand of vegetation is present for filtering runoff through the winter months. Even though the stalks, stems and blades of herbaceous plants may be dead during this season, it is their physical presence that is most responsible for BMP removal efficiencies. These blades and stems also provide winter interest in a well-established meadow, bioswale or bioretention facility. For these reasons, fall cutting is discouraged, unless required for other reasons.

Cuttings should not be left to rot where they grew, rather they should be ground into a mulch that can be composted outside of the facility. While grazing and fire can also be used to eliminate biomass, neither of these alternatives is likely to be acceptable for Green Technology BMPs used in a developed setting.

3.10.2.2 Herbaceous Plant Establishment Practices

Following site preparation procedures as discussed in Section 3.9.1 and the planting procedures discussed in Section 3.9.8, ongoing maintenance is critical in the early years of stand establishment. Still an emerging field, controlling weeds during and after establishment is imperative for sites where warm season grasses and perennials are to be established from seed. While these meadow plants are most vigorous in the long run and will keep out weeds once they are well established, weeds and invasive plants can aggressively colonize a site during their establishment. Unless weeds are controlled during this period, the desired plants will not become established.

After proper site preparation, there are several methods to selectively assist the desired plants. Mowing is the simplest method. It reduces the shade pressure from weeds, and keeps weeds from producing seed. Only the blade tips of the grasses should be cut, producing more basal growth. Note that the growing zone of warm season grasses is several inches above the ground. It is imperative that this growth zone not be cut, or root reserves of the seedlings will be exhausted in replacing it, diminishing stand vigor. Therefore, as the stand grows, the cutting height must rise accordingly.

The adage is “mow early, mow often and mow high” for best results. Eventually, the grasses and forbs will be clipped, but if the mower is set at height of 8-12 inches, this should not be a problem once the seedlings are that high. To ensure stand vigor, the last cutting should not occur less than 45 days before the last frost. This ensures that the plants will have stored adequate carbohydrates for new growth in the spring.

The best equipment for this purpose is a sicklebar mower set to height above the emerging grass seedlings. Unlike rotary mowers, sicklebar cuttings drop cleanly instead of clumping. If possible, clipping should be delayed until midsummer to allow time for ground-nesting birds to complete incubation. However, most circumstances require earlier clipping to ensure adequate control of the weeds and protection of the seedlings.

Herbicides are emerging as a most effective method for controlling weeds and invasives on Green Technology BMPs. Since meadow establishment is still a new field, few herbicides have been specifically formulated to address its needs. However, some manufacturers provide a “Minor Use Registration” that supplements the list of typical crop species appropriate for specific herbicides. The manufacturer should be consulted for more information as their test results come in. Proper use of herbicides requires a systematic approach, extensive knowledge of the plants involved, and training in how to apply herbicides properly. Any herbicide must be applied by trained and certified personnel following the manufacturer’s specifications.

As mentioned above, Plateau™ has recently been introduced specifically for warm season grasses. Escort™ and Oust™ are also listed for releasing warm season grasses resistant to their effects. Plateau™ is very effective when applied after emergence to control many noxious weeds. Not only is it effective for controlling weeds, its persistence suppresses weed germination for months after application. While it may also temporarily suppress growth of certain grasses and forbs, release from weed competition results in much better stand vigor in the long run. When Plateau™ is used as a post-emergent control, it is so effective that a third year stand can be achieved in only one year. This is due to the fact that there is no competition from a nurse crop or any weeds, so the grass put down considerable root growth in the first year.

The only drawback is that it can eliminate some desirable perennial forbs, so it cannot be used at high concentrations as a post-emergent herbicide where forbs are included, at least not until they are well established. There has been very little success in over-seeding forbs (or even planting plugs) once grasses have become established, so secondary planting is much less effective than incorporating forb seeds in the initial mix. As mentioned in Section 3.9.1, herbicides should be used to eliminate problem weeds as much as possible before planting. This avoids the problem of herbicides affecting desired species after planting.

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APPENDIX A:

SUMMARY OF BMP STANDARDS

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FILTER STRIP DESIGN CRITERIA

REFERENCE	MAXIMUM DRAINAGE AREA	PRETREATMENT MEASURES	OVERFLOW	FLOW DEPTH	SLOPE	LENGTH
British Columbia (MWLAP, 2001)		Level spreader; filter strip can also act as pretreatment for larger bmp				
Vermont (Vermont Stormwater Management Manual)		Pea gravel diaphragm, pervious berm	>6 inch head weir on berm		2% - 6%	
Washington (WSDE, 1999)		Gravel flow spreader. Also, can be used as pretreatment for biofiltration swale	Weir, settling basin, or equivalent as needed	1 inch maximum	15% maximum	Sufficient to achieve hydraulic residence time
Claytor & Schueler (CWP, 1996)		Pea gravel diaphragm 12" wide minimum, 24" deep minimum. Sand/gravel pervious berms			<4% longitudinal slope	

FILTER STRIP CONSTRUCTION AND MAINTENANCE CRITERIA

REFERENCE	VEGETATION	SOIL MEDIA	PHYSICAL MAINTENANCE	VEG. MAINTENANCE
BC Ministry of Land, Water, and Air Protection	Erosion resistant, salt & metal tolerant grass species	Native soils with >10% organic content or 50mm compost	Correct erosion problems, remove sediment	Mow grass, remove clippings. Avoid fertilization unless absolutely necessary
VT Manual	Flood and drought resistant grasses	In berm: sand per dry swale sand, gravel AASHTO M-43. Mix with Approx 25% loam to support grass cover		
WA Manual	Drought tolerant, minimum mowing grasses; dense, low growing groundcover species	4" minimum topsoil over undisturbed native soil	Remove leaves, litter, and oily materials. Fertilize, reseed, resod, & regrade.	Mow grass to <4 inches
OR Manual	Native wildflowers, grasses, and ground covers designed not to require mowing		Repair erosion	Should not need mowing more than once or twice annually
Claytor & Schueler (CWP, 1996)	Flood/drought resistant grasses	Dry swale: permeable soil mixture. Wet swale: undisturbed native soil		

BIOFILTRATION SWALE DESIGN CRITERIA

REFERENCE	MAXIMUM DRAINAGE AREA	PRETREATMENT MEASURES	PRETREATMENT QUANTITY	ON-LINE ?	OVERFLOW	FLOW DEPTH	SLOPE	LENGTH	WIDTH	SIDE SLOPES
Vancouver (GVSDD, 1999)	From 2.5 acres at 90% imperv to 5 acres at 35% imper	Weir, riprap pad, level spreader, stilling basin		Yes		<4"		>100 feet	2 - 8 feet	3:1 - 4:1
Vermont (VTDEC)	1.52 acres	Pea gravel diaphragm and curtain drain	10% of WQv	Yes	Not required	Use Manning's equation		2200 feet	2 - 6 feet	>3:1
US EPA (EPA 5)	< 5 acres	Pea gravel diaphragm, small forebay							2 - 8 feet	<3:1
Minnesota (MN USS)		Forebay behind check dam, riprap, pea gravel diaphragm	.05" per impervious acre	Yes		9" avg			2 - 8 feet	<3:1
British Columbia (MWLAP, 2001)					Designed to pass over weir and out of swale	Not to exceed height of bottom vegetation				
Boise Storm Water Plant Materials Resource Guide						Use Manning's equation				<5%
Massachusetts (MA DEP, 1997)		Sediment forebay with check dam or pea gravel diaphragm			V-notched weir in check dam, if wet swale				2 - 8 feet	<3:1
Washington (WSDE, 1999)	<10 acres	Flow spreader, riprap or quarry spall				4-5 inches		>100 feet	2-10 feet	3:1 or 4:1
New Jersey (NJ DEP, 2000)	<25 acres	Pea gravel diaphragm & inlet trench, filter strip, or forebay	.05" per impervious acre of drainage			12" avg, 18" max		Variable based on capacity, slope, velocity, vegetation, soil & site moisture	>15 ft <30 ft top width	<2:1
Oregon (CPES, 1999)						4 inches		Total area = approx 500 sq ft	Total area = approx 500 sq ft	
Delaware (SCD, 1993)	Avg 2 acres					1" design, .4" maximum		>200 feet	<8 feet	>3:1
Maryland (MDE, 1999)	Residential or very small impervious area	Check dams, pea gravel diaphragm, gentle side slopes	.1 inch of runoff per impervious acre storage		V-notch weir for wet swales	Maximum 12" at midpoint and 18" at downstream end point of channel	<4%		2 to 8 feet bottom width	2:1 or flatter (3:1 minimum)
Claytor & Schueler (CWP, 1996)		Pea gravel diaphragm, forebay behind check dam	Forebay volume: .05" per impervious acre of drainage	Yes	V-notch weir for wet swales	4" maximum	1% min., 4% max.	Length necessary for 10 minute residence time	2 - 8 feet	<3:1

BIOFILTRATION SWALE CONSTRUCTION CRITERIA					BIOSWALE MAINTENANCE CRITERIA	
REFERENCE	VEGETATION	SOIL MEDIA	CHECK DAMS	UNDERDRAINS	PHYSICAL MAINTENANCE	VEG. MAINTENANCE
Greater Vancouver Sewerage & Drainage District	Turf grass or native vegetation	Sandy loam topsoil <20% clay	Identical to DNREC (simple)		Debris removal as needed	Mow
Vermont (VTDEC)	Flood/drought resistant grasses	Moist to well drained soil	Pressure treated or natural wood	Dry swales only: 6" perf pvc pipe in gravel		
US EPA (EPA 5)	Dense, stiff grasses with broad leaf surface. In wet swales, use appropriate wetland plants	On site unless dry swale, then use fabricated soil bed	Simple	Perf pipe in gravel, if dry swale design	Remove accumulated solids, debris, and litter	Mow grass, not to exceed 6 inches in height
MN SUS Manual	Native grasses	Sand/soil mix, or on site if highly permeable	Timber or concrete	Perforated pipe in gravel		Periodic as needed
BC Ministry of Water, Land and Air Protection	Slopes: turf, bottom: wetland vegetation	Sandy loam topsoil <20% clay	With or without low flow openings	Suitable for dry swales in developed areas	Remove sediment over vegetation with flat shovel,	mow and re-seed as needed
Boise Storm Water Plant Materials Resource Guide	Evenly distributed, close-growing, water-tolerant grasses	Highly permeable, low clay content			Remove sediment at inflow	Mow grass 3 - 9" high
MA Manual	Fine, dense-growing grasses	50% sand, 50% loam	Build with inlet pipe		Remove debris as needed	Mow, reseed
WA Manual	Mix of fescue, seaside and redtop grasses	Sandy loam and compost mix; <10% clay		>6 inch rock trench length of swale w/ 6 inch perf pipe	Remove sediment and debris as needed	Mow
NJ Manual	See Standards for Soil Erosion and Sedimentation Control in NJ	Sand/organic matter mix		Perf plastic pipe, stone, or curtain drain if consistently inundated	Inspect pretreatment area and bioretention layer	Mow grass to 3 - 6 inches. Maintain grass health & thickness without fertilizer & pesticides if possible
OR Manual	Erosion, drought & inundation resistant grasses and groundcover species that do not require frequent mowing					Mow grass to no less than 6 inches; should not be required more than once or twice annually
Sussex County, DE	Water resistant grass seed mix or wetland species					
Maryland (MDE, 1999)	Mix of sod-forming grasses that can withstand inundation	20 - 30" permeable soil mix	Optional; place as specified; natural or pressure treated wood; no creosote	Wet swale: none. Dry swale: 4" perforated pipe in 6" gravel layer	Remove sediment when 25% of WQv is exceeded	Dry swale: mow to maintain grass height at 4 - 6 inches. Wet swale: infrequent mowing only
Claytor & Schueler (CWP, 1996)	Select based on anticipated hydric conditions	Soil: USCS: ML, SM, or SC. Moderately permeable. Sand: ASTM C-33	Pressure treated rot resistant wood, i.e. black locust	6" gravel/pipe	Inspect pretreatment area; remove sediment build-up, correct erosion, remove trash & debris	Mow grass to 3 - 4 inches. Wet swales require mowing less often.

