City of High Point

Stormwater Best Management Practices Design Manual

Effective Date:
January 1, 2009

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INTRODUCTION

All local governments that review stormwater management plans under a state stormwater program such as Water Supply Watershed, Nutrient Sensitive Waters, or Phase II NPDES program are to provide a substantially equivalent level of water quality protection as the provisions in the North Carolina Division of Water Resources (NCDWR) Stormwater Best Management Practices (BMP) Manual. Therefore, to comply with the NCDWR, and in an effort to improve consistency in stormwater best management practice, design, and approval, the City of High Point has adopted the NCDWR Stormwater BMP Manual. The NCDWR Stormwater BMP Manual can be accessed at http://portal.ncdenr.org/web/lr/bmp-manual.

National Pollutant Discharge Elimination System (NPDES) Phase II stormwater regulations apply jurisdiction-wide. Therefore, BMP requirements shall apply to all property within the city of High Point and its extraterritorial jurisdiction.

All WS-IV water supply watersheds using the high-density option must control the first 1" of rainfall on any site that exceeds 24% built-upon area. In the lower Randleman watershed, any site that exceeds 12% built-upon area must control the first 1" of rainfall. The NCDWR requires that these control measures not only control the first 1" of rainfall, but also remove 85% of the total suspended solids (TSS).

The sources of High Point's drinking water (Oak Hollow Lake, City Lake, and Randleman Reservoir) are largely urban watersheds. As such, the City of High Point believes that additional measures for controlling stormwater runoff, beyond those required by NCDWR, should be installed. Therefore, additional stormwater controls are required on any proposed low density development that exceeds 6% built-upon area and is less than 24% built-upon area (less than 12% built-upon area if the development is in the Randleman Watershed). Additional BMPs include natural infiltration areas, dry detention ponds, and infiltration trenches. Other BMPs that control the first ½" of rainfall may also be acceptable, and engineers are encouraged to discuss any innovative control devices with the Watershed Enforcement Officer and the City Engineer (see attached Stormwater Best Management Practices, Design Manual, Effective Date, January 1, 2000).

In addition to *North Carolina Division of Water Resources BMP Manual, Chapter 10, Wet Detention Basin*, the City of High Point requires the attached additional wet detention basin design elements (see attached Stormwater Best Management Practices, Design Manual, Effective Date, January 1, 2000).

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City of High Point

Stormwater Best Management Practices

Design Manual

Effective Date:
January 1, 2000

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TABLE OF CONTENTS

INTRODUCTION 3

SECTION 1: STORMWATER BMPS..5

1.1 Wet Detention Ponds..5
- 1.1.1 General Design Standards..5
- 1.1.2 Sediment Storage..7
- 1.1.3 Permanent Water Quality Pool..7
- 1.1.4 Temporary Water Quality Pool..8
- 1.1.5 Forebay..8
- 1.1.6 Dam and Embankment Construction..9
- 1.1.7 Principal Spillway..9
- 1.1.8 Emergency Spillway..10
- 1.1.9 Pond Drain..10
- 1.1.10 Maintenance Requirements..10
- 1.1.11 Landscaping Requirements..11

1.2 Extended Detention Wetlands..12
- 1.2.1 General Design Standards..12
- 1.2.2 Permanent Water Quality Pool..14
- 1.2.3 Temporary Water Quality Pool..15
- 1.2.4 Forebay..15
- 1.2.5 Outlet Micropool..15
- 1.2.6 Dam and Embankment..15
- 1.2.7 Principal Spillway..16
- 1.2.8 Emergency Spillway..16
- 1.2.9 Wetland Drain..16
- 1.2.10 Wetland Planting..17
- 1.2.11 Maintenance Requirements..26

1.3 Bioretention Areas..27
- 1.3.1 General Design Guidelines..27
- 1.3.2 Grass Buffer Strip..29
- 1.3.3 Ponding Area..29
- 1.3.4 Planting Soil..29
- 1.3.5 Organic or Mulch Layer..30
- 1.3.6 Plant Material..30
- 1.3.7 Underdrain System..39
- 1.3.8 Sizing Requirements..39
- 1.3.9 Maintenance Requirements..40

1.4 Sand Filtration Facilities....................40

1.4.1 General Design Guidelines....................41
1.4.2 Sedimentation Chamber....................41
1.4.3 Sand Filter Chamber....................42
1.4.4 Underdrain System....................42
1.4.5 Overflow....................43
1.4.6 Access....................43
1.4.7 Other Proprietary Systems....................47
1.4.8 Maintenance Requirements....................47

SECTION 2: ALTERNATIVE STORMWATER CONTROL MEASURES

2.1 Natural Infiltration Areas....................48
2.1.1 General Design Standards....................48
2.1.2 Maintenance Requirements....................50

2.2 Dry Detention Ponds....................50
2.2.1 General Design Standards....................50
2.2.2 Storage Requirements....................50
2.2.3 Principal spillway....................51
2.2.4 Emergency Spillway....................51
2.2.5 Maintenance Requirements....................51

2.3 Infiltration Trenches....................52
2.3.1 Storage Requirements....................52
2.3.2 Maintenance Requirements....................53

REFERENCES....................54

INTRODUCTION

All WS-IV water supply watersheds using the high-density option must control the first 1" of rainfall on any site that exceeds 24% built-upon area. In the lower Randleman watershed, any site that exceeds 12% built-upon area must control the first 1" of rainfall. The North Carolina Department of Environment and Natural Resources (NCDENR) requires that these control measures not only control the first 1" of rainfall, but also remove 85% of the total suspended solids (TSS).

The first section of the manual outlines performance criteria and design standards for structural water quality stormwater BMPs for use in the City of High Point that meet NCDENR's criteria for controlling the 1" rainfall event and providing adequate TSS removal. They include:

- Wet detention ponds
- Constructed stormwater wetlands
- Bioretention areas
- Sand filter systems

The design criteria described herein are based on the work done in the State of Maryland, Prince George's County, The Center for Watershed Protection, the NCDENR Best Management Practices Manual, and the City of Greensboro. Since 1989, wet detention ponds have been used extensively, and exclusively, to control stormwater runoff within the City of High Point's water supply watersheds, but several other BMPs (bioretention areas, sand filters, constructed stormwater wetlands) have now proven to be acceptable alternatives.

Allowing alternatives to wet detention ponds offers developers and the engineering community flexibility in determining how to best control stormwater runoff from a planned development. Because there has been limited use of engineering BMPs other than wet detention ponds in North Carolina, the design criteria are still being revised and updated. On-going studies continue to examine the effectiveness of these BMPs, and the City of High Point will periodically revise our design criteria to reflect any new information.

Where control of the 1" rainfall event in not required, the City of High Point allows for the use of several additional types of BMPs. The sources of High Point's drinking water (Oak Hollow Lake, City Lake and Randleman Reservoir) are largely urban watersheds. As such, the City of High Point believes that additional measures for controlling stormwater runoff, beyond those required by NCDENR, should be installed. Therefore, stormwater controls may be required on any proposed development that exceeds 6% built-upon area and is less than 24% built-upon area (less than 12% built-upon area if the development is in the Randleman Watershed). In the Watershed Critical Area (WCA), alternative measures are <u>required</u> for any proposed development that exceeds 6% built-upon area, and is less than 24% built-upon area (less than 12% built-upon if the proposed development is in the Randleman Watershed). In the General Watershed Area (GWA), a proposed development must earn 100 points on the Score sheet, and alternative measures may be necessary in order to obtain 100 points. These alternative measures include:

- Natural infiltration areas
- Dry detention ponds
- Infiltration trenches

Natural infiltration areas are designed according to the same criteria used by Guilford County, and have remained unchanged with this revision. The design criteria for dry ponds and infiltration trenches also have remained the unchanged. Other BMPs that control the first ½" of rainfall may also be acceptable, and engineers are encouraged to discuss any innovative control devices with the Watershed Enforcement Officer and City Engineer.

Mandatory performance criteria are distinguished from suggested design criteria (the former is required for all sites in High Point, while the latter are only recommended for most sites and conditions). Thus, in the text, mandatory performance criteria are indicated by *italics*, whereas recommended design criteria are shown in normal typeface.

1.1 Wet Detention Ponds

In High Point, the wet detention pond (Figure 1) is the most commonly used BMP for meeting water supply watershed requirements. Wet detention ponds are sized and configured to provide significant removal of pollutants from the incoming stormwater runoff. They maintain a permanent pool of water that is designed for a targeted 85% removal of TSS (Total Suspended Solids) according to the size and imperviousness of the contributing drainage area. Above the permanent pool is a temporary water quality pool, which is designed to hold the runoff resulting from a 1" rain and release it over a period of two to five days.

The design of wet detention ponds is based on controlling the design runoff volume from the long-term average storm in order to settle out suspended solids and pollutants (such as heavy metals and nutrients). Biological treatment also occurs when aquatic vegetation uses the nutrients found in the water and sediment. The Driscoll model (US EPA, 1986) was used to determine the appropriate size of the permanent pool using a long-term average storm statistically calculated from the historical rainfall record. The permanent pool is sized to detain the runoff long enough to attain the targeted TSS removal.

In addition to the permanent water quality pool, the pond must also have a temporary water quality pool designed to control runoff from a 1" rain. This temporary water quality storage is located above the permanent pool and is necessary for two reasons. First, runoff entering the pond can be significantly warmer than the permanent water quality pool. During these periods, plug flow will occur to a lesser extent, and the temporary water quality volume will allow some of the suspended solids to fall out of suspension before being released. The detrimental effects of this will be decreased because the runoff from the 1" storm is slowly released over a period of two to five days. Secondly, the slow release of this small storm runoff volume also helps to reduce downstream erosion.

1.1.1 General Design Standards

Placement of ponds in jurisdictional waters may require Federal and State Permits. It is suggested that ponds not be placed in perennial streams where possible.

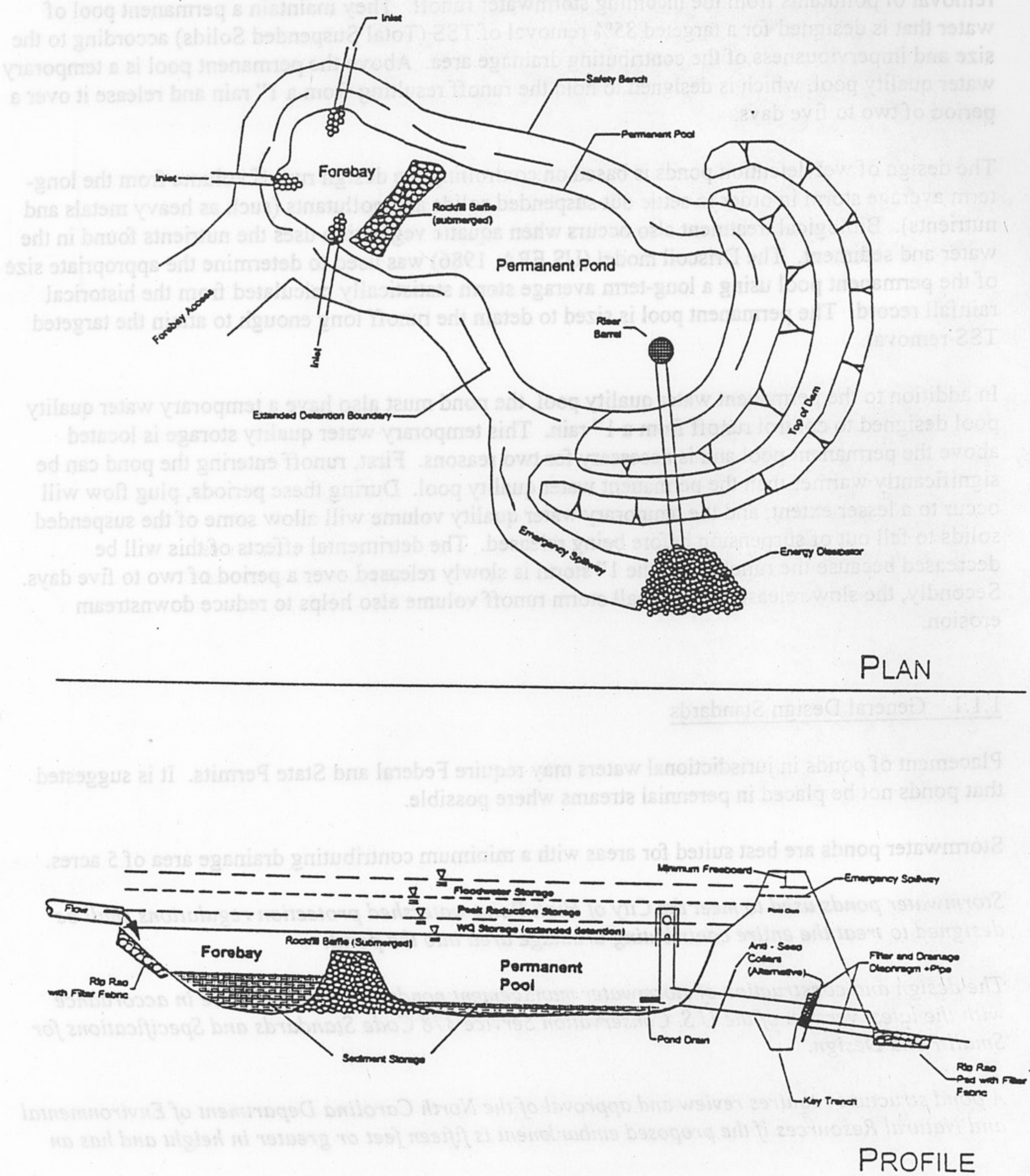
Stormwater ponds are best suited for areas with a minimum contributing drainage area of 5 acres.

Stormwater ponds used to meet the City of High Point watershed protection regulations shall be designed to treat the entire contributing drainage area into the pond.

The design and construction of stormwater management ponds are required to be in accordance with the latest version of the U.S. Conservation Service 378 Code Standards and Specifications for Small Pond Design.

A pond structure requires review and approval of the North Carolina Department of Environmental and Natural Resources if the proposed embankment is fifteen feet or greater in height and has an

Figure 1: Example of Wet Detention Pond



impoundment capacity of at least ten acre-feet. If a permit is required, the detention pond must meet the general requirements herein and those contained in the North Carolina Dam Safety Act.

The pond must be easily accessible for maintenance. A 20' wide access easement shall be provided from the public street right-of-way to the pond and shall be continuous around the pond.

At inflow points to the pond, energy dissipaters such as rip-rap shall be used to reduce the velocity of the flow. The outflow shall be designed to protect against erosion and scour from high velocities and turbulence. Rip-rap shall be provided at the points of discharge as necessary.

Pond embankments shall be 4H:1V or flatter in order to reduce erosion potential, promote wetland vegetation, minimize safety hazards, improve aesthetics and facilitate maintenance activities. Pond embankments of 3H:1V are acceptable if a bench is placed near the normal pool surface. In all cases, a 10-15' bench (max. slope 10%) placed around the pond near the normal pool surface, is strongly encouraged. This bench will allow machinery to gain closer access to the pond during cleanouts. This break in the grade will be a safety amenity and can make the pond more aesthetically pleasing. *Dam embankments shall be 3H:1V or flatter.*

The pond surface area should have a minimum 3:1 length to width ratio (or equivalent created by baffles) in order to limit short-circuiting. The distance between the inlets and outlets should be maximized to increase the pollutant removal capability of the pond.

It is encouraged to create a pond that fits the natural contours of the land but care should be taken to prevent "dead storage zones" (areas outside the flow path between the inlet and outlet) within the pond. Generally, the pond should be narrower at the inlet forebay area and become wider at the outlet. Whenever possible one forebay should be created, with all pond inlet pipes discharging to this forebay.

The bottom of the pond should be slightly sloped from the upstream end to the downstream end. This will allow the pond and captured sediments to drain better when cleanouts are necessary.

1.1.2 Sediment Storage

Temporary storage shall be provided for 0.5 acre-inches of sediment per acre disturbed in the watershed during development. Permanent storage shall be provided after the site is stabilized for 0.125 acre-inch per acre of the total watershed.

1.1.3 Permanent Water Quality Pool

Average permanent water quality pool depths shall be between 3 to 6 feet. A minimum of 3 feet is required.

Permanent Pool Surface Area:

Wet Detention Pond Permanent Pool Surface Area to Drainage Area Ratio (Percent)							
Built-Upon (Percent)	Average Permanent Pool Depth (FT)						
	3.0	4.0	5.0	6.0	7.0	8.0	9.0
10	0.59	0.49	0.43	0.35	0.31	0.29	0.26
20	0.97	0.79	0.70	0.59	0.51	0.46	0.44
30	1.34	1.08	0.97	0.85	0.70	0.64	0.62
40	1.73	1.43	1.25	1.03	0.90	0.82	0.77
50	2.00	1.73	1.50	1.33	1.09	1.00	0.92
60	2.39	2.03	1.66	1.51	1.29	1.17	1.10
70	2.75	2.27	1.96	1.79	1.48	1.35	1.29

Interpolation and extrapolation may be necessary to determine the appropriate surface area to drainage ratios.

1.1.4 Temporary Water Quality Pool

The temporary water quality pool is sized to detain the runoff volume from the first inch of rain. This requirement refers to volume and not a particular design storm.

The discharge rate from the outlet device for this temporary water quality pool shall meet the following:

- *The volume shall draw down to the pre-storm design stage in not less than two days, but not more than 5 days.*

1.1.5 Forebay

A forebay shall be provided for all inlets to the pond. The forebay area is located at the upstream area of the pond where the inlet pipes discharge. The forebay is separated from the rest of the pond by a barrier or baffle, serving to trap coarse sediments and minimizing their migration into the main pond. Collecting the sediment in this one area makes it easier to clean out, since machinery will not have to go into the entire pond.

The forebay baffle should extend to one foot below normal pool elevation. The baffle material may be constructed of earth, rip rap, corrugated aluminum or gabions. If earth baffles are used, provisions should be included to allow the forebay to drain out with the rest of the pond to facilitate sediment removal from the forebay. This could include a rip rap check dam in a section of the earth baffle or a perforated riser pipe connecting the forebay to the main pool.

Total volume of the forebay shall approximate 20% of the basin volume.

1.1.6 Dam and Embankment Construction

The dam or embankment shall be constructed of material with sufficient strength to remain stable and with low permeability to prevent seepage of water through the embankment.

For earth dams, a cutoff trench shall be provided with a minimum width of 4'. The cutoff trench shall be backfilled with clay or other highly impermeable material and compacted to at least ninety five percent (95%) of standard proctor density.

The top width of the dam shall be based on the total height of the embankment. *For heights of 10 feet or less, the minimum top width shall be 10 feet. For heights greater than 10 feet, the minimum top width shall be 15 feet.*

Concrete dams and spillway structures shall be designed and built in accordance with the American Concrete Institute's (ACI) latest guidelines. Particular attention shall be paid to design and analysis, water tightness, concrete quality, and construction practices.

No more than 50% of the pond embankments can be concrete.

1.1.7 Principal Spillway

The principal spillway shall be designed for the 10 yr., predevelopment storm.

The minimum difference in elevation between the principal spillway elevation and the emergency spillway elevation shall be one (1) foot.

The minimum diameter of the principal spillway barrel section (horizontal pipe) shall be twelve inches (12"). The minimum cross-sectional area of the riser section (vertical pipe) shall be 1.5 times that of the barrel section.

Anti-seep collars shall be installed on all pipe conduits through earthen dams and embankments

Vertical risers shall be equipped with an anti-vortex device to improve the flow of water, and with a trash rack or hood to prevent floating debris from clogging the principle spillway.

Anti-floatation calculations shall be submitted, with a minimum safety factor of 1.25. The riser/barrel assemblies shall be new and aluminum or concrete pipe, shall have gasketed joints and the barrel shall be pressure tested.

1.1.8 Emergency Spillway

The emergency spillway shall be designed to safely convey the 100 yr. design storm.

A minimum of one (1) foot of freeboard from the top of the pool elevation from the 100 yr. storm to the top of the dam shall be provided. The minimum difference in elevation between the emergency spillway elevation and the settled top of the dam shall be two (2) feet.

Spillways shall be constructed so as to prevent the discharge through the spillway from coming in contact with the fill section of the dam or principle embankment structure.

1.1.9 Pond Drain

An emergency drain (with pipe sized to drain the pond in 48 hours) shall be installed in all ponds to allow for access for riser repairs and sediment removal. The drain is recommended to be a minimum of 3" above the top of the sediment storage area, but may be placed on the bottom of the pond if the drainpipe is protected to prevent the outflow of accumulated sediment and debris when it is opened.

1.1.10 Maintenance Requirements

Regular maintenance is crucial to insure that a wet detention pond is effectively doing what it was designed to do, which is to remove stormwater pollutants. *Maintenance responsibility for a pond and its buffer shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.*

The principal spillway shall be equipped with a trash rack that provides access for maintenance.

Sediment removal in the forebay shall occur when 50% of the total forebay capacity has been lost.

A maintenance plan shall be provided with the design. The plan shall include a plan for sediment removal and disposal, and agreement to regularly maintain the pond. As a minimum, an acceptable maintenance plan shall include the items/frequency shown as follows:

Suggested Maintenance Schedule for Wet Detention Ponds

Description	Frequency
Mow/maintain buffer vegetation	Quarterly
Inspect bank embankment for erosion and repair as needed	Quarterly
Inspect pipe inlet and outlet areas for undercutting/erosion – repair as needed	Quarterly
Inspect trash rack, principal and emergency spillways for trash, blockage	After large storms

Inspect structural integrity of outflow device	annually
Inspect sediment accumulation	annually

1.1.11 Landscaping Plan

Studies of wet detention ponds in this area show that a well-maintained, aesthetically pleasing pond is more effective than a pond that once constructed, is promptly forgotten. Therefore, the city of High Point requires that a *landscaping plan for a stormwater pond and its buffer shall be prepared to indicate how aquatic and terrestrial areas will be stabilized and established.*

Whenever possible, native wetland plants should be encouraged in a pond design, either along the aquatic bench (fringe wetlands), the safety bench and side slopes (ED wetlands) or within shallow areas of the pool itself.

No fertilizers are allowed after stabilization of the pond or the surrounding area. No chemical weed killers will be permitted for invasive plants, and no chemical applications will be allowed within the pond. Mechanical controls are permitted.

The best elevation for establishing wetland plants, either through transplantation or volunteer colonization, are within six inches (plus or minus) of the normal pool.

To sustain the structural integrity of the dam, no trees or woody vegetation should be allowed on the dam embankments or top of dam. Trees and brush, if desired, are acceptable on pond embankments other than the dam.

The soils of a pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration, and therefore, may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites, and backfill these with uncompacted topsoil.

As a rule of thumb, planting holes should be 3 times deeper and wider than the diameter of the rootball (of balled and burlap stock), and 5 times deeper and wider for container grown stock. This practice should enable the stock to develop unconfined root systems. Avoid species that require full shade, are susceptible to winterkill, or are prone to wind damage. Extra mulching around the base of the tree or shrub is strongly recommended as a means of conserving moisture and suppressing weeds.

1.2 Extended Detention Wetlands

The extended detention wetland is similar in design to that of a wet detention pond. However, an extended detention stormwater wetland is created by varying the treatment volume depths within the system, and establishing several different zones of "microtopography". The extended detention wetland consists of a forebay, a low marsh area, a high marsh area, and a micropool (Figure 2). In extended detention wetlands, extra runoff storage is created above the marsh areas. The basic intent of a stormwater wetland is to create a shallow matrix of sediment, plants, water and detritus that collectively removes multiple pollutants through a series of complementary physical, chemical and biological pathways. Constructed stormwater wetlands are designed to maximize pollutant removal and create "generic" wetland habitats, and are not to be used to mitigate for the loss of natural wetlands under permitting provisions of the wetland protection requirements. Natural wetlands will not be allowed to be converted to stormwater wetlands without the approval of the US Army Corps of Engineers (US ACE) and the NC Division of Water Quality (NC DWQ). The removal of wetland soils and vegetation from natural wetlands to provide a "seedbank" for a stormwater wetland BMP is prohibited, without consultation with the US ACE and NCDWQ. Filling in the stormwater wetlands once they are established may be illegal without a permit.

1.2.1 General Design Guidelines

Placement of wetlands in jurisdictional waters may require Federal and State permits. It is suggested that ponds not be placed in perennial streams where possible.

Stormwater wetlands are best suited for areas with a minimum contributing drainage area of 20 acres.

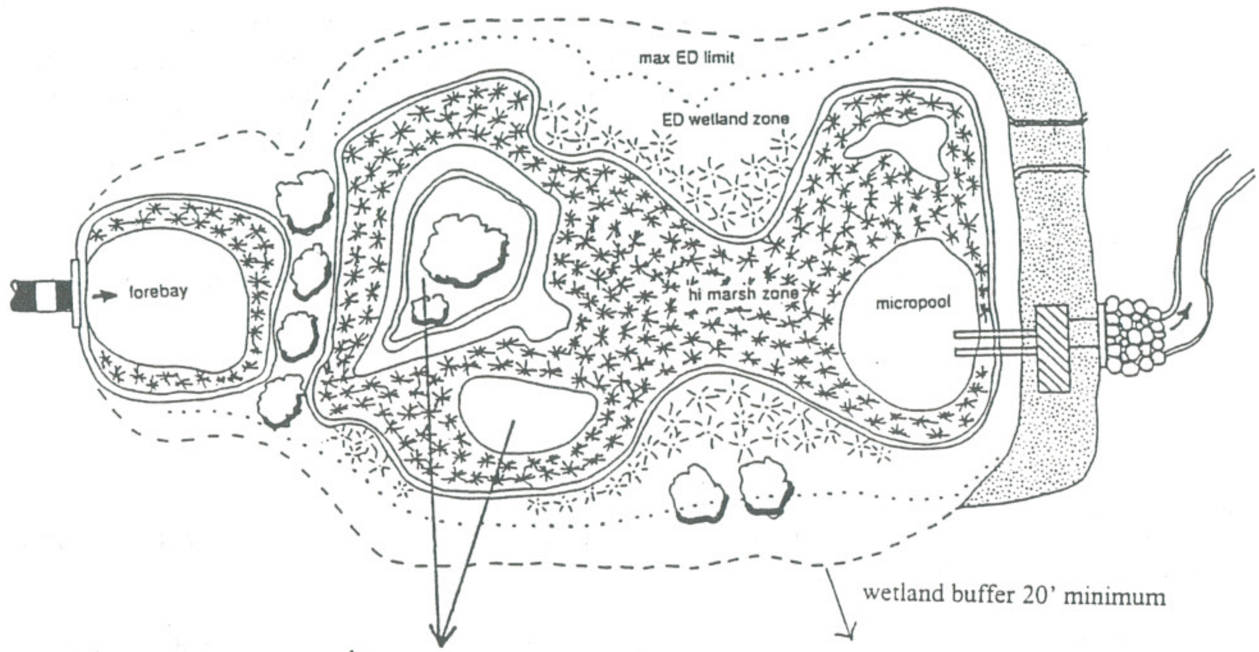
Of primary importance is the availability of water to insure the wetland doesn't go dry. The Metropolitan Washington Council of Governments (Design of Stormwater Wetland Systems) recommends performing a water balance to demonstrate that a stormwater wetland can withstand a thirty-day drought. Researchers at NCSU suggest that the base of wetlands constructed in sandy soils be set to around 6" lower than the seasonally low water table. There may be other methods for determining if the topography and soils are suitable for maintaining wetland plants and aquatic life.

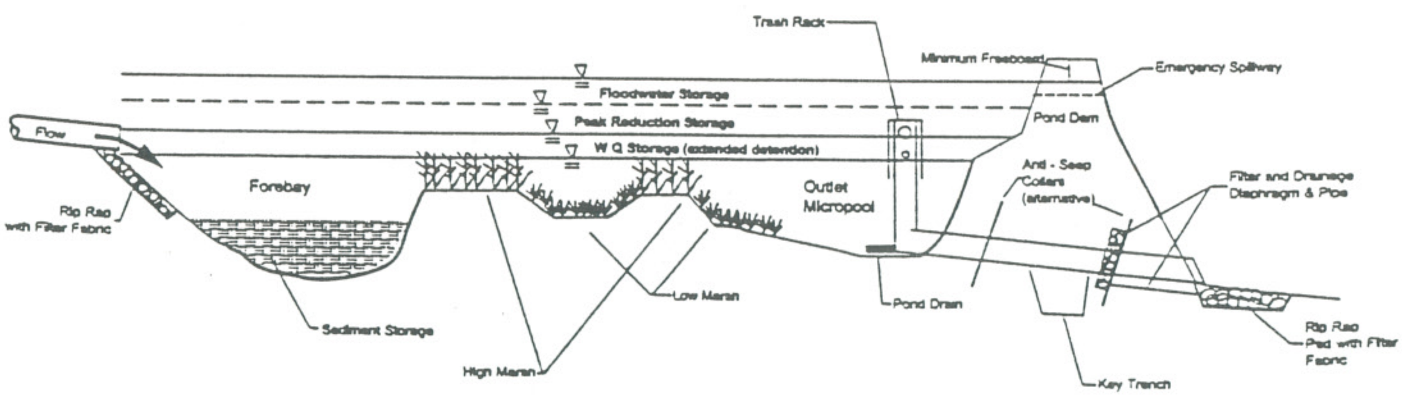
Stormwater wetlands used to meet the City of High Point watershed protection regulations shall be designed to treat the entire contributing drainage area.