BIORETENTION DESIGN CRITERIA

REFERENCE	DRAINAGE AREA, LOADING	PRETREATMENT MEASURES	PRETREATMENT QUANTITY	ON-LINE?	OVERFLOW	PONDING DEPTH	MEDIA DEPTH	LENGTH	WIDTH	SIDE SLOPES
Prince George's County DER, MD	Bioretention area is 5% to 7% of developed area	Filter strip, gravel diaphragm, optional >1 inch sand bed	N/A	No	Berm redirects into swale	<6 inches	>4 feet	>30-40 feet	>10-15 feet	>3:1
Pennsylvania (PACD, 2001)	Identical to PGDER	Buffer strip, optional sand bed	Identical to DNREC	No, if drainage area > 5 acres	Identical to PGDER	Identical to DNREC	Identical to PGDER	Identical to PGDER		Identical to PGDER
FX Browne, Inc		Identical to PGDER	Identical to PGDER	Identical to PGDER	Identical to PGDER	Identical to PGDER	Identical to PGDER	Identical to PGDER		Identical to PGDER
US EPA (EPA 2, EPA 3, EPA 4)	.25-1 acre	Identical to PGDER	Identical to PGDER	Not recommended due to risk of pollutant release	Identical to PGDER	Identical to PGDER	Identical to PGDER	Identical to PGDER		Identical to PGDER
New York (NYSDEC)	<10 Acres 75% ofWQV	Filter strip, Level Spreader and gravel diaphragm, 6" drop at inlet	for 25% of WQV if less than 75% impervious	No, if part of conveyance system	Yes	< 6 inches	4.0 feet	Sized according to Darcy's law		
Delaware (Raymond Green)	Surface area x 5% x Rv	Filter strip, gravel diaphragm, optional >=1 inch sand bed	n/a	No	Berm redirects into swale	< 6 inches	> 4 feet	> 40 feet	>15 feet	< 3:1
Vermont (VTDEC)	Af = (WQv) (df) / (k (hf + df) (tf))	Filter strip, < 1% slope, to convey peak floww/o erosion, pea gravel diaphragm and curtain drain	for 25% of WQv if less than 68% impervious	Yes, if facility must pass 10-year event	6" head overflow weir if necessary	< 6 inches	2.5 to 4 feet	Length: Width = 2:1		3:1
LA Bioretention Manual	Identical to PGDER	Identical to PGDER	Identical to PGDER	Identical to PGDER	6" head emergency overflow weir	<6 inches or <1 foot if underdrain system used	>4 feet	>40 feet	15 - 25 feet	Identical to PGDER
Growing Greener in Your Rappahannock River Watershed	2000 sq ft per impervious acre	Filter strip		No		6 to 9 inches	>3 feet			
Georgia (ARC, 2001)	Identical to VT Manual or >1 acre	3% Filter strip, 60' swale, 30' swale		No	14'x28' overdrain, 20' emergency weir w/ 6" head	<6 inches	>5 feet	Identical to VT Manual		>3:1
NC Cooperative Extension Service (Hunt and White)	5-7% of drainage area, or to hold runoff from first 1" of rainfall			No	Yes, pipe or overflow box	6 to 12 inches; 9 inches std	3-4 feet w/ 2-4 “hardwood mulch	Sized according to Darcy's law		
Vancouver (GVSDD, 1999)	Identical to PGDER	Filter strip, or grass channel w/ pea gravel diaphragm		No	Pea gravel curtain drain	<.15 meters	>1.2 meters	>5 meters	>3 meters	
Idaho (IDDEQ, 2001)	Identical to PGDER			No		Identical to PGDER	Identical to PGDER	Surface area <1 acre		<4% grade

BIORETENTION DESIGN CRITERIA

REFERENCE	DRAINAGE AREA, LOADING	PRETREATMENT MEASURES	PRETREATMENT QUANTITY	ON-LINE?	OVERFLOW	PONDING DEPTH	MEDIA DEPTH	LENGTH	WIDTH	SIDE SLOPES
Stormwatercenter.net	<5 acres	Grass channel, filter strip, or pea gravel		No	Partial exfiltration through gravel curtain drain	6 to 9 inches		Total size 5-10% of impervious area		5% grade
Minnesota (MNUSS)	<2 acres	Identical to PGDER	To remove 25-30% of sediment loads	No	To storm drain system for heavy storms	6 to 9 inches	>4 feet	Total size 5-10% of drainage area		5% grade, or 3:1
US EPA (EPA 1)	5 acres	Curb inlet to municipal storm drain				Approx 6 inches	4 feet	38 feet	12 feet	
New Jersey (NJDEP, 2000)	Identical to PGDER	Filter strip, pea gravel diaphragm		No	Pea gravel curtain drain, storm drain inlet above max ponding depth	<6 inches	3-4 feet	>40 feet	>10-15 feet	Identical to PGDER
Washington (WSDE, 1999)		Filter strip		No	Notched weir		3-6 feet	Sized according to Darcy's law		<3:1
Claytor & Schueler (CWP, 1996)	>1 acre. Will vary depending upon volume of stormwater runoff to be filtered.	Sand/gravel diaphragm, filter strip	Not recommended due to risk of inflow point erosion, mulch disruption, and negative effects on plant material. If on-line system is used, precautions must be taken to protect these components, and drainage area must not exceed .5 acres		Pea gravel curtain drain, overflow storm drain inlet above max ponding depth	<6 inches	>4 feet	>15 feet; sized according to Darcy's law; 3-4% of runoff area size	>10 - 15 feet; sized according to Darcy's Law	<4:1
EQRI, 2001										
EPA Manual	No more than a few acres	Filter strip, pea gravel diaphragm		No		Identical to PGDER				<3:1
Maryland (MDE, 1999)	<10 acres	Stone diaphragm, grass filter strip, optional gravel curtain drain, optional sand layer	>25% of WQv	No, if runoff is delivered by storm drain pipe or is along main conveyance system	Catch basin and outlet pipe	6 - 12 inches	Mulch: 2 - 3 inches. Planting soil: 2.5 - 4 feet. Underdrain gravel jacket: 8 inches	Varies, but follow length:width = 2:1		
Meridian Consulting Engineers, LLC		Pea gravel diaphragm, curtain drain, filter strip		No		6 inches	3 feet	Approx 80 feet	15 foot top width, 8 foot bottom width	4:1 maximum

BIORETENTION CONSTRUCTION AND MAINTENANCE CRITERIA

REFERENCE	VEGETATION	FILTER MEDIA	CONSTRUCTION MEASURES	UNDERDRAINS	MONITOR-ING	STRUCTURE MAINT.	VEG. MAINTENANCE	INSPECTION FREQUENCY
Prince George's County DER, MD	Native Plants: Trees, Shrubs, Herbaceous Cover	Ground cover/mulch, planting soil, sand bed		Pipe in gravel, 3 foot filter cloth below				
Pennsylvania (PACD, 2001)	Identical to PGDER	Identical to PGDER	Minimize compaction, soil lifts < 18 inches	Identical to PGDER		Clean out collector pipes	Monthly until plants established, then annually	
FX Browne, Inc	Identical to PGDER	Identical to PGDER		Identical to PGDER		None	Routine periodic maintenance	
US EPA (EPA 2, EPA 3, EPA 4)	Native species, resistant to pollutants, drought, & inundantion	Sandy loam, loamy sand, loam texture w/ 10-25% clay		Identical to PGDER			Inspect twice/yr, weed/mulch/treat as needed. Add alkaline as needed to reduce pollutant levels	
New York (NYSDEC)	Native Plants	Planting soil w/ mulch. Peat and compost freeze in winter		6" perf. Pipe in gravel				
Delaware (Raymond Green)	Native? Trees, shrubs, herbaceous cover	Ground cover/mulch, planting soil, sand bed	Minimize compaction, rototill 2"-3" sand at base, >12" soil lift	Identical to PGDER			Daily water 2 wks, mulch as needed, repair erosion monthly, replace dead veg biannually	
Vermont (VTDEC)	Native Species	Uniform mix planting soil, mulch, pea gravel diaphragm & curtain drain	Standard soil test & textural analysis, minimize compaction, > 12" soil lift	6" PVC pipe in 1/4" to 3/4" gravel, on 3 foot wide filter cloth	observation well per 1,000 sq. ft. surface area	Connect 2" - 5" stone window to gravel curtain drain		
LA Bioretention Manual	Terrestrial forest ecocsystem	Mulch, uniform mix planting soil	Identical to PGDER	Construct to PGC specs if infiltation rate <.5 inches/hr	Identical to EPA			
Growing Greener in Your Rappahannock River Watershed	Grasses, mulch, shrubs, trees	Mulch, coarse planting soil, sand bed					2 times/year: inspect/replace dead vegetation, add alkaline to soil	
Georgia (ARC, 2001)	Trees & shrubs w/o extensive root systems	Planting soil, stone		6" perf. Sch. 40 pvc pipe in 3' wide gravel bed	Observation well/cleanout drain			
NC Cooperative Extension Service (Hunt and White)	Drought and inundation-tolerant species			Corrugated plastic, 4" - 8" single-wall pipe in gravel or washed stone				

BIORETENTION CONSTRUCTION AND MAINTENANCE CRITERIA

REFERENCE	VEGETATION	FILTER MEDIA	CONSTRUCTION MEASURES	UNDERDRAINS	MONITOR-ING	STRUCTURE MAINT.	VEG. MAINTENANCE	INSPECTION FREQUENCY
Idaho (IDDEQ, 2001)	Trees, brush, broad leaf grass		Avoid compaction				As necessary to promote dense turf	Monthly
Stormwatercenter.net	Trees, shrubs, herbaceous to resist wet and dry conditions	Mulch, sand/soil matrix		Perforated pipe in gravel on filter bed			Identical to DNREC	
Minnesota (MNUSS)	Forest/grassland ecosystem to survive inundation & drought	Planting soil, mulch		Sand bed over filter fabric over corrugated pipe in gravel			Water, remulch, treat/replace as necessary; inspect/clean monthly	
US EPA (EPA 1)		50% sand, 20-30% topsoil, 20-30% compost		Pipe in 8" gravel bed				
New Jersey (NJDEP, 2000)	Native species	Hardwood mulch, planting soil 10-25% clay, 30-55% silt, 35-60% sand		6" perforated plastic pipe w/ 1/4" inflow holes on 6" centers, in 8" pea gravel bed, below 12'18" sand bed			Monthly inspection until plants established, then annual.	Monthly inspection until plants established, then annual.
Washington (WSDE, 1999)	Native plants	Sandy loam or loamy sand	Avoid soil compaction; use 12 inch lifts	Perf pipe in gravel				Semi-annual
Claytor & Schueler (CWP, 1996)	Simulate terrestrial forest community of native species. Include trees, understory, shrubs, herbaceous plants. Dense plant cover to treat stormwater runoff and withstand urban stresses from insect & disease infestations, drought, temperature, wind, exposure. Use 3-zone system in specifying plant material.	Mulch: <3 inch depth. Soil: sandy loam, loamy sand, loam, or loam/sand mix (minimum 35-60% sand, <25% clay)	Minimize compaction: use 12 - 18 inch lifts	4 or 6 inch perforated pipe in 8" gravel bed, maintain a 2 inch cover of gravel over pipe in lieu of filter fabric	One observation well/clean out pipe per ever 1000 sq ft	Pretreatment: annual inspection for clogging. Remove sediments. Replace diaphragm after 3-4 years if needed. Correct filter strip erosion. Inflow/overflow: annual inspection, remove sediment, trash & debris.	Soil: test for pH annually. Mulch biannually. Plant species: annual inspection, replace dead/diseased species; periodic pruning. Remove plant stakes after first growing season	Annual or periodic as needed
Vancouver (GVSDD, 1999)	Native terrestrial forest community	Sandy loam/loamy sand planting soil		>150mm perforated pipe in 800mm gravel bed		Periodic observation during wet season; life exp. 25 yr corr metal, 50-75 yr concrete	Inspect/repair at outset of rainy season & after significant storms, periodic landscaping	

BIORETENTION CONSTRUCTION AND MAINTENANCE CRITERIA								
REFERENCE	VEGETATION	FILTER MEDIA	CONSTRUCTION MEASURES	UNDERDRAINS	MONITOR-ING	STRUCTURE MAINT.	VEG. MAINTENANCE	INSPECTION FREQUENCY
EPA Manual	Native species: strong colonizers, perennials, species adapted to broadest possible ranges of depth, frequency, and hydroperiod. Use 3 zone depth system in selecting plants, with minimal number of species for each zone. Establish herbaceous plants before woody species.		Minimize compaction. Do not place into operation until drainage area has stabilized. Divert runoff if possible during vegetation establishment, or use sodding whenever possible.			Remove sediment, trash & debris. Replace filter media.	Mow grass to 2 - 6 inches. Stabilize vegetative cover to prevent erosion of side slopes.	Monthly and after large storms for first year; then semiannually
Maryland (MDE, 1999)	Native selection of trees, shrubs, and herbaceous materials; use specified hydric tolerance zones for plant selection; do not specify woody vegetation at inflow locations	Planting soil: uniform mix, free of objects larger than 2 inches; sandy loam, loamy sand, loam, loam/sand mix; 30 - 65% sand; <25% clay. Mulch: shredded hardwood only.	Minimize compaction; rototill 2 - 3 inches sand into base before backfilling sand layer; use 12 - 18" lifts to backfill soil; do not construct until drainage area has stabilized	6" perforated pipe in gravel, on 3' wide section filter cloth. Permeable filter fabric between filter media and gravel layer		Clean out sedimentation chamber when sediment depth exceeds 6 inches, and when drawdown time exceeds 36 hours. Remove trash and debris	Stake trees for first growing season only; fertilize only minimally; re-mulch annually where needed; replace dead/diseased vegetation; mow >3 times per growing season to maintain grass height of <12 inches	
Meridian Consulting Engineers, LLC	Trees: river birch, sycamore, willow oak (9). Shrubs: highbush blueberry, inkberry, spicebush, bayberry (11). Perennials: cardinal flower, tall coneflower (>15). Grasses: broomsedge, switchgrass (>15).	Planting soil: uniform mix sandy loam, loamy sand or loam. Mulch: shredded hardwood, aged 6 to 12 months.	Test soil for pH, phosphorus, potassium, organic matter, soluble sites. Minimize compaction using 12 - 18" lifts. Do not use heavy equipment within basin. Do not construct until drainage area has stabilized.	6" PVC pipe placed on 3' wide section filter cloth, in gravel.		Repair erosion, remove old mulch and remulch	Remove/replace dead or diseased plants, treat diseased trees/shrubs, replace stakes/wires	Soil: monthly erosion inspection, as needed. Vegetation: annually or biannually