The wetland should be easily accessible for maintenance. A 20' wide access easement shall be provided from the public street right-of-way to the wetland, and shall be contiguous around the wetland.

Wetland embankments shall be 4H:1V or flatter in order to reduce the erosion potential, promote wetland vegetation, minimize safety hazards, improve aesthetics and facilitate maintenance activities. A wetland embankment of 3H:1V is acceptable if a bench is placed near the normal pool surface. In any case, a 10-15' bench (max. slope 10%) placed around the pond near the normal pool surface, is strongly encouraged. This bench will allow machinery to gain closer access to the pond

Figure 2: The Extended Detention (ED) Wetland





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during cleanouts. This break in the grade will be a safety amenity and can make the pond more aesthetically pleasing. *Dam embankments shall be 3H:1V or flatter.*

The wetland surface shall have a minimum 3:1 length to width ratio (or equivalent with baffles) in order to limit short-circuiting. The distance between the inlets and outlets should be maximized to increase the pollutant removal capability of the wetland.

It is encouraged to create a wetland that fits the natural contours of the land but care should be taken to prevent "dead storage zones" (areas outside the flow path between the inlet and outlet) within the wetland. Generally, the wetland should be narrower at the inlet forebay area and become wider at the outlet. Whenever possible, one forebay should be created, with all pond inlet pipes discharging to this forebay.

Flowpaths across the stormwater wetland shall be maximized. This path may be achieved by constructing internal berms (e.g., high marsh wedges or rock filter cells). Microtopography is encouraged to enhance wetland diversity.

1.2.2 Permanent Water Quality Pool

The major difference between a stormwater wetland and a wet detention pond is the allocation of surface area to different pond depths.

For the system to function as a wetland, 70% of the surface pool area needs to be designed as a marsh with a depth of 0 to 18". Distribution should be evenly split such that 35% of the area will be designed as a "high marsh" (0 to 9 inches), and 35% designed as a "low marsh" (9 to 18 inches).

The remaining 30% of the surface area are to be divided between the forebay and micropool, with a depth of four (4) to six (6) feet.

According to NCDENR, the permanent water quality pool shall be sized based on the Table shown below:

Wetland Permanent Pool Surface Area to Drainage Area Ratio (Percent)							
Percent Built-Upon	10	20	30	40	50	60	70
SA/DA	0.59	0.97	1.34	1.73	2.00	2.39	2.75

1.2.3. Temporary Water Quality Pool

The temporary water quality pool is sized to detain the runoff volume from the first inch of rain. This requirement refers to volume and not a particular design storm.

The discharge rate from the outlet device for this temporary water quality pool should meet the following:

- *The volume shall draw down to the pre-storm design stage in not less than two days, but not more than five days.*

1.2.4 Forebay

The forebay serves to reduce incoming velocity that promotes initial settling of sediment, minimizing the amount of suspended sediment that enters the wetland area. The forebay serves to spread the flow equally over the width of the wetland. The forebay is to be separated from the remaining wetland by an earthen berm that is no lower than one foot below the normal pool. Sediment cleanout may be needed approximately every 3-5 years (depending on the condition of the drainage area). An access to the forebay should be provided from the top of the embankment and extend to the toe of the embankment slope. This access will allow construction equipment to get down in the forebay and will minimize disturbance to the vegetation.

1.2.5 Outlet Micropool

The outlet micropool is required to allow adequate depth for the extended detention release outlet to function properly and to allow a drain to be installed low enough to drain the wetland. The outlet micropool should be 4 to 6 feet deep. The deep pool areas can be used to stock mosquito fish to help control the mosquito population.

1.2.6 Dam and Embankment

The dam or embankment shall be constructed of material with sufficient strength to remain stable and with low permeability to prevent seepage of water through the embankment.

For earth dams, a cutoff trench shall be provided with a minimum width of 4'. The cutoff trench shall be backfilled with clay or other highly impermeable material and compacted to at least ninety five (95%) of standard proctor density.

The top width of the dam shall be based on the total height of the embankment. *For heights of 10 feet or less, the minimum top width shall be 10 feet. For heights greater than 10 feet, the minimum top width shall be 15 feet.*

Concrete dams and spillway structures shall be designed and built in accordance with the American Concrete Institute's (ACI) latest guidelines. Particular attention shall be paid to design and analysis, water tightness, concrete quality, and construction practices.

1.2.7 Principal Spillway

The principal spillway shall be designed for the 10 yr., predevelopment storm.

The minimum difference in elevation between the principal spillway elevation and the emergency spillway elevation shall be one (1) foot.

The minimum diameter of the principal spillway barrel section (horizontal pipe) shall be twelve (12) inches. The minimum cross-sectional area of the riser section (vertical pipe) shall be 1.5 times that of the barrel section.

Anti-seep collars shall be installed on all pipe conduits through earthen dams and embankments.

Vertical risers shall be equipped with an anti-vortex device to improve the flow of water, and with a trash rack or hood to prevent floating debris from clogging the principal spillway.

Anti-floatation calculations shall be submitted, with a minimum safety factor of 1.25. The riser/barrel assemblies shall be new and aluminum or concrete pipe, shall have gasketed joints and the barrel shall be pressure tested.

1.2.8 Emergency Spillway

The emergency spillway shall be designed to safely convey the 100 yr. design storm.

A minimum of one (1) foot of freeboard from the top of the pool elevation from the 100 yr. storm to the top of the dam shall be provided. The minimum difference in elevation between the emergency spillway elevation and the settled top of the dam shall be two (2) feet.

Spillways shall be constructed so as to prevent the discharge through the spillway from coming in contact with the fill section of the dam or principal embankment structure.

1.2.9 Wetland Drain

An emergency drain (with pipe sized to drain the wetland in 48 hours) shall be installed in all ponds to allow for access for riser repairs and sediment removal. Drain is recommended to be a minimum of three (3) inches above the top of the sediment storage area, but may be placed on the bottom of the wetland if the drainpipe is protected to prevent the outflow of accumulated sediment and debris when it is opened.

1.2.10 Wetland Planting

A *wetland-planting plan is to be developed as part of the wetland design (Figure 3).* Selecting the proper plant species and planting locations is an important part in creating a successful stormwater wetland BMP. A wetland-planting plan should be prepared by a qualified landscape architect and wetlands ecologist as part of the design of the wetland.

The following recommendations are based on the "Design of Stormwater Wetland Systems, by T. Schueler and included in Maryland Performance Criteria for Urban BMPs:

"The transplanting window extends from early April to mid-June. Planting after these dates is not recommended, as the wetland plants need a full growing season to build the root reserves needed to get through the winter. If at all possible, the plants should be ordered at least three months in advance to ensure the availability of the desired species.

The optimal depth requirements for several common species of emergent wetland plants are often six (6) inches of water or less.

To add diversity to the wetland, 5 to 7 species of emergent wetland plants should be used, drawn from the suggested species listed in Table 1. Of these, at least three species should be selected from the "aggressive colonizer" group (e.g. bulrush, pickerelweed, arrow arum, three square and rice cutgrass).

The most common and reliable technique for establishing an emergent wetland community in a stormwater wetland is to transplant nursery stock obtained from local aquatic plant nurseries.

Source of planting information:	Piedmont Environmental Center 1220 Penny Rd. High Point, NC 27265 (336) 883-8531
Local plant nursery:	Tom's Creek Nursery 6454 Old NC Hwy 49 Denton, NC 27239

The wetland area should be sub-divided into separate planting zones of more or less constant depth. Approximately half of the wetland surface area should be planted. One plant species should be planted within each flagged planting zone, based on their approximate depth requirements. Plants should be installed in clumps with individual plants located an average of 18 inches on center within each clump. Individual plants should be spaced no closer than 12 inches and no further than 24 inches on center.

Figure 3: Sample Pondscaping Plan

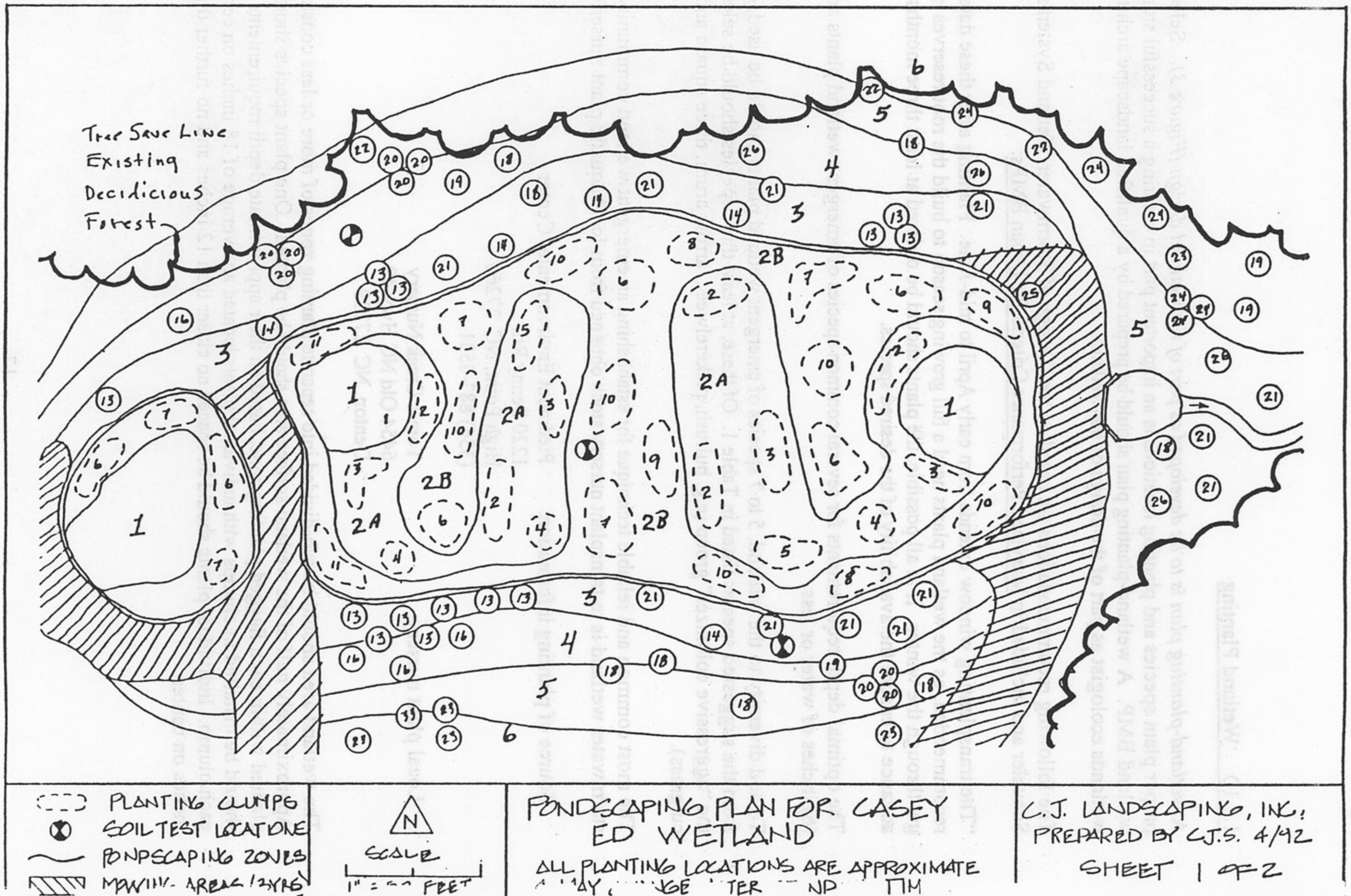


Figure 3 (continued): Sample Pondscaping Plan

PLANT MATERIALS By Pondscaping Zone

KEY	SPECIES	QTY	SIZE
▶ **Zone 1: Deep Pool**			
1	Wild Celery	25	Tubers, cheesecloth sinkers.
▶ **Zone 2A: Low Marsh**			
2	Duck Potato	375	Containers or peat pot 18" o.c.
3	Pickerelweed	300	
4	Arrow Arum	275	
5	Wild Rice	150	
▶ **Zone 2B: High Marsh**			
6	Common 3-Square	500	Container or peat pot 18" o.c.
7	Softstem Bulrush	500	
8	Lizards Tail	150	
9	Sweet Flag	150	
10	Rice Cutgrass	150	
11	Sedge spp.	150	
▶ **Zone 3: Shoreline**			
12	Switchgrass over Red Fescue		
13	Button Bush	8	Container
14	River Birch	6	Container
21	Black Willow	12	1" caliper container.
▶ **Zone 4: Riparian**			
15	Tall Fescue, wildlife mix	100 lbs/ac	Hydroseed
13	Button Bush	4	Container
16	Green Ash	4	2" B & B
17	Arrowood Viburnum	24	Container on embankments.
18	Silky Dogwood	4	2" B & B
19	Sycamore	4	2" B & B
▶ **Zone 5: Floodplain**			
15	Tall Fescue	100 lbs/ac	Hydroseed
18	Silky Dogwood	4	2" B & B
26	Tulip Poplar	4	2" B & B
20	Elder Berry	9	Container
21	Black Willow	12	1" B & B
22	Shad Bush	4	1" B & B
▶ **Zone 6: Upland**			
23	Willow Oak	6	2" B & B
24	Spice Bush	3	Container
19	Tulip Poplar	4	2" B & B
18	Silky Dogwood	2	2" B & B
▶ **Embankment**			
23	Periwinkle	48	Container

PONDSCAPING SEQUENCE

1. Temporary stabilization of all disturbed areas within 72 hours of final grade.
2. Aquatic planting window 4/1 - 6/15.
3. Reconfirm planting elevations one week prior to planting.
4. Revise plan, stake and flag.
5. De-water wetland 24 hrs before planting.
6. Plant wetland, remaining trees/shrubs.
7. Mulch, water stock, as needed.
8. Inspect pondscape twice/yr.
9. Reinforce planting at end of 1st and 2nd growing season.
10. Restrict mowing to designated areas.
11. Suppress weeds/vines on trees/shrubs during years 2 and 3.

PONDSCAPING NOTES

1. No trees in embankment or along mowed maintenance access area.
2. Tree-save line denotes limit of disturbance during wetland excavation.
3. Pondscaping zones and marsh planting zones to be confined in field after excavation.
4. Existing topsoil to be stockpiled and used to dress pondscaping zones 4,5,6.
5. Reinforcement planting after first growing season based on field inspection of marsh plant survival / colonization rates.
6. Three soil pit tests taken to confirm general soil properties.
7. Switchgrass overseeded on Red Fescue in Pondscaping Zone 3, Tall Fescue and Wildlife grass mix used in Zones 4,5,6 within three days of final grading for erosion control.
8. Six inches of wood mulch around all trees and shrubs, planting holes to be threetimes rootball diameter.

PLANTING CLUMPS SOIL TEST LOCATIONS PONDSCAPING ZONES MOWING AREAS (3YRS)	N SCALE 1" = 50 FEET	PONDSCAPING PLAN FOR CASEY ED WETLAND ALL PLANTING LOCATIONS ARE APPROXIMATE & MAY CHANGE AFTER STANDING TIME	C.J. LANDSCAPING, INC.; PREPARED BY CJ.S. 4/92 SHEET 2 OF 2

Table 1: Native Plant Guide for Stormwater Management Areas in the Mid-Atlantic

Native Plant Guide for Stormwater Management Areas in the Mid-Atlantic, USA

Plant Name	*Zone*	*Form*	*Available*	*Inundation Tolerance*	*Wildlife Value*	*Notes*
Trees and Shrubs						
American Beech (*Fagus grandifolia*)	5,6	Dec. Tree	no	no	High. Mammals and birds.	Prefers shade and rich, well drained soils.
American Holly (*Ilex opaca*)	5,6	Dec. Tree	yes	limited	High. Songbirds-food cover, nesting	Coastal Plain only. Prefers shade and rich soils.
American Hornbeam (*Carpinus caroliniana*)	4,5	Dec. Tree	yes	some	Moderate. Food, browsing.	Most common in floodplains and bottomland of Piedmont and mountains.
Arrowwood Viburnum (*Viburnum dentatum*)	3,4	Dec. Shrub	yes	yes	High. Songbirds and mammals	Grows best in sun to partial shade.
Bald Cypress (*Taxodium distichum*)	3,4	Dec. Tree.	yes	yes	Little food value but good perching site for waterfowl.	Forested Coastal Plain wetlands. North of normal range. Tolerates drought.
Bayberry (*Myrica pensylvanica*)	4,5,6	Dec. Shrub	yes	yes	High. Nesting, food, cover. Berries last into winter.	Coastal Plain only. Roots fix N_2. Tolerates slightly acidic soil.
Bitternut Hickory (*Carya cordiformis*)	4,5,6	Dec. Tree	no	no	High. Food.	Moist soils or wet bottomland areas.
Black Cherry (*Prunus serotina*)	5,6	Dec. Tree	yes	no	High. Fruit is eaten by many birds.	Temporarily flooded forested areas. Possible fungus infestation.
Black Walnut (*Juglans nigra*)	5,6	Dec. Tree	yes	some	High. Food.	Temporarily flooded wetlands along floodplains. Well drained, rich soils.
Blackgum or Sourgum (*Nyssa sylvatica*)	4,5,6	Dec. Tree	yes	yes	High. Songbirds, egrets, herons, raccoons, owls.	Can be difficult to transplant. Prefers sun to partial shade.
Black Willow (*Salix nigra*)	3,4,5	Dec. Tree	yes	yes	High. Browsing and cavity nesters.	Rapid growth, stabilizes streambanks. Full sun.
Buttonbush (*Cephalanthus occidentalis*)	2,3,4,5	Dec. Shrub	yes	yes	High. Ducks and shorebirds. Seeds nectar and nesting.	Full sun to partial shade. Will grow in dry areas.

Table 1 (cont'd.): Native Plant Guide for Stormwater Management Areas in the Mid-Atlantic

Plant Name	*Zone*	*Form*	*Available*	*Inundation Tolerance*	*Wildlife Value*	*Notes*
Chestnut Oak *(Quercus prinus)*	5,6	Dec. Tree	no	no	High. Cover, browse and food.	Gypsy Moth Target. Dry soils.
Common Choke Cherry *(Prunus virginiana)*	5,6	Dec. Tree	no	no	High. Birds, mammals. Fruit and cover.	Prefers drier conditions.
Common Spicebush *(Lindera benzoin)*	3,4,5	Dec. Shrub	yes	yes	Very high. Songbirds.	Shade and rich soils. Tolerates acidic soils. Good understory species.
Eastern Cottonwood *(Populus deltoides)*	4,5	Dec. Tree	yes	yes	Moderate. Cover, food.	Shallow rooted, subject to windthrow. Invasive roots. Rapid growth.
Eastern Hemlock *(Tsuga canadensis)*	5,6	Conif. Tree	yes	yes	Moderate. Mostly cover and some food.	Tolerates all sun/shade conditions. Tolerates acid soil.
Eastern Red Cedar *(Juniperus virginiana)*	4,5,6	Conif. Tree	yes	no	High. Fruit for birds. Some cover.	Full sun to partial shade. Common in wetlands, shrub bogs and edge of streams.
Elderberry *(Sambucus canadensis)*	3,4,5,6	Dec. Shrub	yes	yes	Extremely high for food and cover, for birds and mammals.	Full sun to partial shade.
Flowering Dogwood *(Cornus florida)*	6	Dec. Tree	yes	no	High. Birds, food.	Prefers rich, moist soils. Dogwood anthracnose possible problem.
Fringe Tree *(Chionanthus viginicus)*	3,4,5	Dec. Shrub or small tree	yes	some	Moderate. Food and cover.	Full sun to partial shade. Tolerates acid soil.
Green Ash, Red Ash *(Fraxinus pennsylvanica)*	4,5	Dec. Tree	yes	yes	Moderate. Songbirds.	Rapid growing, streambank stabilizer. Full sun to partial shade.
Hackberry *(Celtis occidentalis)*	5,6	Dec. Tree	yes	some	High. Food and cover.	Full sun to partial shade.
Ironwood/ Hophornbeam *(Ostrya virginiana)*	5,6	Dec. Tree	yes	some	Moderate. Food and browse.	Tolerant of all sunlight conditions.

Table 1 (cont'd.): Native Plant Guide for Stormwater Management Areas in the Mid-Atlantic

Plant Name	*Zone*	*Form*	*Available*	*Inundation Tolerance*	*Wildlife Value*	*Notes*
Larch, Tamarack *(Larix laricina)*	3,4	Conif. Tree	no	yes	Low. Nest tree and seeds.	Rapid initial growth. Full sun, acidic boggy soils.
Loblolly Pine *(Pinus taeda)*	5,6	Conif. Tree	yes	some	Moderate. Food, nesting, squirrels.	Coastal Plain only. Tolerant of extreme soil conditions.
Mountain Laurel *(Kalmia latifolia)*	6	Evergreen	no	no	Low. Cover and nectar. Foliage is toxic to cattle and deer.	Partial shade, acidic soils.
Persimmon *(Diospyros virginiana)*	4,5,6	Dec. Tree	yes	some	Extremely high. Birds, mammals	Not shade tolerant. Well drained soils.
Pin Oak *(Quercus palustris)*	3,4,5,6	Dec. Tree	yes	yes	High. Mast. Tolerates acidic soil.	Gypsy Moth Target. Prefers sun to partial shade.
Red Chokeberry *(Pyrus arbutifolia)*	3,4,5	Dec. Shrub	no	yes	Moderate. Songbirds.	Bank stabilizer. Partial sun.
Red Maple *(Acer rubrum)*	3,4,5,6	Dec. Tree	yes	yes	High seeds and browse. Tolerates acidic soil.	Rapid Growth.
Red Oak *(Quercus rubra)*	5,6	Dec. Tree	yes	no	High. Food and cover	Gypsy Moth Target. Prefers well drained, sandy soils.
River Birch *(Betula nigra)*	3,4,5	Dec. Tree	yes	yes	Low, but good for cavity nesters.	Bank erosion control. Full sun.
Scarlet Oak *(Quercus coccinea)*	5,6	Dec. Tree	yes	no	High. Food and cover.	Gypsy Moth Target. Difficult to transplant.
Shadbush, Serviceberry *(Amelanchier canadensis)*	4,5,6	Dec. Shrub	yes	yes	High. Nesting, cover and food. Birds and mammals.	Prefers partial shade. Common in forested wetlands and upland woods.
Silky Dogwood *(Cornus amomum)*	3,4,5	Dec. Shrub	yes	yes	High. Songbirds, mammals.	Shade and drought tolerant. Good bank stabilizer.

Table 1 (cont'd.): Native Plant Guide for Stormwater Management Areas in the Mid-Atlantic

Plant Name	*Zone*	*Form*	*Available*	*Inundation Tolerance*	*Wildlife Value*	*Notes*
Smooth Alder *(Alnus serrulata)*	3,4,5	Dec. Tree	no	yes	High. Food, cover.	Rapid Growth. Stabilizes streambanks.
Sourwood *(Oxydendrum arboreum)*	5,6	Dec. Tree	yes	no	Moderate. Food.	Ornamental.
Swamp Oak *(Quercus bicolor)*	3,4,5	Dec. Tree	yes	yes	High. Mast.	Full sun to partial shade. Good bottomland tree.
Sweetgum *(Liquidambar styraciflua)*	4,5,6	Dec. Tree	yes	yes	Moderate. Songbirds.	Tolerates acid or clay soils. Sun to partial shade.
Sycamore *(Platanus occidentalis)*	4,5,6	Dec. Tree	yes	yes	Low. Food, cavities for nesting.	Rapid Growth. Common in floodplains and alluvial woodlands.
Tulip Tree *(Liriodendron tulipifera)*	5,6	Dec. Tree	yes	no	Moderate. Seeds and nest sites.	Full sun to partial shade. Well drained soils. Rapid growth.
Tupelo *(Nyssa sylvatica vari biflora)*	3,4,5	Dec. Tree	yes	yes	High. Seeds, cavity nesters.	Ornamental.
White Ash *(Fraxinus americana)*	5,6	Dec. Tree	yes	no	High. Food.	All sunlight conditions. Well drained soils.
White Oak *(Quercus alba)*	5,6	Dec. Tree	yes	some	High. Food and cover.	Gypsy Moth Target. Prefers well drained soils.
Willow Oak *(Quercus phellos)*	4,5,6	Dec. Tree	yes	yes	High. Mast.	Full sun to partial shade. Common in temporarily flooded forested wetlands.
Winterberry *(Ilex verticillata)*	3,4,5	Dec. Shrub	yes	yes	High. Cover and fruit for birds. Holds berries into winter.	Full sun to partial shade. Seasonally flooded areas.
Witch Hazel *(Hamamelis virginiana)*	4,5	Dec. Shrub	yes	no	Low. Food for squirrels, deer and ruffed grouse.	Prefers shade. Ornamental

Table 1 (cont'd.): Native Plant Guide for Stormwater Management Areas in the Mid-Atlantic

Plant Name	*Zone*	*Form*	*Available*	*Inundation Tolerance*	*Wildlife Value*	*Notes*
Wetland Plants						
Arrow arum (*Peltandra virginica*)	2,3	Emergent	yes	up to 1 ft.	High. Berries are eaten by wood ducks.	Full sun to partial shade.
Arrowhead/Duck potato (*Saggitaria latifolia*)	2,3	Emergent	yes	up to 1 ft.	Moderate. Tubers and seeds eaten by ducks.	Aggressive colonizer.
Broomsedge (*Andropogon virginicus*)	2,3	Perimeter.	yes	up to 3 in.	High. Songbirds and browsers. Winter food and cover.	Tolerant of fluctuating water levels & partial shade.
Bushy Beardgrass (*Andropogon glomeratus*)	2,3	Emergent	yes	up to 1 ft.		Requires full sun.
Cattail (*Typha spp.*)	2,3	Emergent	yes	up to 1 ft.	Low. Except as cover.	Aggressive. May eliminate other species. Volunteer. High pollutant treatment.
Coontail (*Ceratophyllum demersum*)	1	Submergent	no	yes	Low food value. Good habitat and shelter for fish and invertebrates.	Free floating SAV. Shade tolerant. Rapid growth.
Common Three-Square (*Scirpus pungens*)	2	Emergent	yes	up to 6 in.	High. Seeds, cover. Waterfowl, songbirds.	Fast colonizer. Can tolerate periods of dryness. Full sun. High metal removal.
Duckweed (*Lemna sp.*)	1,2	Submergent/ emergent	yes	yes	High. Food for waterfowl and fish.	High metal removal.
Lizard's Tail (*Saururus cernuus*)	2	Emergent	yes	up to 1 ft.	Low, except wood ducks.	Rapid growth. Shade tolerant.
Marsh Hibiscus (*Hibiscus moscheutos*)	2,3	Emergent	yes	up to 3 in.	Low. Nectar.	Full sun Can tolerate periodic dryness.
Pickerelweed (*Pontederia cordata*)	2,3	Emergent	yes	up to 1 ft.	Moderate. Ducks. Nectar for butterflies.	Full sun to partial shade.
Pond Weed (*Potamogeton pectinatus*)	1	Submergent	yes	yes	Extremely high. Waterfowl, marsh and shorebirds.	Removes heavy metals.

Table 1 (cont'd.): Native Plant Guide for Stormwater Management Areas in the Mid-Atlantic

Plant Name	Zone	Form	Available	Inundation Tolerance	Wildlife Value	Notes
Rice Cutgrass *(Leersia oryzoides)*	2,3	Emergent	yes	up to 3 in.	High. Food and cover.	Full sun although tolerant of shade. Shoreline stabilization.
Sedges *(Carex spp.)*	2,3,4	Emergent	yes	up to 3 in.	High. Waterfowl, songbirds.	Many wetland and several upland species.
Soft-stem Bulrush *(Scirpus validus)*	2,3	Emergent	yes	up to 1 ft.	Moderate. Good cover and food.	Full sun. Aggressive colonizer. High pollutant removal.
Smartweed *(Polygonum spp.)*	2,3,4	Emergent	yes	up to 1 ft.	High. Waterfowl, songbirds. Seeds and cover.	Fast colonizer. Avoid weedy aliens such as P. perfoliatum.
Soft Rush *(Juncus effusus)*	2,3,4	Emergent	yes	up to 3 in.	Moderate.	Tolerates wet or dry conditions.
Spatterdock *(Nuphar luteum)*	2	Emergent	yes	up to3 ft	Moderate for food but high for cover.	Fast colonizer. Tolerant of fluctuating water levels.
Switchgrass *(Panicum virgatum)*	2,3,4,5,6	Perimeter	yes	up to 3 in..	High. Seeds, cover for waterfowl, songbirds.	Tolerates wet/dry conditions.
Sweet Flag *(Acorus calamus)*	2,3	Perimeter	yes	up to 3 in.	Low.	Tolerant of dry periods. Not a rapid colonizer. Tolerates acidic conditions.
Waterweed *(Elodea canadensis)*	1	Submergent	yes	yes	Low.	Good water oxygenator. High nutrient, copper, manganese and chromium removal.
Wild Celery *(Valisneria americana)*	1	Submergent	yes	yes	High. Food for waterfowl. Habitat for fish and invertebrates.	Tolerant of murky water and high nutrient loads.
Wild Rice *(Zizania aquatica)*	2	Emergent	yes	up to 1 ft.	High. Food for birds.	Prefers full sun.