INFILTRATION STRUCTURE DESIGN CRITERIA

REFERENCE	DRAINAGE AREA, LOADING	PRETREATMENT MEASURES	PRETREATMENT QUANTITY	ON-LINE?	OVERFLOW	DEPTH TO SHWT	MEDIA DEPTH	INFILTRATION RATE	GEOTEXTILE	STONE
unknown			Required			>4 feet		use 50% of min. infiltrometer rate at design depth, location		
Wyoming (WYDEQ)	Not to exceed 5 acres	Sump pit, swale w/ check dam, or plunge pool; buffer strip			Berm	>3 feet below trench bottom	3 - 8 feet	>0.5 inches per hour	Filter fabric 1 foot below surface and lining sides	1.5 - 2.5" diameter clean aggregate or bank run stone
Vermont (VTDEC)	<5 acres	Pea gravel filter, plunge pool, grass channel	1/4 of runoff volume	No	Slot overflow weir, vegetated overflow channel, grassed berm	>4 feet	>4 feet	>.5 inches per hour through undisturbed subsoils	Class C or better; must conform to trench irregularities and allow for a 6" minimum overlap	Rounded, washed bank gravel; must meet AASHTO Std. M-43, Size Nos. 2 or No. 3
New Jersey (NJDEP, 2000)		>20 foot grass buffer strip around perimeter, detention basin				>3 feet		Design to 1.25" in 2 hours	Filter fabric lining bottom and sides of trench	
Minnesota (MNUSS)	<2 acres	Grit chamber, swale w/ check dam, filter strip, or sediment forebay	To remove 25 - 30% of sediment loads		Grassed berm	>3 feet	4 feet	>.5 inches per hour	Filter fabric lines sides & bottom; layer 1 foot below surface to trap debris; must allow for 12" overlap	1.5 - 2.5 inch diameter clean stone
Claytor & Schueler (CWP, 1996)	<5 acres	Plunge pool, filter strip, grass channel, or sedimentation vault			Grassed berm		3 - 8 feet	Runoff must exfiltrate through undisturbed subsoil >.5 inches per hour	Class C or better	Washed bank run gravel aggregate, 1.5 - 2.5 inch diameter; must meet AASHTO Std. M-43, size 2 or 3, in 12 inch lifts
OMM, 1997		Required		No		>4 feet			Filter fabric with 12 inch overlap	
New Jersey (NJDEP, 2000)	Maximum 1 acre per structure	Swale or 20 foot buffer strip			Grassed berm	>3 feet		>.5 inches per hour		
New York (NYSDEC, 2001)	Identical to CWP	Identical to CWP	Identical to CWP	Identical to CWP	Identical to CWP	>4 feet	Identical to CWP	None if underdrain system is used, otherwise >0.5 inches per hour	Identical to CWP	Identical to CWP

INFILTRATION STRUCTURE DESIGN CRITERIA										
REFERENCE	DRAINAGE AREA, LOADING	PRETREATMENT MEASURES	PRETREATMENT QUANTITY	ON-LINE?	OVERFLOW	DEPTH TO SHWT	MEDIA DEPTH	INFILTRATION RATE	GEOTEXTILE	STONE
Florida (FLDEP, 1999)		Sediment trap or filter strip		No	Weir or smart box	>4 feet	>2 feet		Woven or non-woven synthetic filter fabric	Clean, washed stone aggregate: granite, pea gravel, or river rock; avoid limestone
Maryland (MDE, 1999)	<5 acres	Grass buffer strip, grass channel, sediment forebay, concrete level spreader	>25% of WQv	No	Berm	>4 feet	3 - 8 feet	>0.5 inches per hour	Class C or better, directly beneath pea gravel filter layer and lining sides. Must have greater permeability than parent soil	1.5 - 2.5 inch diameter clean stone - bank run gravel preferred
Washington (WSDE, 1999)		Filter strip, sediment trap		No	Metal weir, overflow spreader	>3 feet	>4 feet		Filter fabric lining sides	1.5 - 1.75 inch diameter washed rock

INFILTRATION STRUCTURE CONSTRUCTION CRITERIA					INFILTRATION STRUCTURE MAINTENANCE CRITERIA			
REFERENCE	CONSTRUCTION MEASURES	VEGETATION	FILTER MEDIA	UNDERDRAINS	MONITORING	STRUCTURE MAINT.	VEG. MAINTENANCE	INSPECTION FREQUENCY
unknown	Mark in field, verify soils, dry season, spoils >15' away, leave 1' if used for sedimentation		<30% clay, <40%silt/clay		Observation well required			
Wyoming (WYDEQ)	Build after other watershed disturbances & construction activities complete; rototill trench bottom		High in organic matter and loam; use sand layer at trench bottom	Can be installed to increase trench life by allowing conversion to a sand filter should trench fail. Must remain capped until trench failure.	Capped observation well			
Vermont (VTDEC)	Minimize compaction, excavate to design dimensions, place stone aggregate in 12 inch lifts followed by filter fabric; do not create voids between fabric and sides; do not use as sedimentation trap during excavation	Fescue grasses on side slopes and basin floor	Silt loam	6" Sch 40 perforated PVC pipe, corrugated metal distribution pipe	Capped, locking observation well, 6" PVC Sch 40 pipe		Mow biannually, may require refertilization in second year	
New Jersey (NJDEP, 2000)	Avoid compaction, till trench floor	Water tolerant, low maintenace, rapid germinating fescue grasses on floor and side slopes	Sand, sandy loam, loamy sand		Capped observation well: perforated PVC pipe w/ rebar anchor	Partial or complete replacement of topsoil or stone fill if infiltration capacity severely reduced	Mow, remove debris	Semiannually and after major storm events
Minnesota (MNUSS)	Construct after site has stabilized. Do not use as temporary sediment traps during construction. Minimize compaction. Build to specs. Avoid smearing trench bottom and sides.	Not necessary for bottom of trench.	Undisturbed native soil		Capped observation well: 6" perforated PVC pipe w/ 1/2" rebar anchor & 9 " square steel foot plate	Remove sediment, debris, dead vegetation. Inspect and clean pretreatment devices		After major storms for a few months, then twice per year minimum
Claytor & Schueler (CWP, 1996)	Do not build until area is stable, build to design, use 12 inch lifts, do not mix soil with stone aggregate, avoid creating voids between filter fabric and excavation sides	Dense stand, preferably fescue grasses	Sand filter 6" deep above undisturbed permeable soil; native if possible	Perforated PVC pipe	Bolted, capped, locking observation well of 6 inch PVC pipe		Mow twice a year, refertilize with 10-6-4 ratio at a rate of 500 lb per acre	
OMM, 1997	Build after drainage area has stabilized. Avoid compaction (use 12" lifts) and soil smearing between aggregate and geotextile		Topsoil or aggregate over undisturbed native soil	4 - 6 inch peforated PVC pipe	4 - 6" locking, capped observation well	Document performance characteristics in log book.		Monthly during rainy season, quarterly during dry season for first year.

INFILTRATION STRUCTURE CONSTRUCTION CRITERIA					INFILTRATION STRUCTURE MAINTENANCE CRITERIA			
REFERENCE	CONSTRUCTION MEASURES	VEGETATION	FILTER MEDIA	UNDERDRAINS	MONITORING	STRUCTURE MAINT.	VEG. MAINTENANCE	INSPECTION FREQUENCY
New Jersey (NJDEP, 2000)	Avoid compaction, seed floor and side slopes within one week of construction	Dense turf of water tolerant fescue grasses. 12 inch layer of coarse sand may be used in place of vegetative bottom	Sand, sandy loam, loamy sand		Capped observation well	Debris and sediment removal	Mow twice a year; fertilization, pruning, pest control as needed to maintain healthy growth	Semiannually and after major storm events
New York (NYSDEC, 2001)	Identical to CWP	Identical to CWP	Identical to CWP	Identical to CWP	Identical to CWP	Identical to CWP	Identical to CWP	Identical to CWP
Florida (FLDEP, 1999)	Keep heavy equipment, sediment and erosion away from trench area; do not build until site is stabilized; light compaction only		Can be permeable rock, stable soil, or cohesionless soil or sand	Not required because perforated pipe is used for conveyance and distribution inside aggregate backfill	4 to 6 inch perforated PVC pipe, capped and locked			First year: quarterly and after large storms, maintain log book; then at least semiannually
Maryland (MDE, 1999)	Construct after site has stabilized, build to design, avoid soil smearing and fill voids, minimize compaction	Dense stand, preferably fescue grasses	2" pea gravel over clean stone	Not required	Observation well: anchored 6 inch diameter perforated PVC pipe with lockable cap		Mow twice yearly. Refertilize after 2nd year if necessary	
Washington (WSDE, 1999)			Compacted permeable backfill, stone aggregate, native soil	Perforated 4" or 6" PVC pipe in gravel & filter fabric				

APPENDIX B

TYPICAL DETAILS

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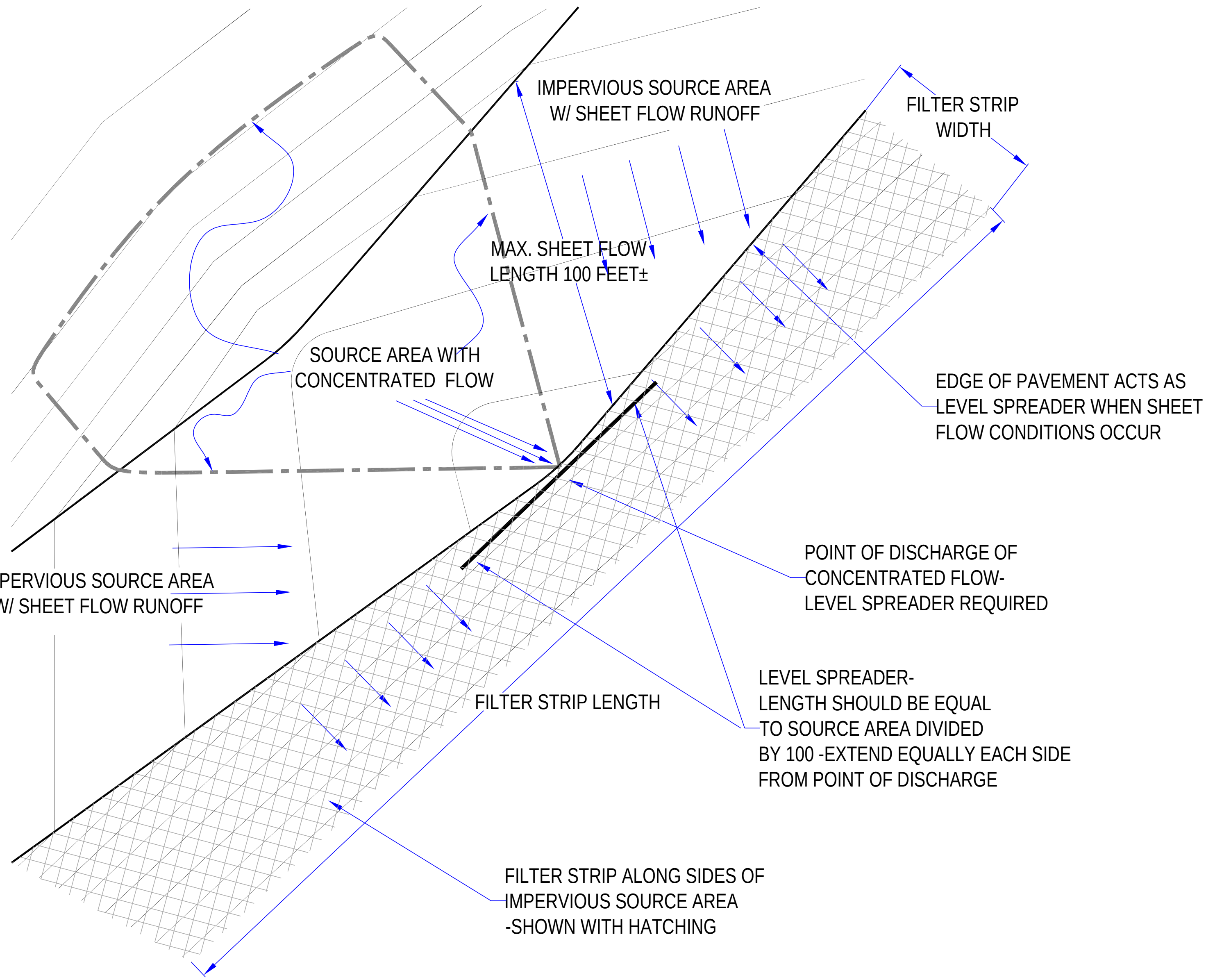
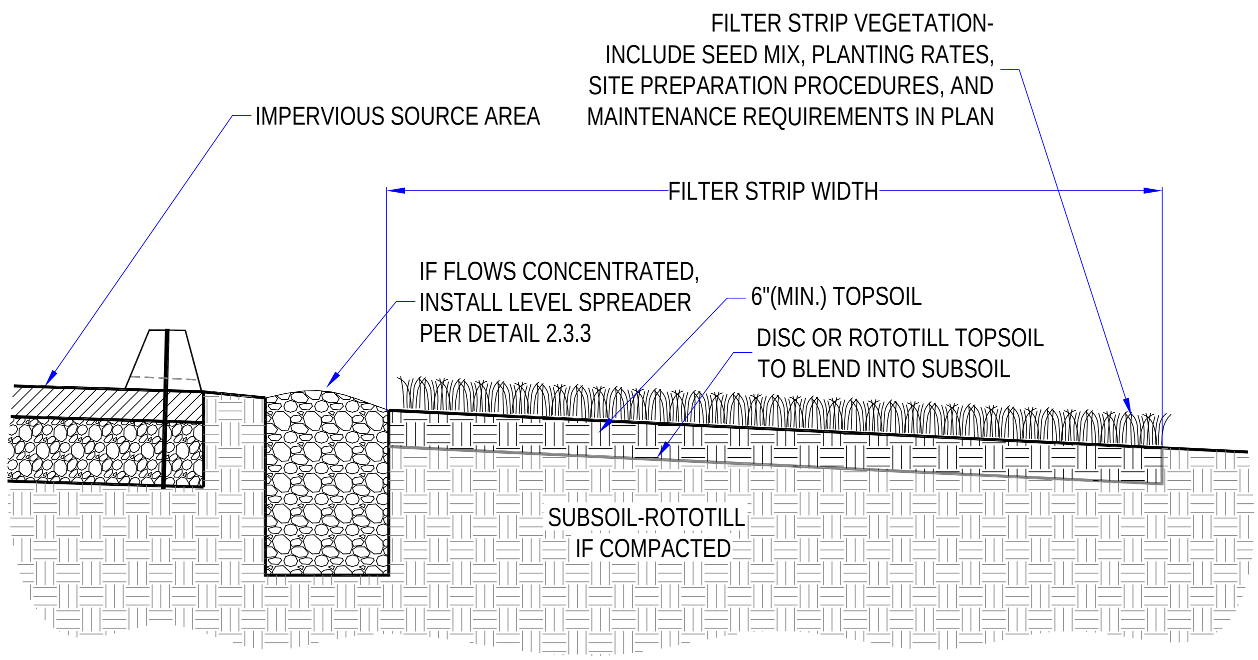
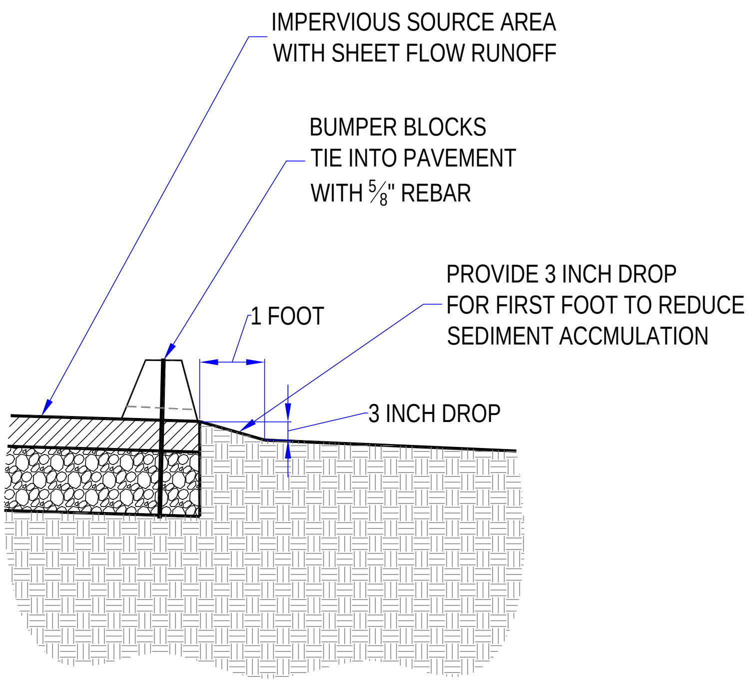