Post-nursery care of wetland plants is very important in the interval between delivery of the plants and their subsequent installation, as they are prone to desiccation. Stock should be frequently watered and shaded while on-site.

A wet hydroseed mix should be used to establish permanent vegetative cover in the buffer outside of the permanent pool. For rapid germination, scarify the soil to ½ inch prior to hydroseeding. Alternatively, red fescue or annual rye can be used as a temporary cover for the wet species.

Because most stormwater wetlands are excavated to deep sub-soils, they often lack the nutrients and organic matter needed to support vigorous growth of wetland plants. At these sites, three to six inches of topsoil or wetland mulch should be added to all depth zones in the wetland from one foot below the normal pool to six inches above. Wetland mulch is preferable to topsoil if it is available.

The stormwater wetland should be staked at the onset of the planting season. Depths in the wetland should be measured to the nearest inch to confirm the original planting zones. At this time, it may be necessary to modify the pondscape plan to reflect altered depths or the availability of wetland plant stock. Surveyed planting zones should be marked on an "as-built" or design plan and located in the field using stakes or flags. The wetland drain should be fully opened at least three days prior to the planting date (which should coincide with the delivery date for the wetland plant stock).

Wetland mulch is another technique to establish a plant community that utilizes the seedbank of wetland soils to provide the propagules for marsh development. The majority of the seedbank is contained within the upper six inches of the donor soils. The mulch is best collected at the end of the growing season. Best results are obtained when the mulch is spread 3 to 6 inches deep over the high marsh and semi-wet zones of the wetland (-6 inches to +6 inches relative to the normal pool). *If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting will be required.*

1.2.11 Maintenance Requirements

Regular maintenance is important to insure that a constructed wetland is effectively doing what it was designed to do, which is to remove stormwater pollutants. *Maintenance responsibility for the stormwater wetland and its buffer shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.*

The principal spillway shall be equipped with a trash rack that provides access for maintenance.

Sediment removal in the forebay shall occur when 50% of the total forebay capacity has been lost.

A maintenance plan shall be provided with the design, which shall include a plan for sediment removal and disposal, and agreement to regularly maintain the wetland. As a minimum, an acceptable maintenance plan shall include the items/frequency shown as follows:

Suggested Maintenance Schedule for Constructed Stormwater Wetlands

Description	Frequency
Mow/maintain buffer vegetation	Quarterly
Inspect bank embankment for erosion and repair as needed	Quarterly
Inspect pipe inlet and outlet areas for undercutting/erosion – repair as needed	Quarterly
Inspect trash rack, principal and emergency spillway for trash, blockage	After large storms
Inspect structural integrity of outflow device	Annually
Inspect sediment accumulation	Annually
Plant survival and distribution compliant with as-built pondscaping plans?	Twice a year in first 3 years after construction; annually thereafter

1.3 Bioretention Areas

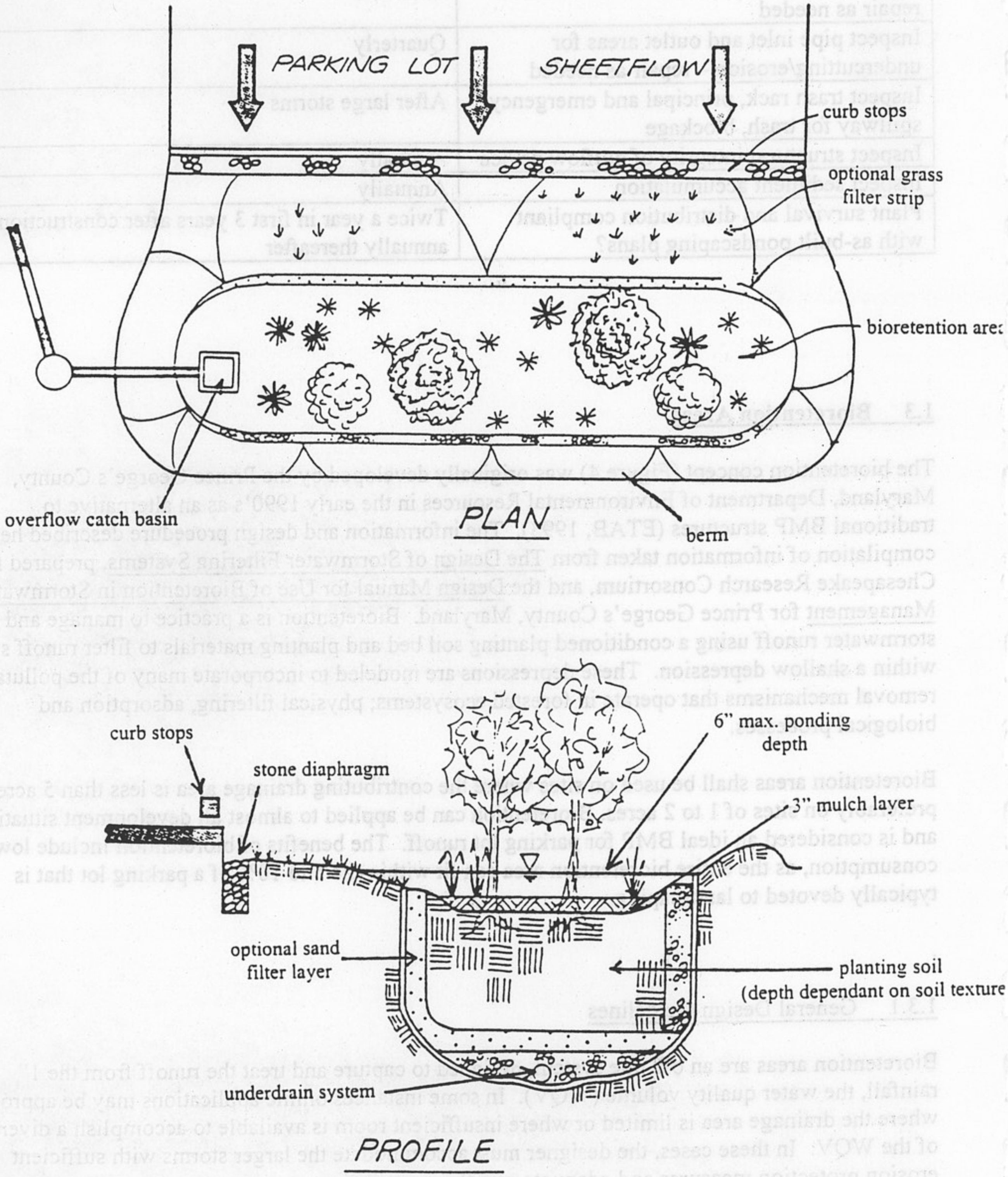
The bioretention concept (Figure 4) was originally developed by the Prince George's County, Maryland, Department of Environmental Resources in the early 1990's as an alternative to traditional BMP structures (ETAB, 1993). The information and design procedure described here is a compilation of information taken from The Design of Stormwater Filtering Systems, prepared for the Chesapeake Research Consortium, and the Design Manual for Use of Bioretention in Stormwater Management for Prince George's County, Maryland. Bioretention is a practice to manage and treat stormwater runoff using a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression. These depressions are modeled to incorporate many of the pollutant removal mechanisms that operate in forested ecosystems; physical filtering, adsorption and biological processes.

Bioretention areas shall be used on sites where the contributing drainage area is less than 5 acres, preferably on sites of 1 to 2 acres. Bioretention can be applied to almost all development situations, and is considered an ideal BMP for parking lot runoff. The benefits of bioretention include low land consumption, as the entire bioretention area can fit within the 5 to 10% of a parking lot that is typically devoted to landscaping.

1.3.1 General Design Guidelines

Bioretention areas are an off-line system, designed to capture and treat the runoff from the 1" rainfall, the water quality volume (WQV). In some instances online applications may be appropriate where the drainage area is limited or where insufficient room is available to accomplish a diversion of the WQV. In these cases, the designer must accommodate the larger storms with sufficient erosion protection measures and adequate overflow provisions.

Figure 4: Bioretention Area



Bioretention area components have been combined to have complementary roles or functions to improve water quality. The six major components of the bioretention area are:

- Grass buffer strip
- Ponding area
- Planting soil
- Organic or mulch layer
- Plant material
- Underdrain system

1.3.2 Grass Buffer Strip

A grassed buffer strip is recommended to aid in reducing the incoming velocity as well as capturing coarser sediment particles. This will extend the design life and reduce replacement and maintenance of the bioretention system.

1.3.3 Ponding area

This ponding area above the mulch layer and vegetation root zone provides surface storage for a percentage of the WQV. This area also allows for particulate settling during the detention period allowing finer particles to settle on the surface of the mulch layer. A maximum ponding depth of 6" is recommended based on providing surface storage for a period of less than 4 days. NCDENR cautions that a ponding time in excess of four days limits the potential plant species for the bioretention area, and provides an encouraging breeding round for mosquitoes and other undesirable insects.

1.3.4 Planting soil

The planting soil is the region that provides the source of water and nutrients for the plants to sustain growth. The voids in the soil also provide for stormwater storage. NCDENR recommends a planting soil having a composition of at least 10 to 25 percent clay and being of a sandy loam or loamy sand texture. Loamy soils may be utilized for the planting soil but must consist of 35% sand. *If a soil of this texture is used, the soil depth must be 4 feet.* Prince George's County conducted a two-year study of the effectiveness of bioretention areas, and they suggest a soil composition of 50% sand, 20% leaf mulch, and 30% topsoil. The maximum clay content should be less than 10%. *If a soil of this texture is used, the soil depth can be reduced to 3 feet.* Soil shall be of uniform composition, free of stones, stumps, roots or similar objects larger than one inch, brush, or any other material or substance which may be harmful to plant growth, or a hindrance to planting or maintenance operations. Planting soil shall be tested and meet the following criteria:

pH range:	5.5 – 6.5
Organic matter:	1.5 – 3.0%
Magnesium (Mg):	35 lbs/acre
Phosphorus (P_2O_5):	100 lbs/acre
Potassium (K_2O):	85 lbs/acre
Soluble salts:	not to exceed 500ppm

The following testing frequencies shall apply to the above soil constituents:

- pH, organic matter: 1 test per 90 cubic yards, but no less than 1 test per bioretention area
- Magnesium, phosphorus, potassium, soluble salts: 1 test per 500 cubic yards, but no less than 1 test per borrow source.
- One grain size analysis shall be performed per 90 cubic yards of planting soil, but no less than 1 test per bioretention area.

1.3.5 Organic or mulch layer

The organic or mulch layer provides an environment for plant growth by maintaining moisture and allowing for the decomposition of organic matter. The surface layer acts as a filter for finer particles still in suspension and maintains an environment for the microbial community to help breakdown urban runoff pollutants.

Hardwood mulch or chips should be used because they resist floatation better than other landscape covers. Optimum age of the mulch is 12 months. The mulch should be clean free of weeds, soil, roots, plastic, etc.

Mulch should be reapplied wherever is has been displaced through erosion. Mulch layer should be 3 inches thick, and should be replaced once per year or whenever is decays.

1.3.6 Plant material

A bioretention area landscape plan shall be prepared and include the type and number of plantings, plant location, installation guidelines, and post-installation inspection and maintenance guidelines.

Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an ecosystem consisting of an upland oriented community dominated by trees, but having a distinct community, or sub-canopy, of understory trees, shrubs and herbaceous materials. The intent is to establish a diverse, dense plant cover to treat stormwater runoff and withstand urban stresses from insect and disease infestations, drought, temperature, wind and exposure.

The proper selection and installation of plant materials is key to a successful system. There are essentially three zones within a bioretention facility (Figure 5). The lowest elevation supports plant species adapted to standing and fluctuating water levels. The middle elevation supports a slightly drier group of plants, but still tolerates fluctuating water levels. The outer edge is the highest elevation and generally supports plants adapted to dryer conditions.

See Table 2 for suggested planting material for bioretention areas. A minimum of 3 species of each tree, shrub, and herbaceous planting should be specified with a minimum planting density of 1000 stems/acre. A higher planting density may be desired for landscaping purposes.

Figure 5: Example Planting Zones for Bioretention Area

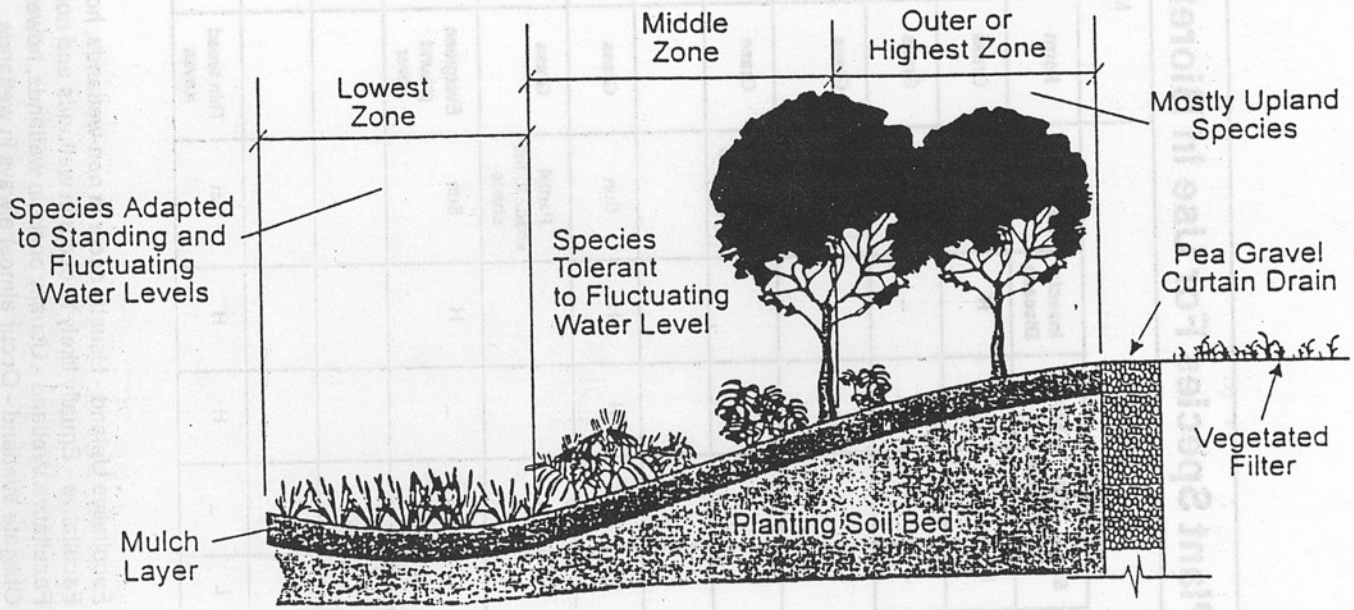


Table 2: Recommended Plant Species For Use In Bioretention - Herbaceous Species

Species	Moisture Regime		Tolerance						Morphology			General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Agrostis alba redtop	FAC	Mesic-Xeric	1-2	H	–	H	H	Shade	Grass	2-3'	Fiberous Shallow	Yes	High	–
Andropogon gerardi bluejoint	FAC	Dry Mesic-Mesic	1-2	–	–	–	–	Sun	Grass	2-3'	Fiberous Shallow	Yes	High	–
Andropogon virginicus broomsedge	–	Wet meadow	1-2	L	–			Full sun	Grass	1-3'		Yes	High	Tolerant of fluctuating water levels and drought.
Carex vulpinoidea fox sedge	OBL	Freshwater marsh	2-4	L	–			Sun to partial sun	Grass	2-3.5'	Rhizome	Yes	High	–
Chelone glabra														
Deschampsia caespitosa tufted hairgrass	FACW	Mesic to wet Mesic	2-4	H	–	H	H	Sun	Grass	2-3'	Fiberous Shallow	Yes	High	May become invasive.
Glyceria striata fowl mannagrass, nerved mannagrass	OBL	Freshwater marsh, seeps	1-2	L	–			Partial shade to full shade	Grass	2-4'	Rhizome	Yes	High	–
Hedera helix English ivy	FACU	Mesic	1-2	–	–	–	H	Sun	Evergreen ground cover	–	Fiberous Shallow	No	Low	–
Hibiscus palustris														
Iris kaempferi														
Iris pseudacorus yellow water iris	OBL	Mesic to wet Mesic	2-4	L	–	H	H	Sun	Thin broad leaves	1-4'	Bulb	Yes	Med	–

H High Tolerance
M Medium Tolerance
L Low Tolerance

FACU Facultative Upland - Usually occur in non-wetlands, however, occasionally found in wetlands.
FAC Facultative - Equally likely to occur in wetlands and non-wetlands.
FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Occur almost always in wetlands

Adapted from the Prince George's County Design Manual for use of Bioretention in Stormwater Management

Table 2: Recommended Plant Species For Use In Bioretention - Herbaceous Species

Species	Moisture Regime		Tolerance					Morphology				General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Lobelia siphilitica														
Lotus Corniculatus birdsfoot-trefoil	FAC	Mesic-Xeric	1-2	H	L	H	H	Sun	Grass	2-3'	Fiberous Shallow	Yes	High	Member of the legume family.
Onoclea sensibilis sensitive fern, beadfern	FACW							Shade		1-3.5'			H	
Pachysandra terminalis Japanese pachysandra	FACU	Mesic	1-2	–	–	–	M	Shade	Evergreen ground cover	–	Fiberous Shallow	No	Low	–
Panicum virgatum switch grass	FAC to FACU	Mesic	2-4	H	–	–	H	Sun or Shade	Grass	4-5'	Fiberous Shallow	Yes	High	Can spread fast and reach height of 6'.
Vinca major large periwinkle	FACU	Mesic	1-2	–	–	–	H	Shade	Evergreen ground cover	–	Fiberous Shallow	No	Low	Sensitive to soil compaction and pH changes.
Vinca minor common periwinkle	FACU	Mesic	1-2	–	–	–	H	Shade	Evergreen ground cover	–	Fiberous Shallow	No	Low	–
Indian grass														
Little bluestem														
Deer tongue														
Green coneflower														

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FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Occur almost always in wetlands

Adapted from the Prince George's County Design Manual for use of Bioretention in Stormwater Management

Table 2: Recommended Plant Species For Use In Bioretention - Shrub Species

Species	Moisture Regime		Tolerance					Morphology			General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Aronia arbutifolia *(Pyrus arbutifolia)* red chokeberry	FACW	Mesic	1-2	H	–	H	M	Sun to partial sun	Deciduous shrub	6-12'	–	Yes	High	Good bank stabilizer. Tolerates drought.
Berberis thunbergii Japanese barberry	FAC	Mesic	2-4	H	H	H	M	Sun	Rounded, broad dense shrub	5-7'	Shallow	No	Med	–
Clethra alnifolia sweet pepperbush	FAC	Mesic to wet Mesic	2-4	H	–	–	H	Sun to partial sun	Ovoid shrub	6-12'	Shallow	Yes	Med	Coastal plain species.
Cornus Stolonifera *(Cornus sericea)* red osier dogwood	FACW	Mesic-Hydric	2-4	H	H	H	M	Sun or shade	Arching, spreading shrub	8-10'	Shallow	Yes	High	Needs more consistent moisture levels.
Cornus amomum silky dogwood	FAC	Mesic	1-2	L	–	–	M	Sun to partial sun	Broad-leaved	6-12'	–	Yes	High	Good bank stabilizer
Euonymous alatus winged euonymous	FAC	Mesic	1-2	H	H	H	M	Sun or shade	Flat, dense horizontal branching shrub	5-7'	Shallow	No	No	–
Euonymous europaeus spindle-tree	FAC	Mesic	1-2	M	M	M	M	Sun to partial sun	Upright dense oval shrub	10-12'	Shallow	No	No	–
Hamamelis virginiana witch hazel	FAC	Mesic	2-4	M	M	M	M	Sun or shade	Vase-like compact shrub	4-6'	Shallow	Yes	Low	–
Hypericum densiflorum common St. John's wort	FAC	Mesic	2-4	H	M	M	H	Sun	Ovoid shrub	3-6'	Shallow	Yes	Med	–
Ilex glabra inkberry	FACW	Mesic to wet Mesic	2-4	H	H	–	H	Sun to partial sun	Upright dense shrub	6-12'	Shallow	Yes	High	Coastal plain species.
Ilex verticillata winterberry	FACW	Mesic to wet Mesic	2-4	L	M	–	H	Sun to partial sun	Spreading shrub	6-12'	Shallow	Yes	High	–

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Table 2: Recommended Plant Species For Use In Bioretention - Shrub Species

Species	Moisture Regime		Tolerance					Morphology			General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Itea virginica tassel-white, Virginia sweetspire	OBL	Mesic	1-2	M	–	–	M	Sun or shade	Broad-leaved, deciduous shrub	6-12'	–	Yes	Low	–
Juniperus communis "compressa" common juniper	FAC	Dry Mesic-Mesic	1-2	M	H	H	M-H	Sun	Mounded shrub	3-6'	Deep taproot	No	High	Evergreen
Juniperus horizontalis "Bar Harbor" creeping juniper	FAC	Dry Mesic-Mesic	1-2	M	H	H	M-H	Sun	Matted shrub	0-3'	Deep taproot	No	High	Evergreen
Lindera benzoin spicebush	FACW	Mesic to wet Mesic	2-4	H	–	–	H	Sun	Upright shrub	6-12'	Deep	Yes	High	–
Myrica pennsylvanica bayberry	FAC	Mesic	2-4	H	M	M	H	Sun to partial sun	Rounded, compact shrub	6-8'	Shallow	Yes	High	Coastal plain species.
Physocarpus opulifolius ninebark	FAC	Dry Mesic to wet Mesic	2-4	M	–	–	H	Sun	Upright shrub	6-12'	Shallow	Yes	Med	May be difficult to locate.
Viburnum cassinoides northern wild raisin	FACW	Mesic	2-4	H	H	H	H	Sun to partial sun	Rounded, compacted shrub	6-8'	Shallow	Yes	High	–
Viburnum dentatum arrow-wood	FAC	Mesic to wet	2-4	H	H	H	H	Sun to partial sun	Upright, multi-stemmed shrub	8-10'	Shallow	Yes	High	–
Viburnum lentago nannyberry	FAC	Mesic	2-4	H	H	H	H	Sun to partial sun	Upright, mlti-stemmed shrub	8-10'	Shallow	Yes	High	–

H High Tolerance
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Table 2: Recommended Plant Species For Use In Bioretention - Tree Species

Species	Moisture Regime		Tolerance					Morphology				General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Acer rubrum red maple	FAC	Mesic-Hydric	4-6	H	H	H	H	Partial sun	Single to multi-stem tree	50-70'	Shallow	Yes	High	–
Amelanchier canadensis shadbush	FAC	Mesic	2-4	H	M	–	H	Partial sun	Single to multi-stem tree	35-50'	Shallow	Yes	High	Not recommended for full sun.
Betula nigra river birch	FACW	Mesic-Hydric	4-6	–	M	M	H	Partial sun	Single to multi-stem tree	50-75'	Shallow	Yes	High	Not susceptible to bronze birch borer.
Betula populifolia gray birch	FAC	Xeric-Hydric	4-6	H	H	M	H	Partial sun	Single to multi-stem tree	35-50'	Shallow to deep	No	High	Native to New England area.
Fraxinus americana white ash	FAC	Mesic	2-4	M	H	H	H	Sun	Large tree	50-80'	Deep	Yes	Low	–
Fraxinus Pennsylvanica green ash	FACW	Mesic	4-6	M	H	H	H	Partial sun	Large tree	40-65'	Shallow to deep	Yes	Low	–
Ginko biloba Maidenhair tree	FAC	Mesic	2-4	H	H	H	H	Sun	Large tree	50-80'	Shallow to deep	No	Low	Avoid female species-offensive odor from fruit.
Gleditsia triacanthos honeylocust	FAC	Mesic	2-4	H	M	–	M	Sun	Small caopled large tree	50-75'	Shallow to deep variable taproot	Yes	Low	Select thornless variety.
Juniperus virginiana eastern red cedar	FACU	Mesic-Xeric	2-4	H	H	–	H	Sun	Dense single stem tree	50-75'	Taproot	Yes	Very high	Evergreen
Liquidambar styraciflua sweet gum	FAC	Mesic	4-6	H	H	H	M	Sun	Large tree	50-70'	Deep taproot	Yes	High	Edge and perimeter; fruit is a maintenance problem.
Nyssa sylvatica black gum	FACW	Mesic-Hydric	4-6	H	H	H	H	Sun	Large tree	40-70'	Shallow to deep taproot	Yes	High	–

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Table 2: Recommended Plant Species For Use In Bioretention - Tree Species

Species	Moisture Regime		Tolerance					Morphology				General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Platanus acerifolia London plane-tree	FACW	Mesic	2-4	H	–	–	M	Sun	Large tree	70-80'	Shallow	No	Low	Tree roots can heave sidewalks.
Platanus occidentalis sycamore	FACW	Mesic-Hydric	4-6	M	M	M	M	Sun	Large tree	70-80'	Shallow	Yes	Med	Edge and perimeter; fruit is a maintennance problem; tree is also prone to windthrow.
Populus deltoides eastern cottonwood	FAC	Xeric-Mesic	4-6	H	H	H	L	Sun	Large tree with spreading branches	75-100'	Shallow	Yes	High	Short lived.
Quercus bicolor Swamp white oak	FACW	Mesic to wet Mesic	4-6	H	–	H	H	Sun to partial sun	Large tree	75-100'	Shallow	Yes	High	One of the faster growing oaks.
Quercus coccinea scarlet oak	FAC	Mesic	1-2	H	M	M	M	Sun	Large tree	50-75'	Shallow to deep	Yes	High	–
Quercus macrocarpa bur oak	FAC	Mesic to wet Mesic	2-4	H	H	H	M	Sun	Large spreading tree	75-100"	Taproot	No	High	Native to Midwest.
Quercus palustris pin oak	FACW	Mesic-Hydric	4-6	H	H	H	M	Sun	Large tree	60-80'	Shallow to deep taproot	Yes	High	–
Quercus phellos willow oak	FACW	Mesic to wet Mesic	4-6	H	–	–	H	Sun	Large tree	55-75'	Shallow	Yes	High	Fast growing oak.
Quercus rubra red oak	FAC	Mesic	2-4	M	H	M	M	Sun to partial sun	Large spreading tree	60-80'	Deep taproot	Yes	High	–
Quercus shumardii Shumard's red oak	FAC	Mesic	2-4	H	H	H	M	Sun to partial sun	Large spreading tree	60-80'	Deep taproot	No	High	Native to Southeast.

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Adapted from the Prince George's County Design Manual for use of Bioretention in Stormwater Management

Table 2: Recommended Plant Species For Use In Bioretention - Tree Species

Species	Moisture Regime		Tolerance					Morphology				General Characteristics		Comments
Scientific Name Common Name	Indicator Status	Habitat	Ponding (days)	Salt	Oil/ Grease	Metals	Insects/ Disease	Exposure	Form	Height	Root System	Native	Wildlife	
Robinia pseudo-acacia black locust	FAC	Mesic-Xeric	2-4	H	H	H	M	Sun	Typically tall and slender	30-50'	Shallow	Yes	Low	Edge and perimeter; fruit is a maintenance problem; tree is also prone to windthrow.
Sophora japonica Japanese pagoda tree	FAC	Mesic	1-2	M	M	–	M	Sun	Shade tree	40-70'	Shallow	No	Low	Fruit stains sidewalk.
Taxodium distichum bald cypress	FACW	Mesic-Hydric	4-6	–	–	M	H	Sun to partial sun	Typically single stem tree	75-100'	Shallow	Yes	Low	Not well documented for planting in urban areas.
Thuja occidentalis arborvitae	FACW	Mesic to wet Mesic	2-4	M	M	M	H	Sun to partial sun	Dense single stem tree	50-75'	Shallow	No	Low	Evergreen
Zelkova serrata Japanese zelkova	FACU	Mesic	1-2	M	M	–	H	Sun	Dense shade tree	60-70'	Shallow	No	Low	Branches can split easily in storms.

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1.3.7 Underdrain system

Because the native soils in Guilford County do not generally allow for adequate infiltration, all bioretention areas shall have an underdrain system placed beneath the planting soil. The underdrain should consist of perforated piping with a gravel jacket. An optional intermediate layer of geotextile fabric or pea gravel can be placed between the planting soil and gravel jacket to prevent clay from getting into the pipe. Recommended design for underdrain system includes: 6" minimum perforated pipe systems (min. of 4") within an 8" gravel bed (min. of 2" cover over pipe). The pipe should have 3/8" perforations, spaced at 6" centers (for 6" pipe), with a minimum of 4 holes per row. The pipe should be spaced at a maximum of 10' on-center and a minimum grade of 0.5% should be maintained. At least one cleanout per run should be provided. The underdrain system should be connected to the conventional drainage system, or should daylight to a suitable non-erosive outfall (Design of Stormwater Filtering Systems).