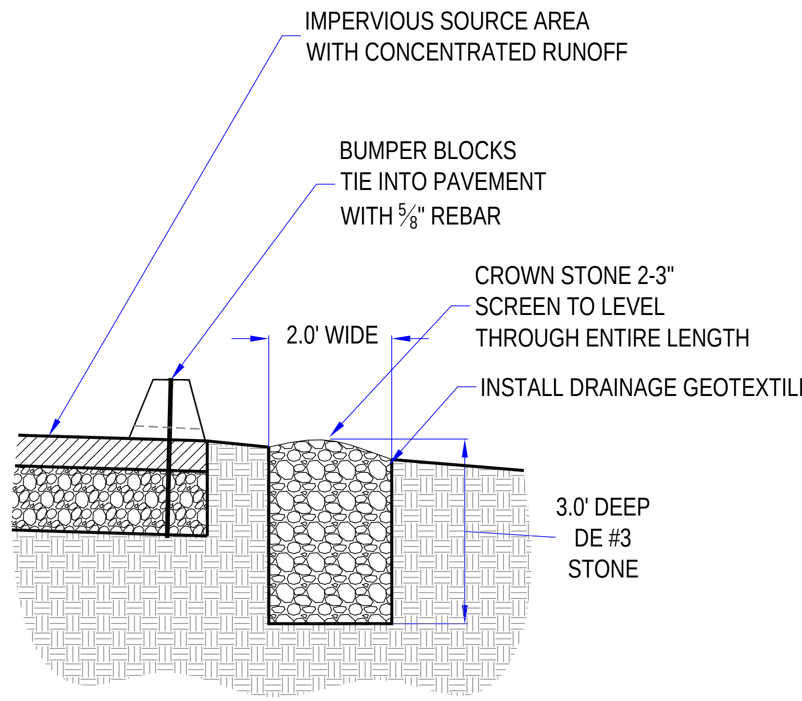
GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL FILTER STRIP DESIGN CRITERIA (N.T.S.)	DETAIL NUMBER: 2.3.1 DATE: JUNE 2005



GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL FILTER STRIP SECTION (N.T.S.)	DETAIL NUMBER: 2.3.2 DATE: JUNE 2005

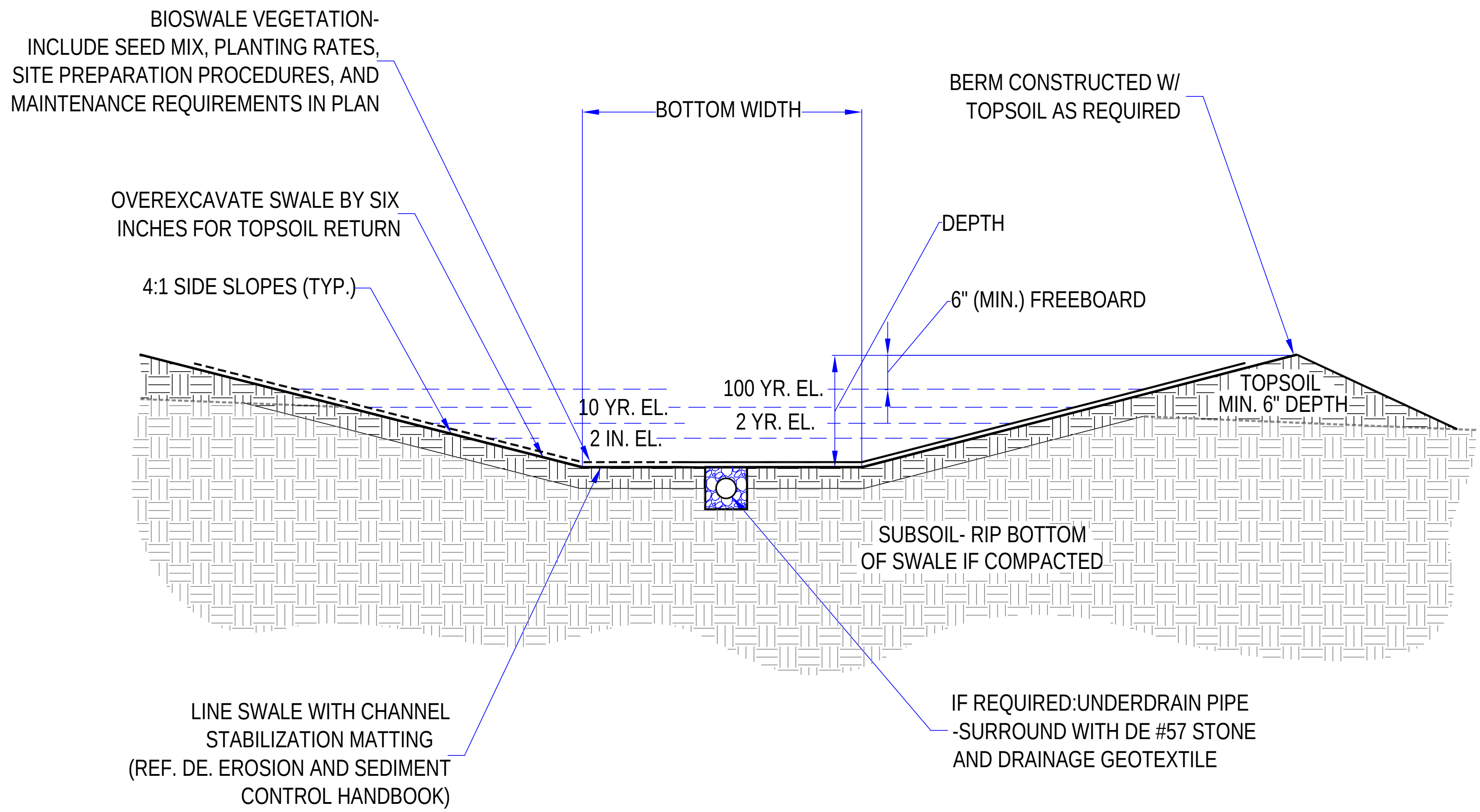


PAVEMENT LEVEL SPREADER

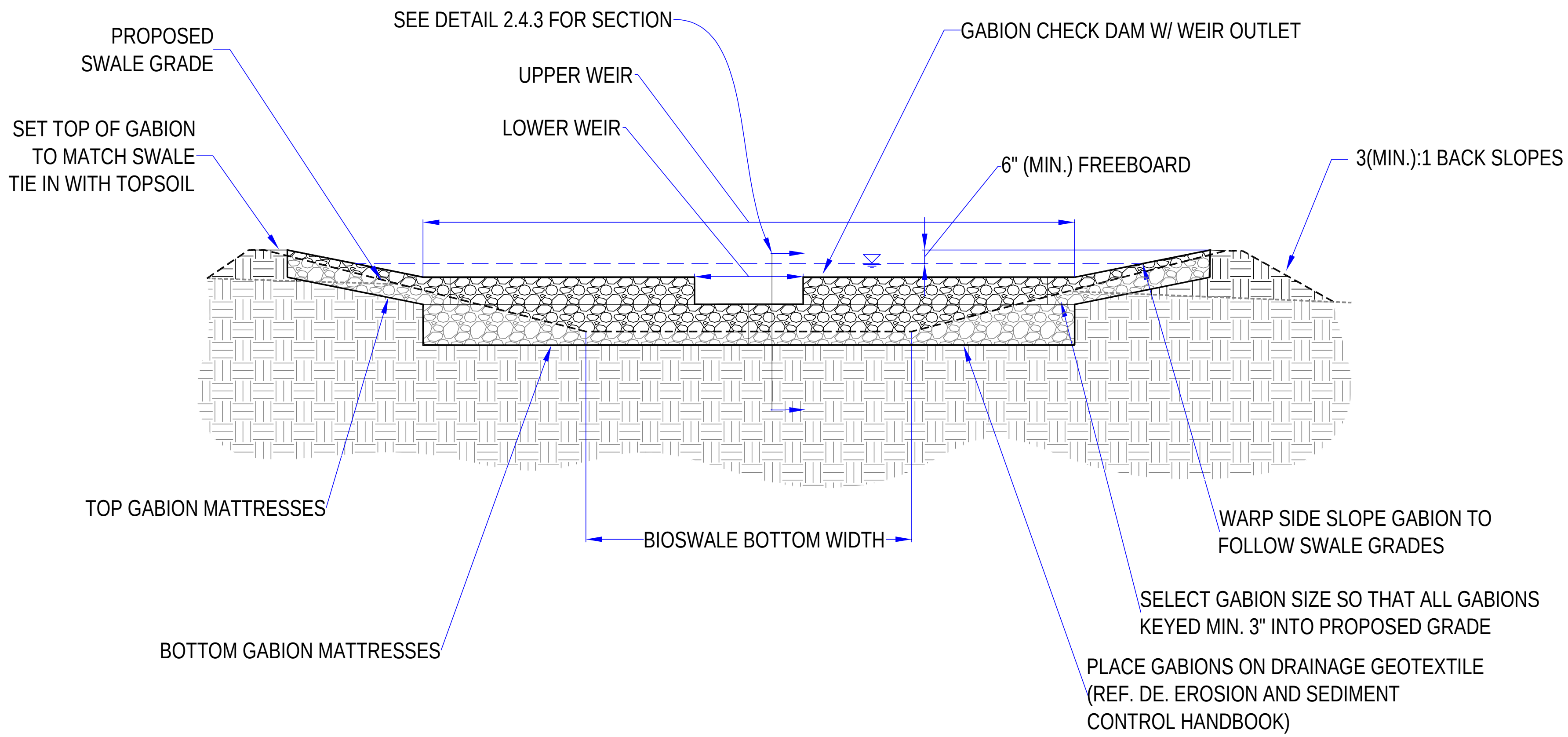


TRENCH LEVEL SPREADER

GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL LEVEL SPREADERS (N.T.S)	DETAIL NUMBER: 2.3.3 DATE: JUNE 2005



GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL BIOFILTRATION SWALE (N.T.S.)	DETAIL NUMBER: 2.4.1 DATE: JUNE 2005