1.3.8 Sizing Requirements

Bioretention areas are sized to control the water quality volume (WQV) from a 1" rainfall, which will effectively treat 90% of the annual average rainfall. One method, the **Short Cut Method,** (Schueler, 1987) can be used to obtain a reasonably accurate estimate of the treatment volume

$$WQV = \frac{P * R_v * DA}{12} \text{ where}$$

WQV = Water Quality Volume, in acre-feet

P = rainfall, inches (1.0 since controlling for 1" rainfall)

R_v (volumetric runoff coefficient) = $0.05 + 0.009(I)$, where

I = % imperviousness

DA = drainage area, acres

The filter area shall be sized based on the principles of Darcy's Law, and the experiences in Maryland and Prince George's County. The required filter bed area is computed using the following equation:

$$A_f = (WQV * d_f)/[k * (h_f + d_f) * t_f] \text{ where}$$

A_f = surface area of filter bed, ft^2

d_f = filter bed depth (minimum of 3' or 4' depending on soil texture)

k = coefficient of permeability of filter media (assume 0.5 ft/day based on Claytor and Schueler, 1996), ft/day

h_f = average height of water above filter bed, ft ($1/2 * h_{max}$)

t_f = design filter bed drain time, days (48 hours is recommended for bioretention areas)

WQV = Water Quality Treatment Vol. (ft^3)

1.3.9 Maintenance Requirements

Suggested Maintenance Schedule for Bioretention Areas:

DESCRIPTION	METHOD	FREQUENCY	TIME OF YEAR
		Soil	
Inspect and Repair Erosion	Visual	Monthly	Monthly
		Organic Layer	
Remulch any void areas	By hand	Whenever needed	Whenever needed
Remove previous mulch layer before applying new layer (optional)	By hand	Once every two or three years	Spring
Any additional mulch added	By hand	Once a year	Spring
		Plants	
Remove and replacement of all dead and diseased vegetation considered beyond treatment	See planting specification		3/15 to 4/30 and 10/1 to 11/30
Treat all diseased trees and shrubs	Mechanical or by hand	N/A	Varies, but will depend on insect or disease infestation
Water of plant material shall take place at end of each day for 14 consecutive days and after planting has been completed	By hand	Immediately after completion of project	N/A
Replacement of support stakes	By hand	Once a year	Only remove stake in the spring
Replace any deficient stakes or wires	By hand	Whenever needed	Whenever needed

1.4 Sand Filtration Facilities

Sand filters are intended for use on small urban sites that would not normally support the hydrology of a wet detention pond and where the soils permit stormwater filtration. The primary mechanism for pollutant removal is through sedimentation, filtration and microbial activity within the sand. As stormwater flows through the filter, the filtration media trap and absorb pollutants present in the stormwater. Sand filtration systems are beneficial when land space is scarce or expensive, because they can be designed to be placed underground or to border the perimeter of a parking lot or other impervious surface.

There are two basic components of a sand filter design: the sediment chamber and the sand chamber. The sediment chamber reduces the amount of sediment that reaches the sand chamber, and facilitates sheet flow into the sand chamber. The sand chamber filters out the finer sediments and pollutants bound to these sediments, and provides a media for biological activity.

Drainage areas directed to each sand filter should be kept below 5 acres in size.

The Center for Watershed protection recommends that sand filters be used primarily to treat runoff from impervious or nearly impervious surfaces. The findings from several studies report that most of the particulate load in urban runoff is made up of the coarser fractions, consisting of sand/gravel particle sizes greater than approximately 40 microns. This being the case, the sedimentation chamber can capture the coarser grained material, and the filter chamber will be less prone to clogging. Sand filters designed to treat runoff from purely impervious surfaces will therefore require less sedimentation area and volume than those designed to treat runoff from more pervious surfaces.

In North Carolina, water quality control measures must be designed for 85% removal of Total Suspended Solids. The design requirements included herein are those recommended by the Center for Watershed Protection, in the Design of Stormwater Filtering Systems.

1.4.1 General Design Guidelines

The entire facility should hold 75% of the water quality volume, WQV.

1.4.2 Sedimentation Chamber

In order to prolong the life and effectiveness of the sand filtering system, pretreatment, primarily through the settling of sediments, is needed. The settling efficiency is primarily a function the surface loading (rate of outflow divided by the basin surface area). The following equation is used to size the pretreatment settling basin surface area.

$A_s = -(Q/v) * Ln(1 - E)$ where:

A_s = Sedimentation basin surface area (ft^2)
E = Trap efficiency; which is the target removal efficiency of suspended solids (set equal to 90%)
v = Particle settling velocity; for $I < 75\%$ use settling velocity = 0.0004 ft/sec (target ~ 20 micron size particles). For $I \geq 75\%$ use settling velocity = 0.0033 ft/sec (target ~ 40 micron size particles). [I = % impervious surface].
Q = Rate of outflow from the basin, WQV(water quality volume)/t (detention time), use 24 hrs.

Based on the above equation:

$$A_s = 0.066 * WQV\ (ft^2) \qquad \text{for } I < 75\%$$

$A_s = 0.0081 * WQV (ft^2)$ for $I \geq 75\%$

Although the settling efficiency is independent of depth, a minimum basin depth of 2 feet is recommended to minimize particle resuspension.

Length to width ratio should be 2H:1V or greater.

1.4.3 Sand Filter Chamber

The primary design parameter for filtration basins is surface area. The following equation should be used to size the sand filter bed area:

$A_f = WVQ *(d_f)/[k*(h_f+d_f)(t)]$ where,

A_f = sand filter bed area (ft^2)
WQV = water quality volume (ft^3)
d_f = depth of filter material, ft. (1.5 ft minimum)
k = coefficient of permeability for sand bed, ft/day (recommend 3.5 ft/day)
h_f = average height of water above filter bed, ft. ($1/2 * h_{max}$)
t = time required for the water quality volume to filter through the sand bed, days (recommend 40 hours (1.67 days) as minimum)

Flow should be evenly distributed across the filtration chamber.

The *sand bed should be a minimum of 18 inches depth and the top of the bed should be completely level.* The sand should be clean ASTM C-33 medium aggregate concrete sand.

For underground sand filter facilities, a 5 feet minimum height clearance should be provided between the top of the sand bed and the bottom of the slab to provide clearance for future maintenance.

It is recommended to use a dewatering valve placed just above the sand bed layer to drain the facility should the sand bed become clogged.

1.4.4 Underdrain Systems

An underdrain system shall be used to collect water that has percolated through the sand filter. The preferred pipe is 6 inch perforated schedule 40 PVC piping placed in an 8 to 10 inch gravel jacket. Although some designs call for filter fabric between the gravel bed and sand layer, this fabric could present clogging problems and therefore a 3-inch layer of pea gravel is suggested. To ensure adequate drainage, the bottom of the chamber should be sloped toward the underdrain pipes, which should be spaced approximately 10 feet along the filter bed. The underdrain may discharge to a main collector pipe or to an outlet chamber.

1.4.5 Overflow

Sand filtration facilities should be placed off-line (divert runoff from storms greater than the one inch rainfall before entering the facility) whenever possible. A by-pass structure can be used to direct flow away from the filtration facility once the treatment volume has been exceeded.

For on-line facilities, an overflow should be placed in the sediment chamber and be designed to carry the 10 year design storm at a minimum. The overflow needs to be placed as far upstream of the filtration bed as possible to prevent the initial WQV from being flushed out by the subsequent runoff.

1.4.6 Access

Adequate access to underground sand and pretreatment chambers shall be provided for inspection and maintenance. It is preferred that large aluminum or steel doors be placed to access the sand filtration chamber. Steps will need to be provided for the underground facility. Also, observation manholes or doors should be provided for the overflow chamber and the sedimentation chamber. Maintenance to the underground sand filtration facility will involve entering a confined space and the appropriate provisions should be made to comply with OSHA confined space requirements.

Three examples of sand filters are given. Figure 6 and 7 are examples of underground sand filters that might be used in an area where land values are very high, or where there are severe physical limitations is siting a BMP. The District of Columbia (DC) sand filter, is recommended for use on sites draining less than 1 acre, and that are highly urbanized (Figure 6). Another underground sand filtering system, the Delaware Sand Filter (or Perimeter Sand Filter, Figure 7), was originally developed by Mr. Earl Shaver of the Delaware Department of Natural Resources and Environmental Control, and was primarily intended to border the perimeter of parking lots (hence the name Perimeter Sand Filter). The system consists of two concrete chambers; a grated steel inlet to the wet sedimentation chamber and a sand filtration chamber. The WQV flows into the filter bed via distribution slots or multiple orifices, while larger storm volumes bypass the filter chamber through an overflow weir. The filter bed chamber consists of an 18" sand bed over a gravel/perforated pipe underdrain system with several outlets, which discharges into a manifold pipe collection system.

The other type of sand filter, the surface sand filter (SSF), was first developed and used in Austin, Texas (Figure 8). The sand filter can be placed in a concrete or earth basin. A sedimentation basin is needed to pretreat the incoming runoff and to bypass larger storm events. The City of Austin found that it was important to size the sedimentation chamber to remove suspended solids to prevent excessive sediment loading on the sand filtration chamber. Since the SSF is an open basin, it will generally cost less than the other enclosed sand filter types and is usually practical to treat a larger drainage area.

Figure 6: Example of Underground (DC) Sand Filter

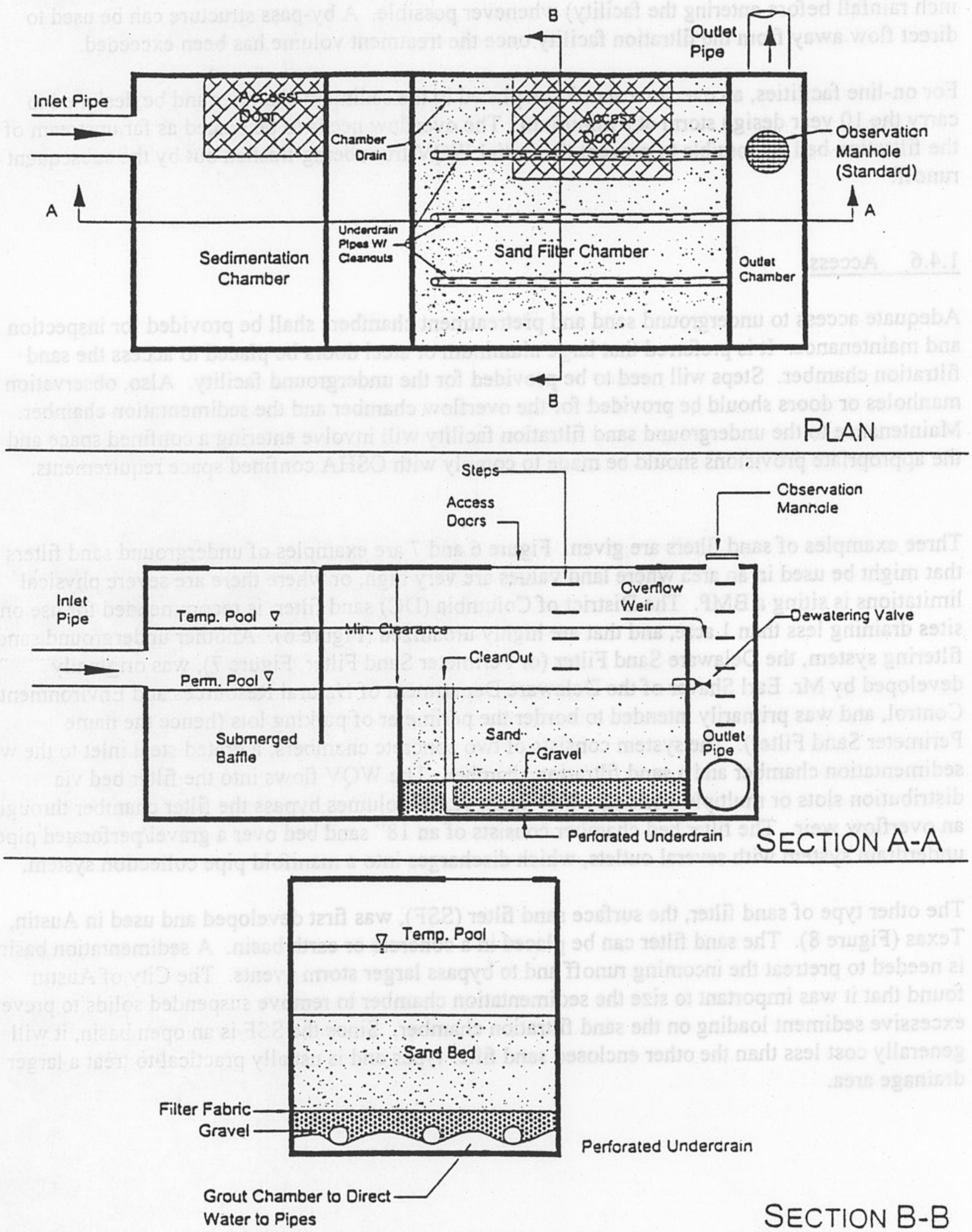


Figure 7: Example of Perimeter Sand Filter
(Delaware Sand Filter)