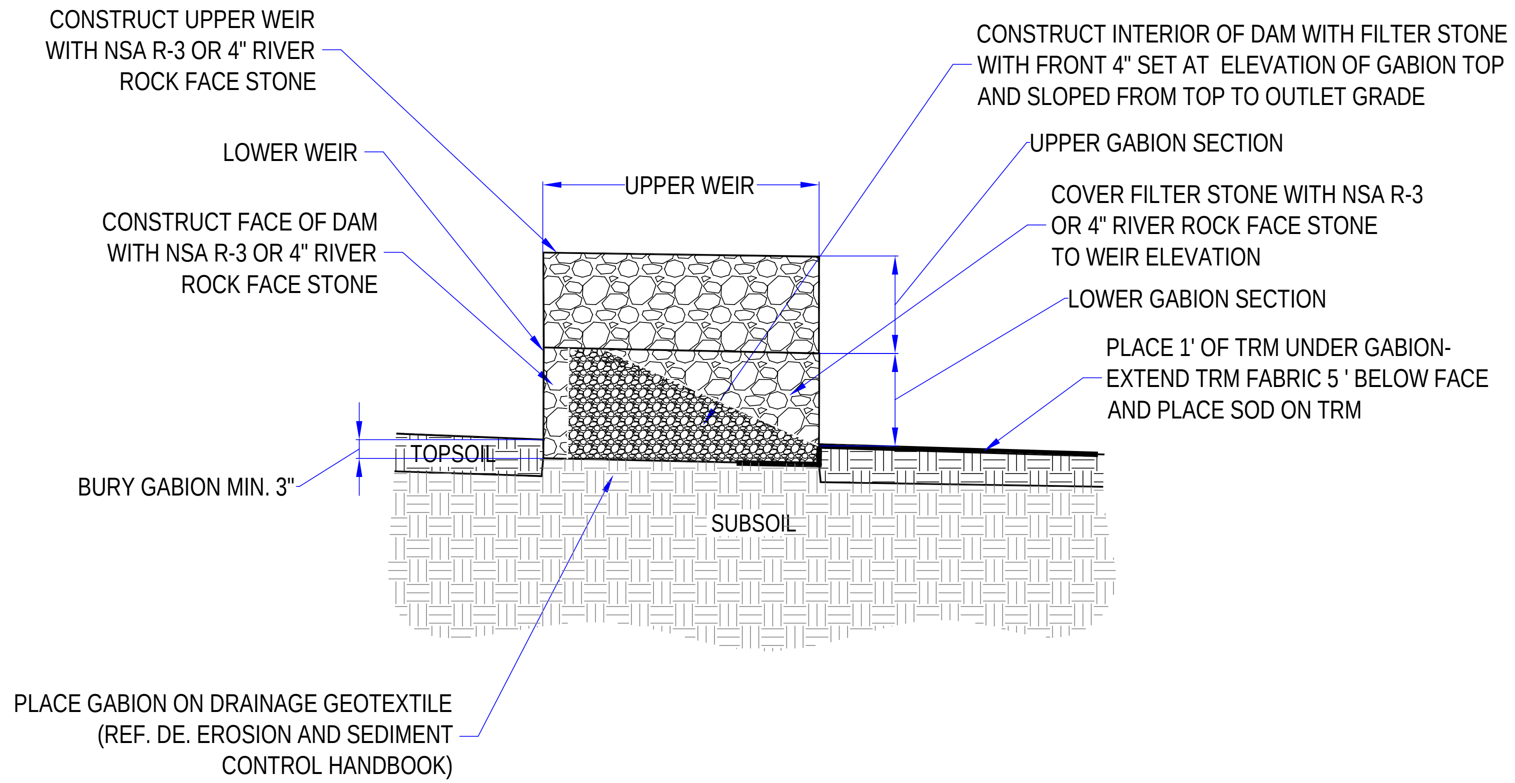


GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH

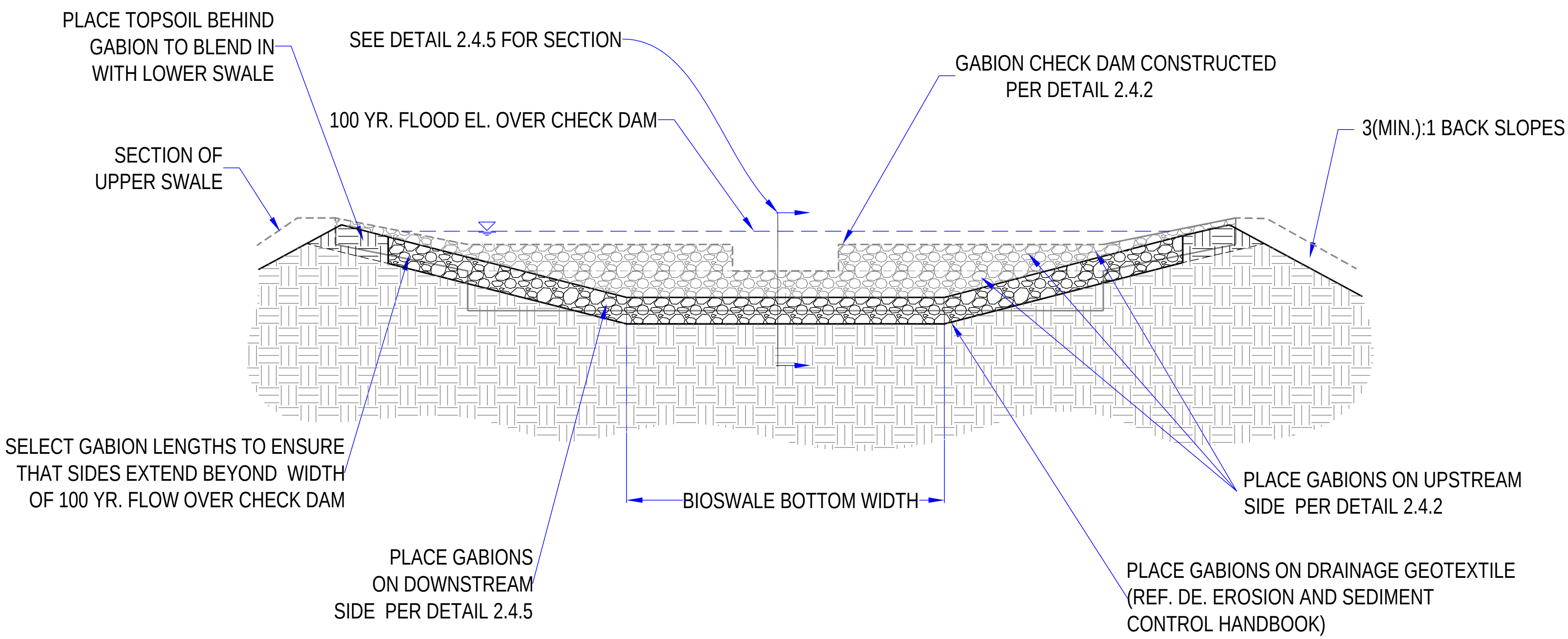
TYPICAL DETAIL
GABION WEIR CHECK DAM
(N.T.S.)

DETAIL NUMBER: 2.4.2

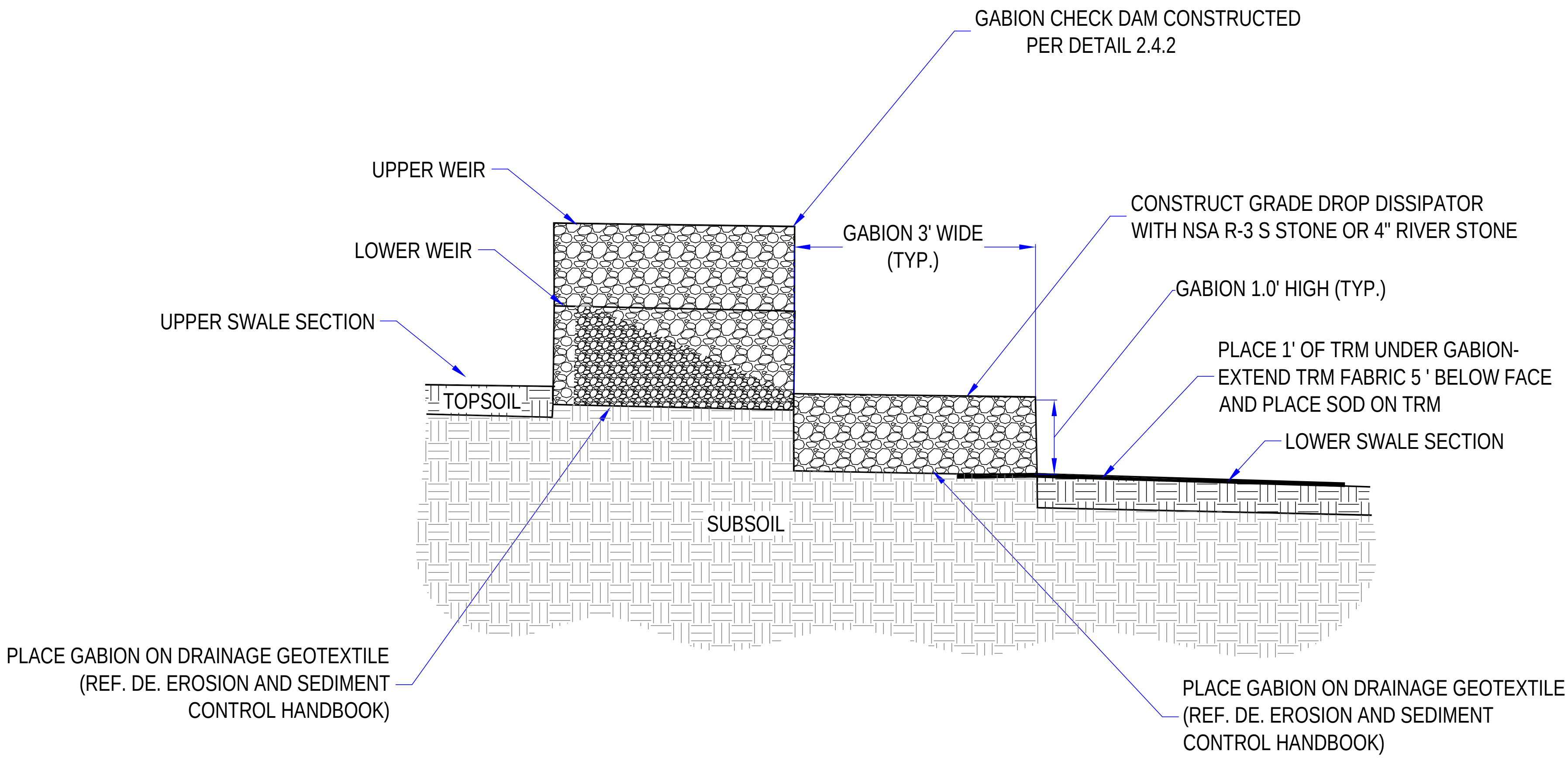
DATE: JUNE 2005



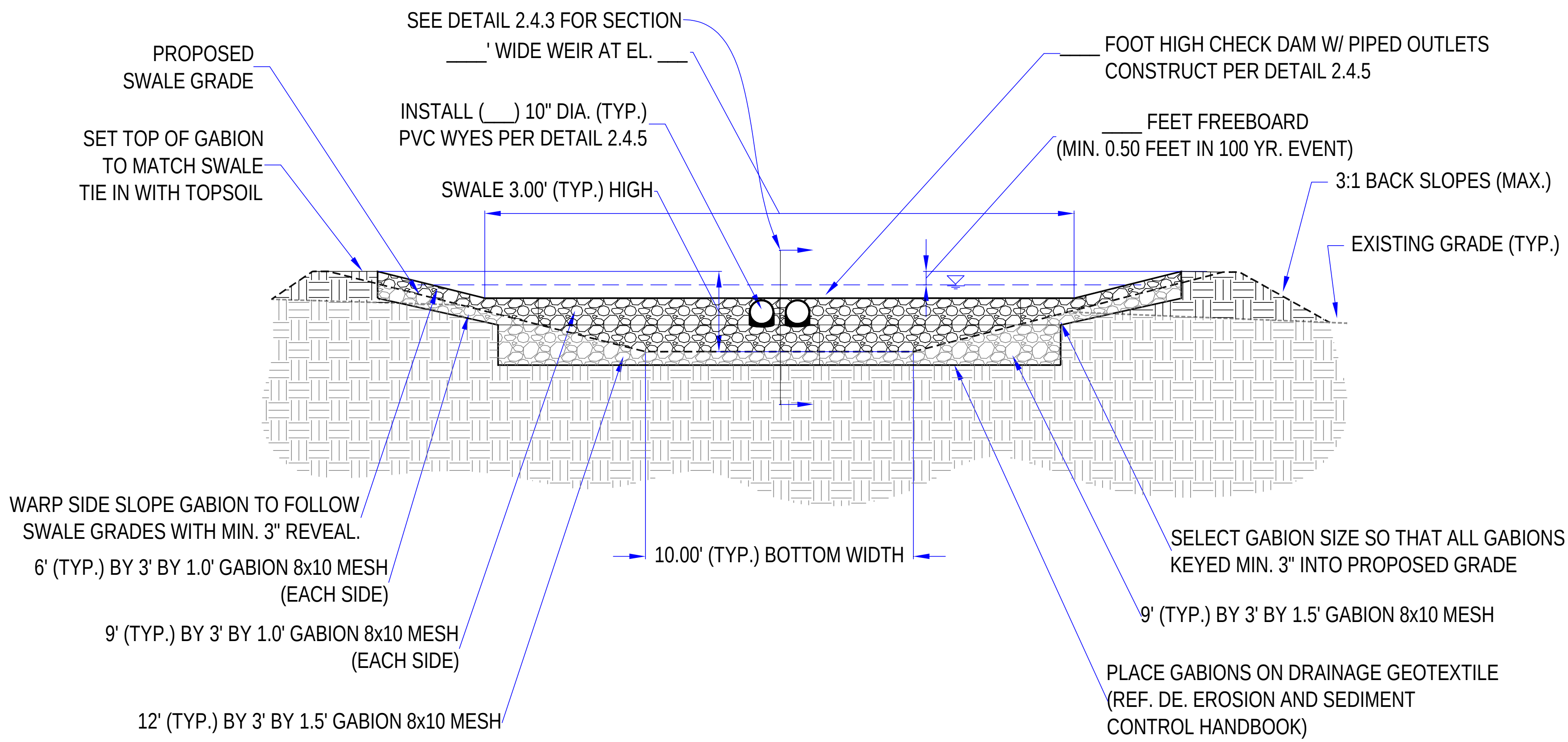
GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL GABION WEIR CHECK DAM - SECTION (N.T.S.)	DETAIL NUMBER: 2.4.3 DATE: JUNE 2005



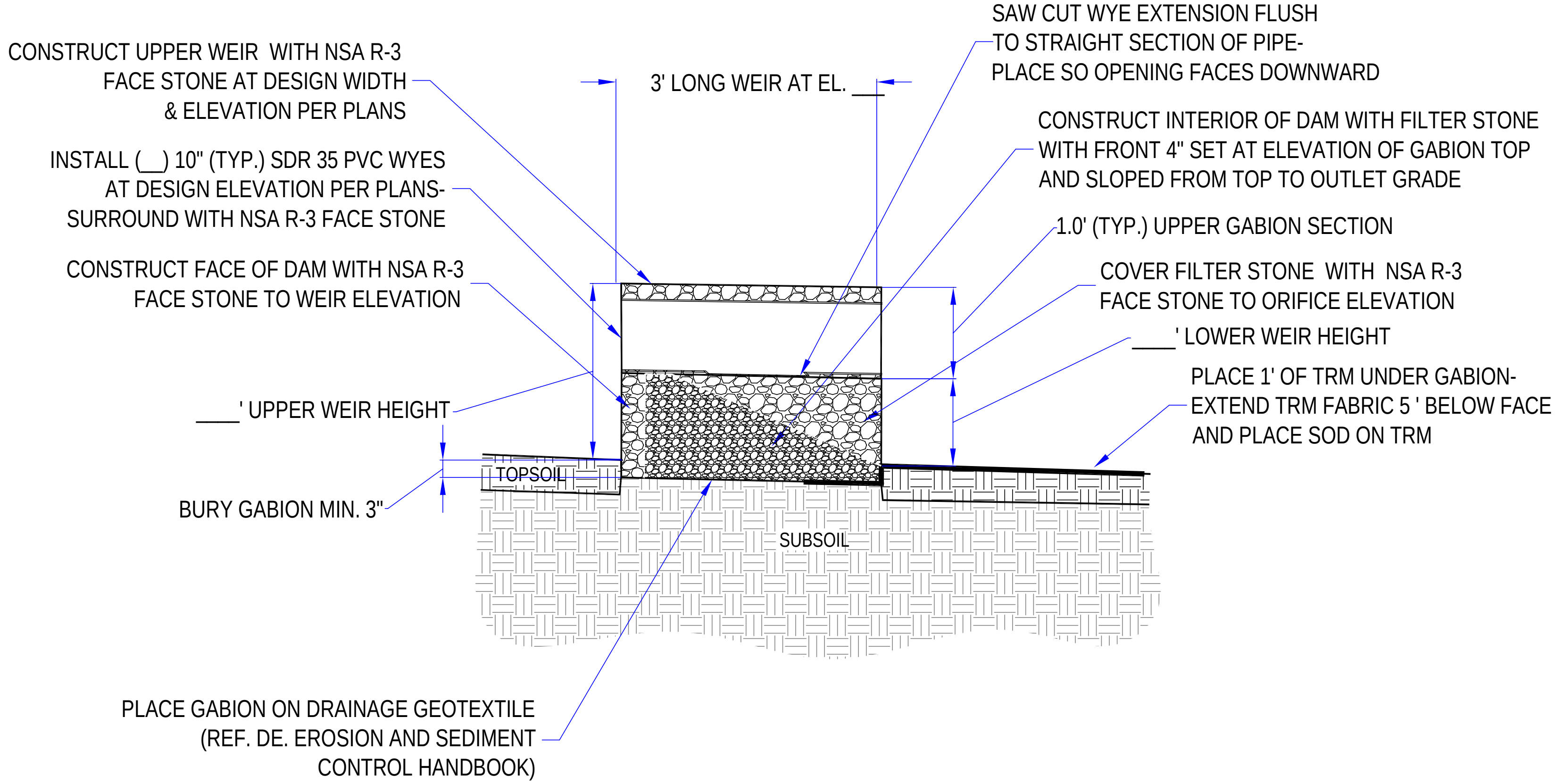
GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL GRADE DROP CHECK DAM (N.T.S.)	DETAIL NUMBER: 2.4.4 DATE: JUNE 2005



GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL GRADE DROP CHECK DAM- SECTION (N.T.S.)	DETAIL NUMBER: 2.4.5 DATE: JUNE 2005

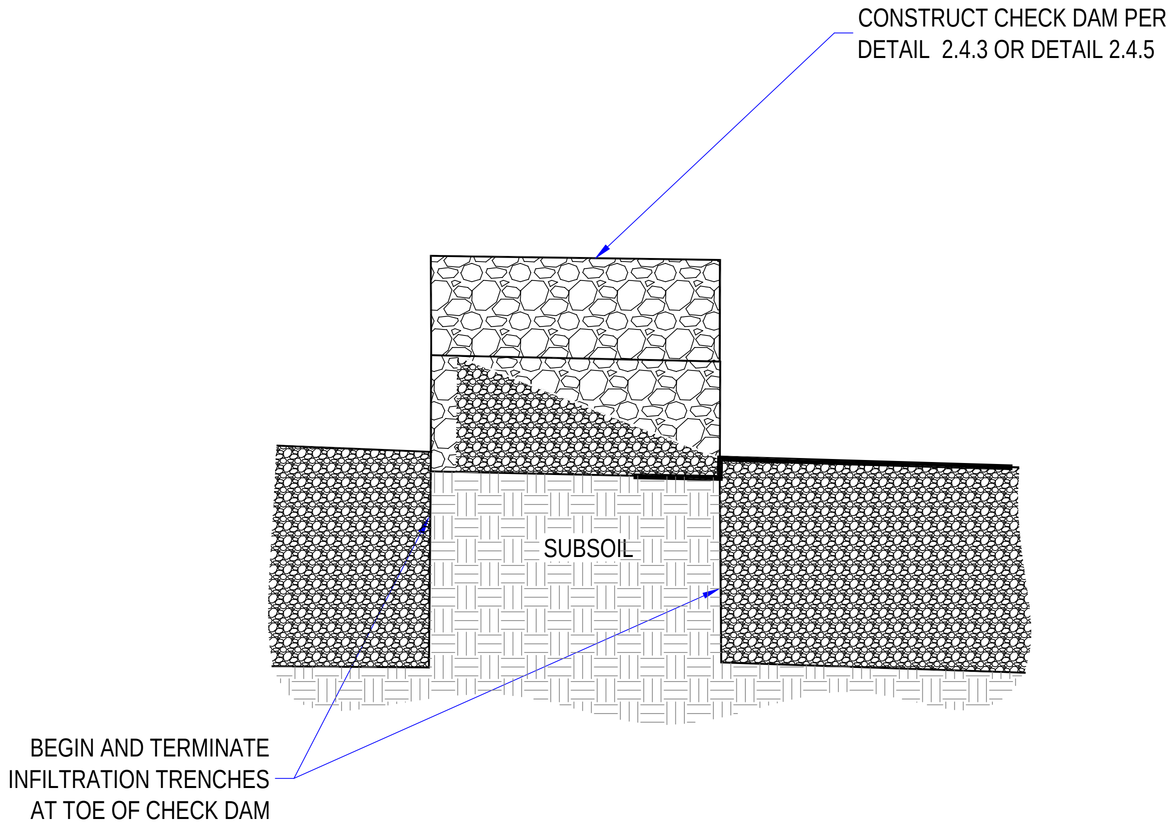


GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL GABION CHECK DAM W/ PVC WYE ORIFICES SECTION	DETAIL NUMBER: 2.4.6 DATE: JUNE 2005



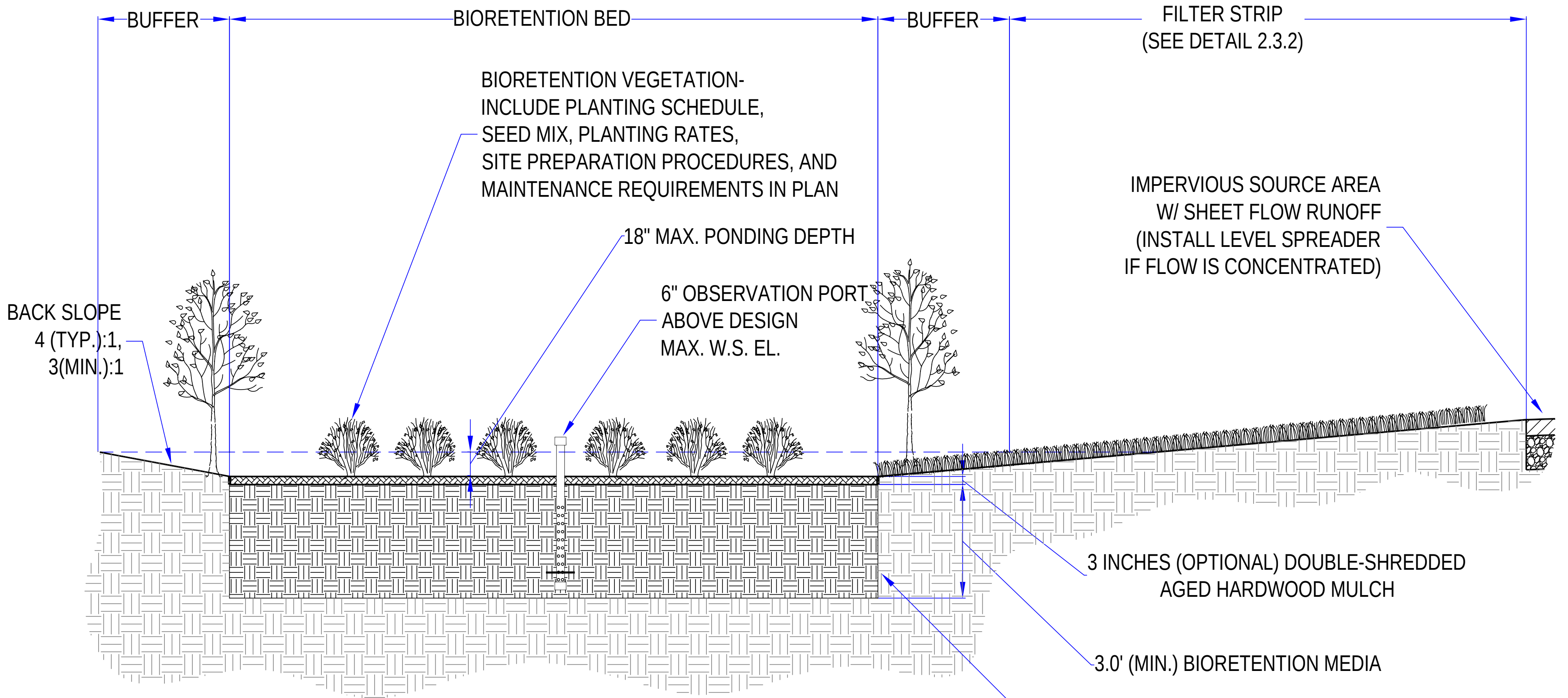
PROFILE THROUGH GABION CHECK DAM W/ PVC WYE ORIFICES (TYP.)
(N.T.S.)

GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL GABION CHECK DAM W/ PVC WYE ORIFICES PROFILE	DETAIL NUMBER: 2.4.7 DATE: JUNE 2005



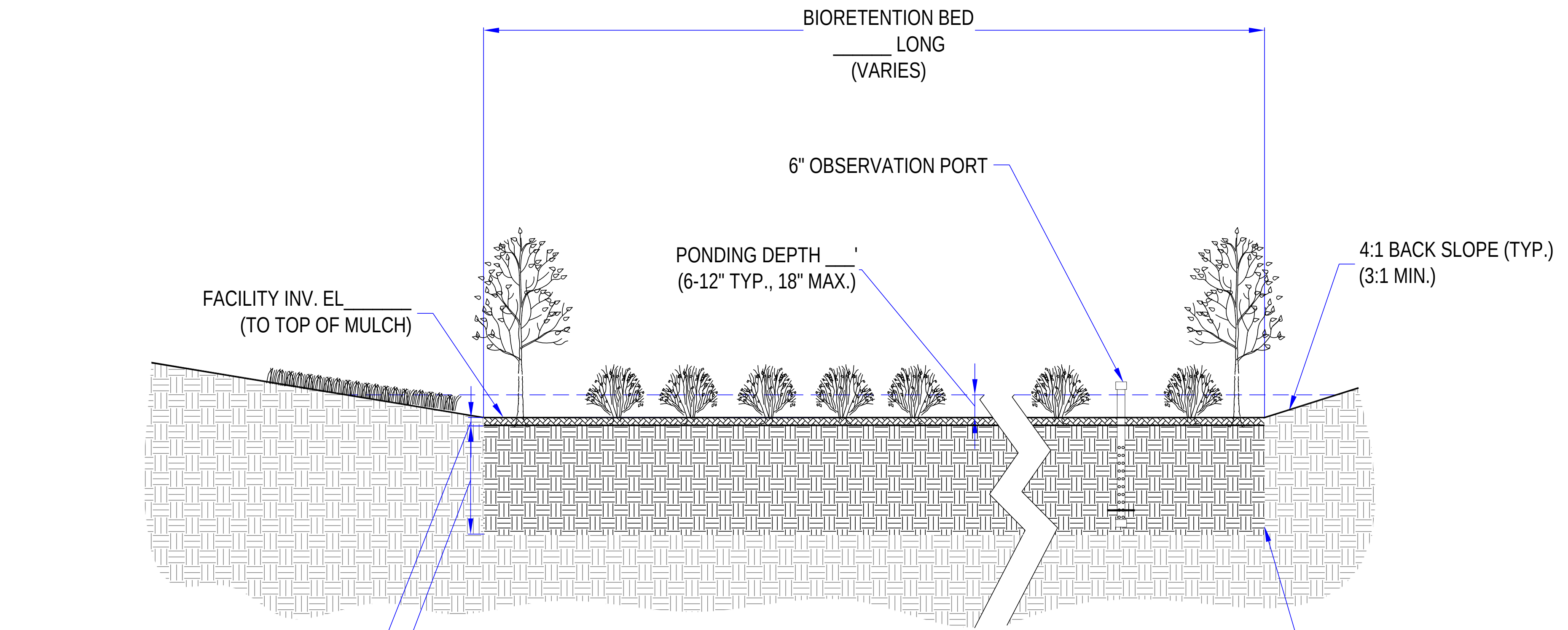
PROFILE THROUGH CHECK DAM (TYP.)
(N.T.S.)

GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL CHECK DAM WITH INFILTRATION TRENCH PROFILE	DETAIL NUMBER: 2.4.8 DATE: JUNE 2005



NOTE: REFER TO GREEN TECHNOLOGY STANDARDS AND SPECIFICATIONS FOR DESIGN STANDARDS AND MATERIAL SPECIFICATIONS

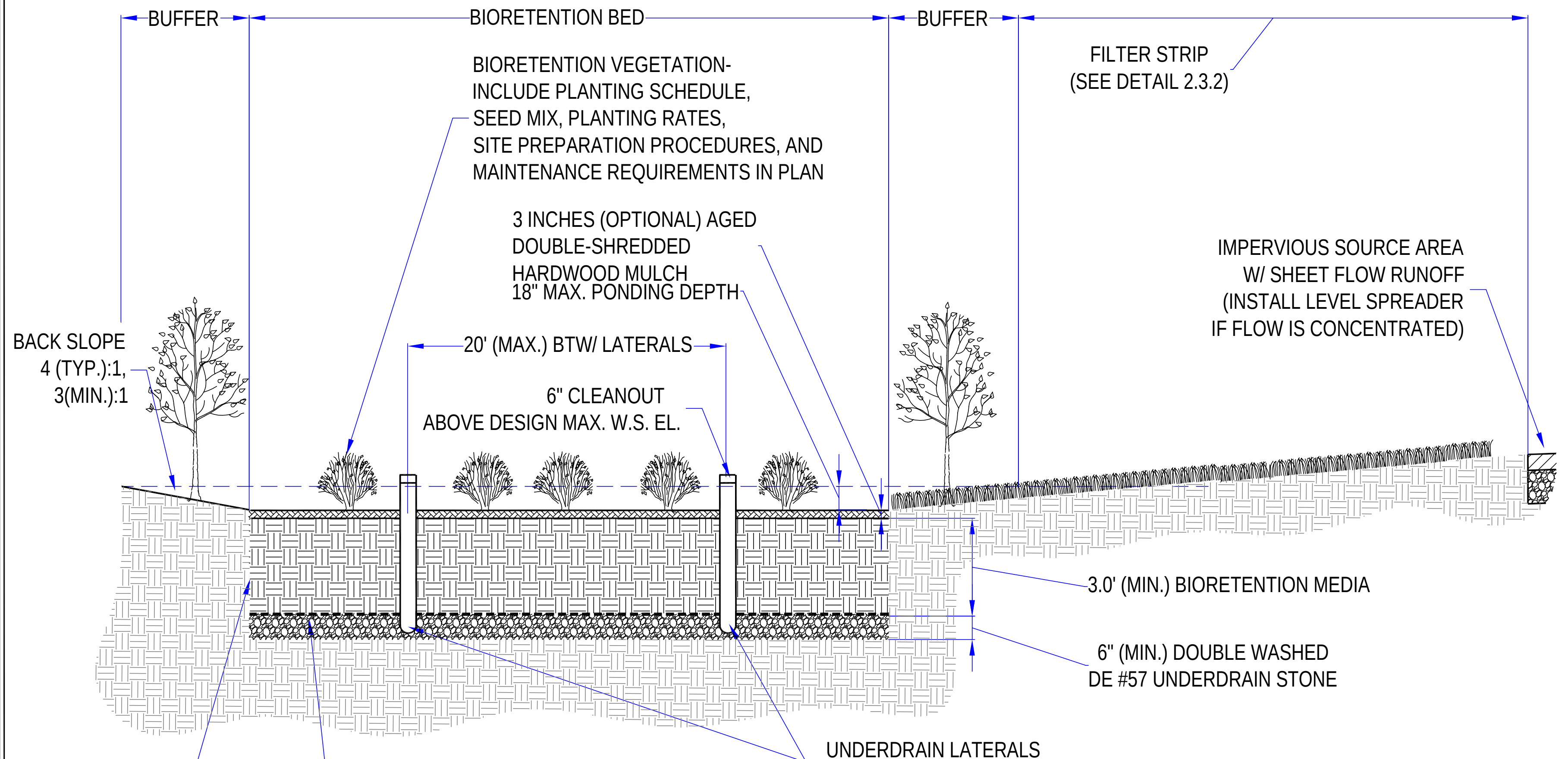
GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL STANDARD BIORETENTION FACILITY (N.T.S.)	DETAIL NUMBER: 2.5.1 DATE: JUNE 2005



PROFILE THROUGH BIORETENTION BED (TYP.)
(N.T.S.)

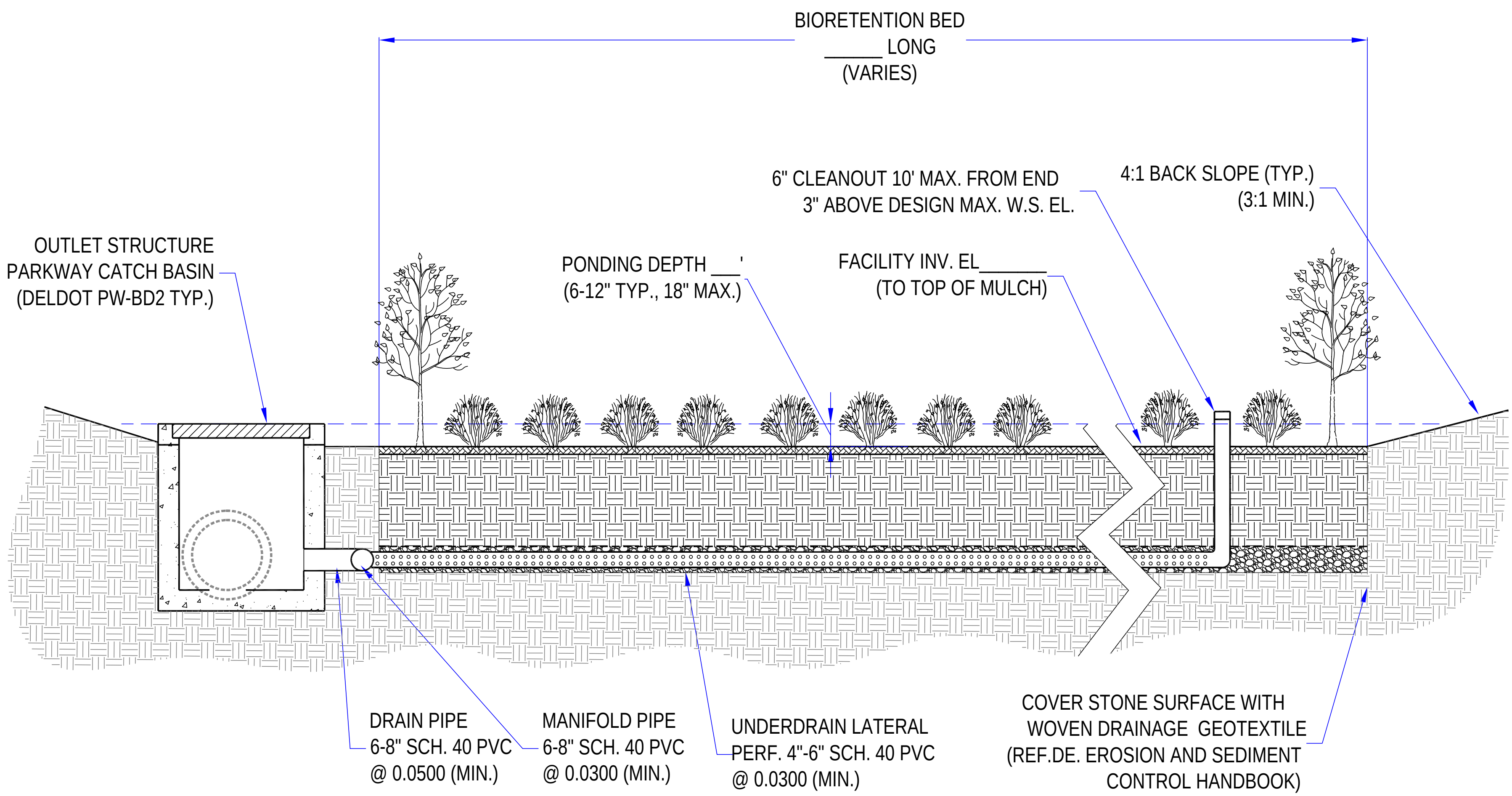
NOTE: REFER TO GREEN TECHNOLOGY STANDARDS AND SPECIFICATIONS FOR DESIGN STANDARDS AND MATERIAL SPECIFICATIONS

GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL STANDARD BIORETENTION FACILITY PROFILE	DETAIL NUMBER: 2.5.2 DATE: JUNE 2005



NOTE: REFER TO GREEN TECHNOLOGY STANDARDS AND SPECIFICATIONS FOR DESIGN STANDARDS AND MATERIAL SPECIFICATIONS

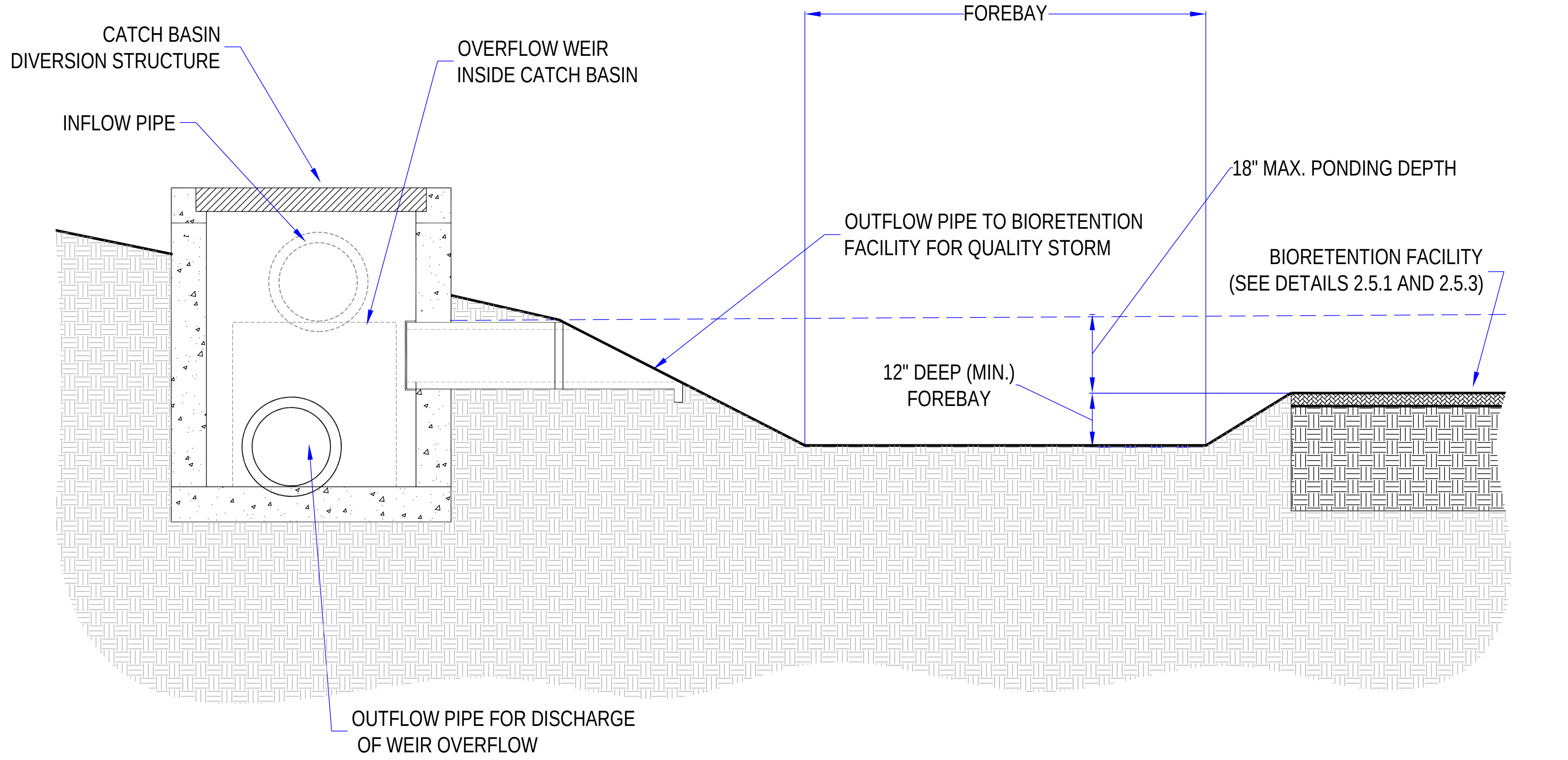
GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL BIORETENTION FACILITY W/ UNDERDRAIN (N.T.S.)	DETAIL NUMBER: 2.5.3 DATE: JUNE 2005



PROFILE THROUGH BIORETENTION BED & OUTLET (TYP.)
(N.T.S.)

NOTE: REFER TO GREEN TECHNOLOGY STANDARDS AND SPECIFICATIONS FOR DESIGN STANDARDS AND MATERIAL SPECIFICATIONS

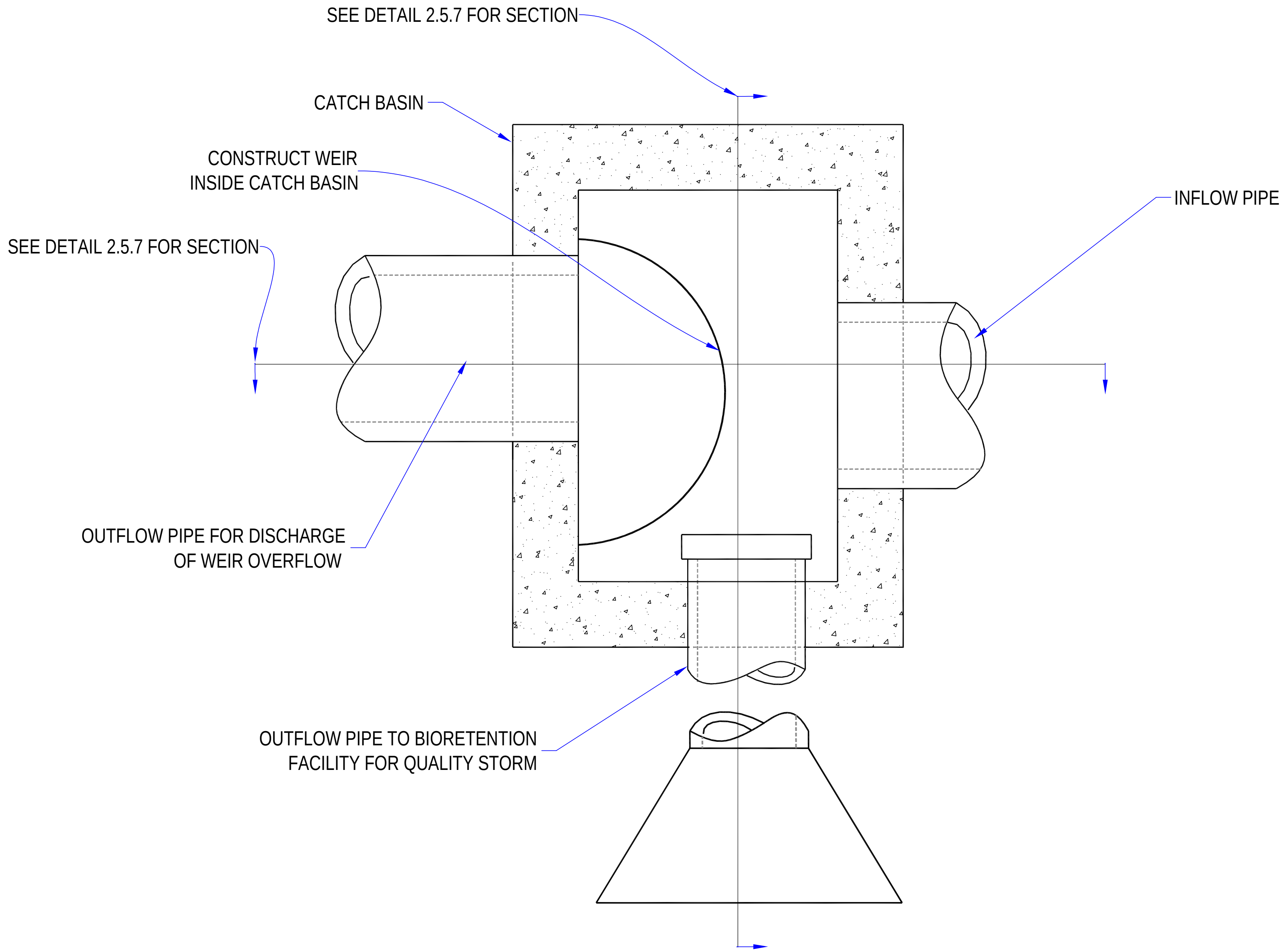
GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL BIORETENTION FACILITY W/ UNDERDRAIN & OUTLET PROFILE	DETAIL NUMBER: 2.5.4 DATE: JUNE 2005



PROFILE THROUGH DIVERSION BOX AND FOREBAY (TYP.)
(N.T.S.)

NOTE: REFER TO GREEN TECHNOLOGY STANDARDS AND SPECIFICATIONS FOR DESIGN STANDARDS AND MATERIAL SPECIFICATIONS

GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL DIVERSION STRUCTURE WITH FOREBAY (N.T.S.)	DETAIL NUMBER: 2.5.5 DATE: JUNE 2005

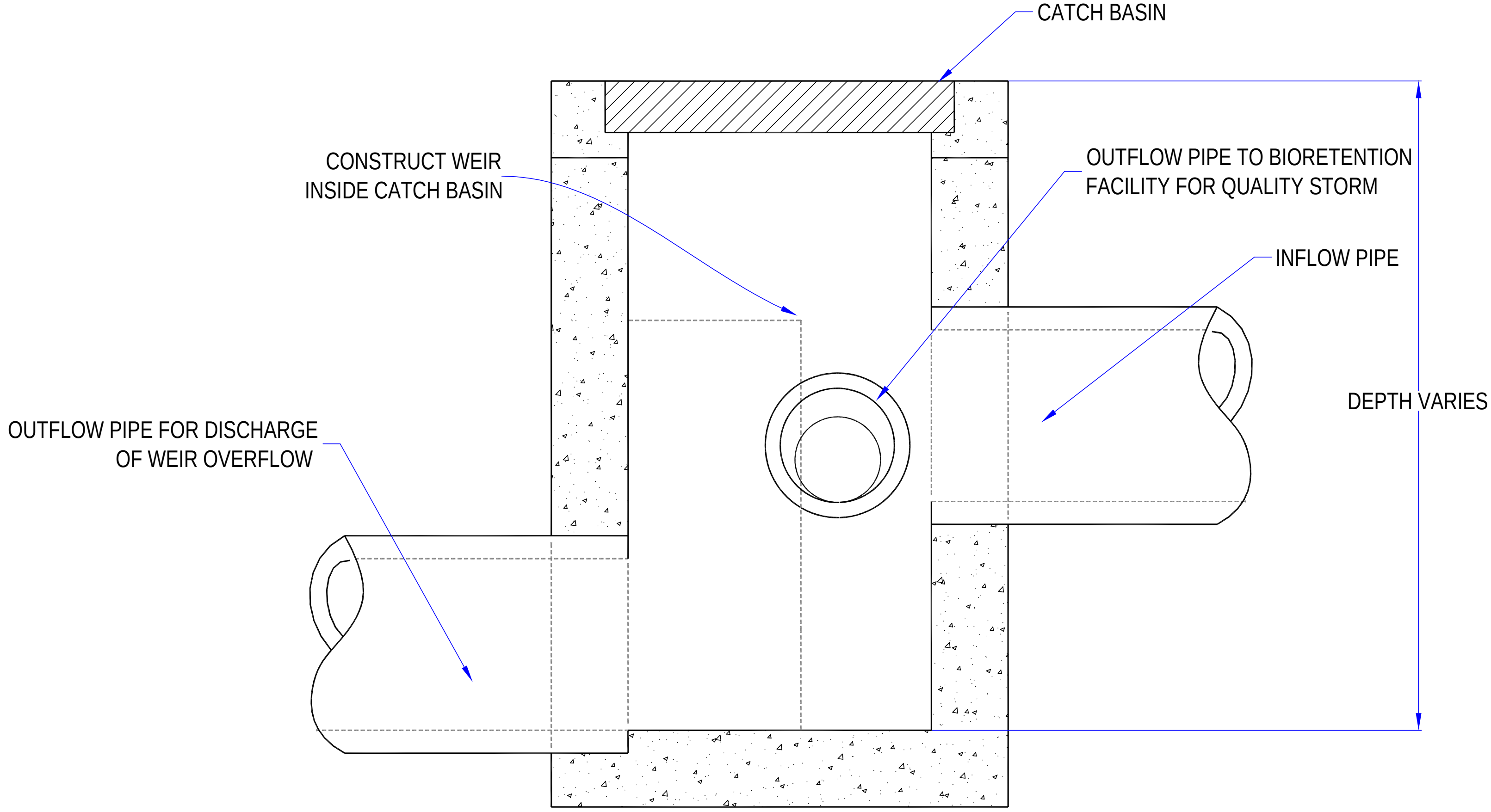


GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH

TYPICAL DETAIL
DIVERSION STRUCTURE-PLAN
(N.T.S.)

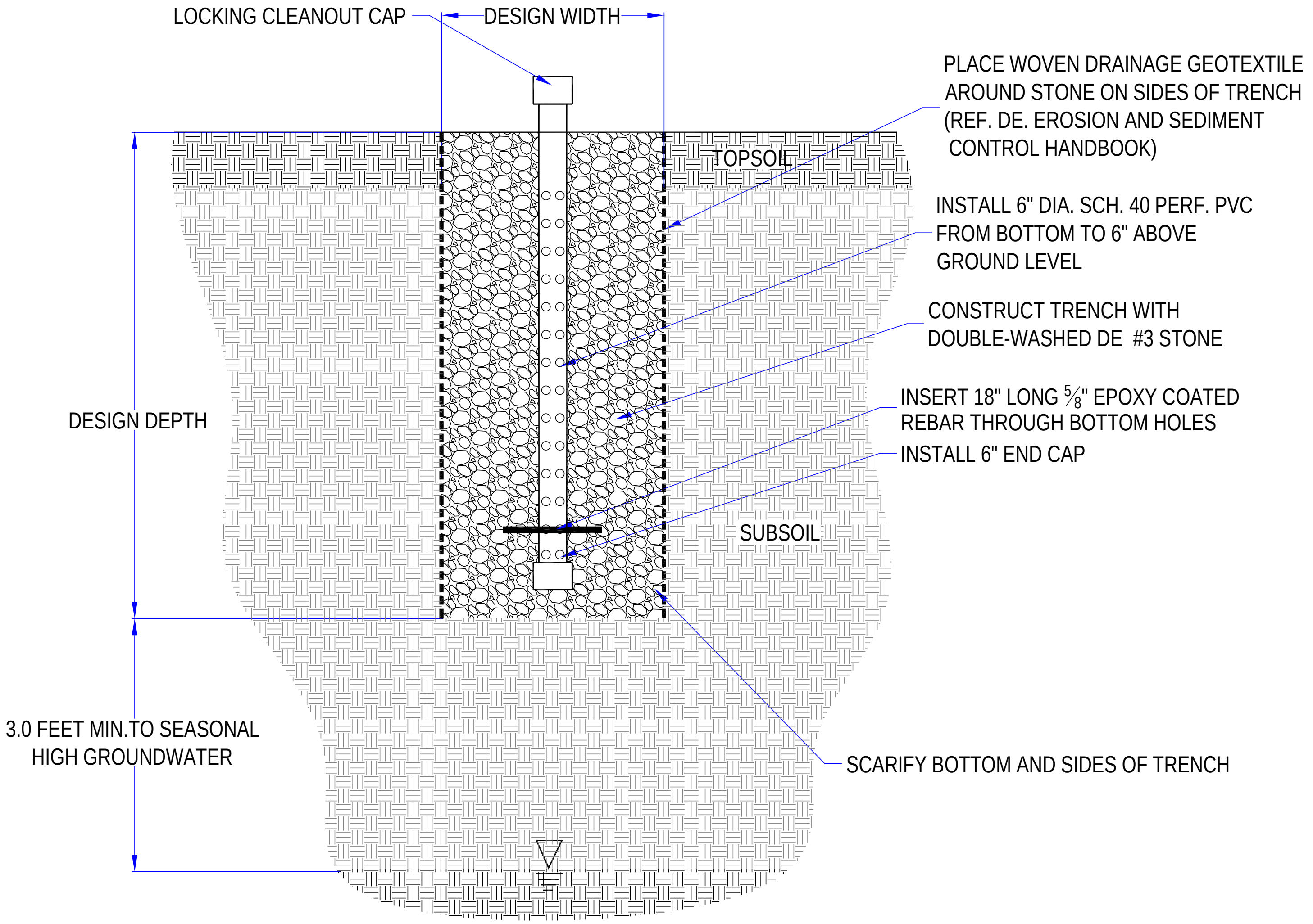
DETAIL NUMBER: 2.5.6

DATE: JUNE 2005



SECTION THROUGH DIVERSION BOX (TYP.)
(N.T.S.)

GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL DIVERSION STRUCTURE-SECTION (N.T.S.)	DETAIL NUMBER: 2.5.7 DATE: JUNE 2005



GREEN TECHNOLOGY: THE DELAWARE URBAN RUNOFF MANAGEMENT APPROACH	TYPICAL DETAIL INFILTRATION TRENCH AND OBSERVATION PORT (N.T.S.)	DETAIL NUMBER: 2.6.1 DATE: JUNE 2005