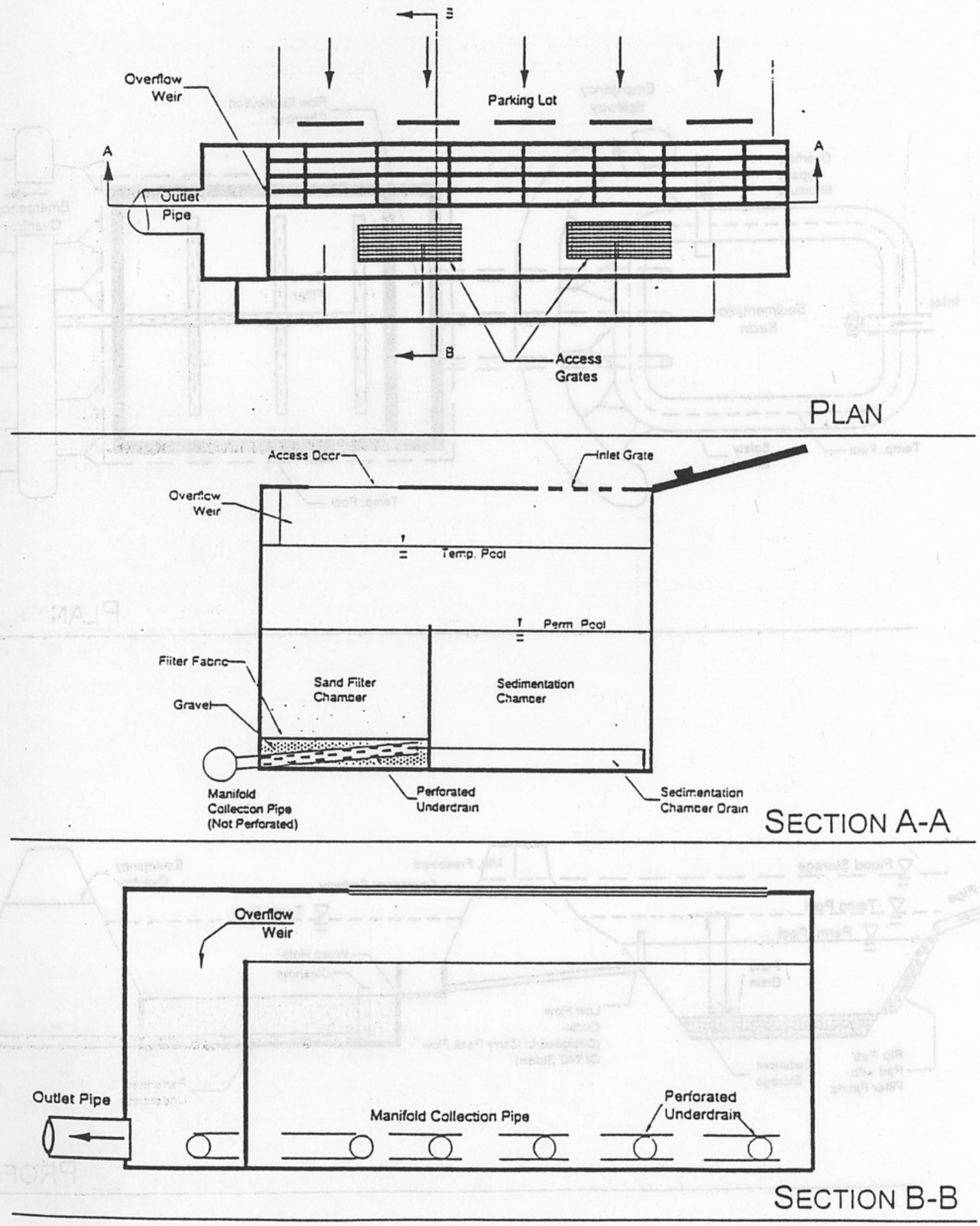
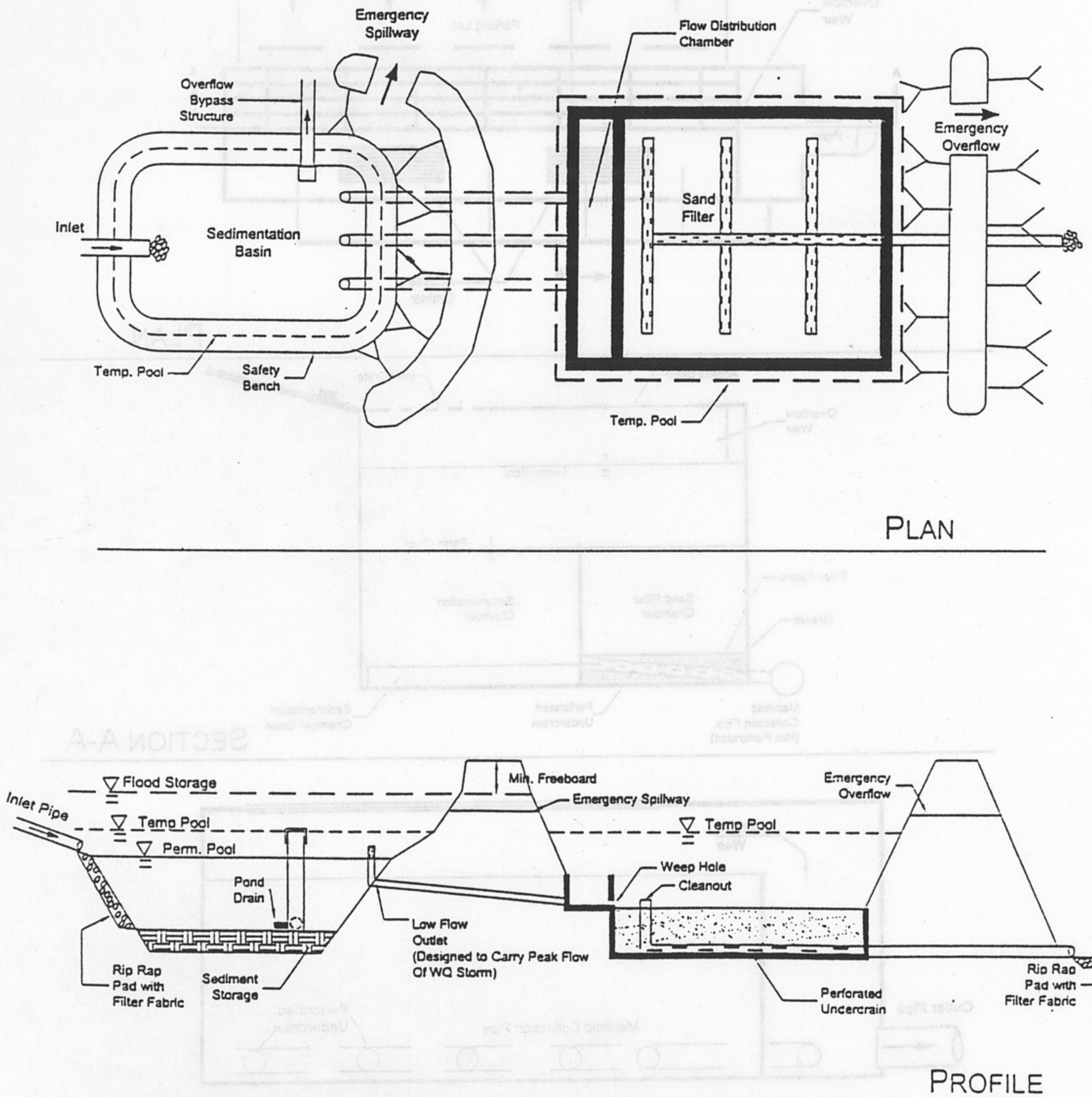


Figure 8: Example of Surface Sand Filter



1.4.7 Other Proprietary Systems

Other proprietary systems may be used to control stormwater runoff, as long as they can be designed to treat the first one-inch of runoff, and achieve 85% removal of TSS. Several proprietary systems have been used successfully elsewhere, and may be applicable in High Point. StormFilter™ by Stormwater Management®, Portland, Oregon (1-800-548-4667 or *www.stormwatermgt.com*), and StormTreat™ by StormTreat™ Systems, Sandwich, Massachusetts (1-508-833-1033 or *www.stormtreat.com*) are two of several commercially available systems.

1.4.8 Maintenance

A paved area sweeping program is recommended for all properties that utilize a sand filter. Sweeping paved areas on a periodic basis will help to extend the life of the filter by reducing the pollutant load and debris entering the filter. Sweeping should be done in such a manner as to prevent debris from entering inlets leading to the sand filter.

Mowing/landscaping activities on the property should be conducted in such a way to prevent lawn and plant clippings as well as eroded sediment from entering the filter facility. One way to prevent clippings from entering the facility is to use mulching mowers or to bag and remove clippings, especially in areas that drain to the filter.

The following inspection/maintenance activities should be conducted on a quarterly basis (4 times per year), unless noted otherwise.

- Overall Sand Filter Facility
  1. *Accumulated paper, trash, and debris are removed from the filtration facility.*
  2. *Check to verify that there are no signs of cracking or deteriorating concrete (every 6 months at a minimum).*

- Sedimentation Chamber
  1. *Check to verify that the perforated pipe or low flow orifice (if applicable) is clear of debris.*
  2. *Measure the sediment depth at several locations in the sedimentation chamber (every 6 months at a minimum). The sediment chamber should be cleaned out when sediment levels exceed the design level (12" if no level is given). The sludge should be disposed of at an approved site.*

- Filtration Chamber
  1. *Monitor the performance of the filter bed (every 6 months at a minimum). If the drawdown time of the filter bed is greater than twice the initial design drawdown time, corrective maintenance is needed.* Corrective maintenance includes:
     (a) Clean out the underdrain system
     (b) Replace the top layer of the sand filter bed

Accumulated sediment on top of the sand bed and the top layer of discolored sand should be scraped off. The removed sand should be replaced with new sand of the original specifications. The sediment and contaminated sand should be disposed at an approved site.

If a filter fabric/screen is used on top of the sand layer, replace it with a new fabric/screen of the original specifications. If gravel is used on top of the filter fabric/screen, rinse the gravel well and reuse. The sediment rinsed from the gravel should be collected. The used filter/screen and collected sediment is to be disposed at the landfill. Before replacing the fabric/screen, be sure to check to see if the sand layer is contaminated.

(c) If the appropriate drawdown time cannot be restored, the owner will be required to remove and replace the filter bed and underdrain system.
If the filter bed is not draining at all, the stagnated water must be released by the dewatering valve or pumped out before corrective maintenance can be done to the sand bed.

- Outlet Chamber/Outlets
  1. *Check to verify that the outlet is discharging when water is present in the filtration chamber.* When the water level is above the filter bed, check the outlet area to ensure that the sand filter is functioning. If there is no discharge from the outlet, the system is nonfunctional and corrective maintenance is needed immediately to restore drawdown.

  2. *Check to verify that there is no erosion at the outlet areas.* The downstream areas from the outlet of the sand filter should be checked to ensure there is no erosion taking place. Eroded areas should be revegetated. A velocity dissipater, if not already in place, may be needed if erosion continues to occur.

2.1 Natural Infiltration Areas

Natural infiltration is defined as a method that allows runoff to infiltrate an undisturbed soil covered with natural vegetation. It is a non-structural practice, and one that does not require maintenance. All that is required is that the area remains natural and undisturbed. Generally, these areas are forested; the soil surface remains covered with leaves, needles, and organic matter. Areas such as these must be protected from use by vehicles, humans and livestock as this will damage the surface mulch and thus lower the infiltration capability.

2.1.1 General Design Standards

The following equation will be used to determine if the first half inch of runoff from an impervious surface can be retained on-site by natural infiltration.

$$U = (KTI)/[(CD) - 0.5]$$

Where:

- U = Natural Infiltration area needed for infiltration of runoff from built-upon area, acres
- K = .5, a constant representing the first half inch
- T = Total acres of land in the tract, or land under consideration.
- I = Impervious surface, %/100
- C = Effective water capacity, In./in. (water/soil)
- D = Depth of soil A horizon, In. (determined from Table 2 or on-site investigation)
- 0.5 = First half inch of rainfall

Effective water capacity (C) and infiltration rate (f) are functions of the soil texture as presented in the Table below:

Soil Type	C In./In	D In.	F In./Hr	Hydrologic Soil Group
Appling sandy loam	0.25	6	1.02	B
Cecil, Madison Sandy loam	0.25	4	1.02	B
Enon, Vance, Helena Fine sandy loam and sandy loam	0.17	4	0.27	B
Cecil, Enon, Madison, Coronaca and Mecklenburg Sandy clay loam and clay loam	0.14	4	0.17	B or C

Some basic requirements for the undisturbed areas are:

1. Runoff from the built-upon area (I) flows onto the undisturbed area (U) as sheet flow, using structures or diversions if necessary to accomplish sheet flow.

2. Undisturbed area (U) –
   a. has less than 10% slope
   b. has an excellent wood cover, (multiply U by 2 for grass cover)
   c. is not in a floodplain or a wetland
   d. has a stable soil (not highly erodible or subject to landslides), and
   e. will remain undisturbed so as to maintain the infiltration rate

3. If the undisturbed area is between 10% and 15% slope, an additional 10% area is required for each percent of slope over 10%

2.1.2 Maintenance Requirements

Natural infiltration areas shall be protected by silt fence during active construction on the site or when land-disturbing activities may deposit sediment in the infiltration area. Additional protection measures may be required by the Enforcement Officer to prevent the encroachment of vehicles, etc. Encroachments by construction vehicles and or improper construction of drainage facilities can render an infiltration area useless and void the watershed development plan approval.

2.2 Drv Detention Basins

A dry detention basin is an impoundment formed by constructing a dam or embankment or by a combination of excavation and an embankment with an outlet structure to detain surface runoff for periods of generally around 24 hours. There is no permanent water quality pool.

2.2.1 General Design Standards

Avoid placing these structures in environmentally sensitive areas such as streams and wetlands.

Dry detention basins must be easily accessible for maintenance. A 20' wide access easement shall be provided from the public street right-of-way to the basin and shall be continuous around the pond.

At inflow points to the basin, energy dissipaters such as rip-rap shall be used to reduce the velocity of the flow. The outflow shall be designed to protect against erosion and scour from high velocities and turbulence. Rip-rap shall be provided at the points of discharge as necessary.

Basin embankments shall be 4H:1V of flatter in order to reduce erosion potential, promote wetland vegetation minimize safety hazards, improve aesthetics and facilitate maintenance activities.

The minimum length to width ratio shall be 3H:1V (or equivalent created by baffles) in order to limit short-circuiting. The distance between the inlets and outlets should be maximized to increase the pollutant removal capability of the pond.

2.2.2 Storage Requirments

Detention volumes for a 24-hour detention time shall meet the requirements below:

% Impervious	Storage Capacity* (inches)
0 – 6%	NR
7 – 12%	0.1

13 – 25%	0.2
26 – 35%	0.3
36 – 50%	0.4
51 – 70%	0.5

Storage capacity is in units of inches per acre of drainage area

2.2.3 Principal Spillway

The principal spillway shall be designed for the 10 yr. predevelopment storm

The minimum difference in elevation between the principal spillway elevation and the emergency spillway elevation shall be one (1) foot.

Anti-seep collars shall be installed on all pipe conduits through earthen dams and embankments.

Vertical risers shall be equipped with an anti-vortex device to improve the flow of water, and with a trash rack or hood to prevent floating debris from clogging the principal spillway.

Anti-floatation calculations shall be submitted, with a minimum safety factor of 1.25. The riser/barrel assemblies shall be new and aluminum or concrete pipe, shall have gasketed joints and the barrel shall be pressure tested.

2.2.4 Emergency Spillway

The emergency spillway shall be designed to safely convey the 100 yr. design storm.

A minimum of one (1) foot of freeboard from the top of the pool elevation from the 100 yr. storm to the top of the dam shall be provided. The minimum difference in elevation between the emergency spillway elevation and the settled top of the dam shall be two (2) feet.

Spillways shall be constructed so as to prevent the discharge through the spillway from coming in contact with the fill section of the dam or principal embankment structure.

2.2.5 Maintenance Requirements

To sustain the structural integrity of the dam, no trees or woody vegetation should be allowed on the dam embankments or top of dam. Trees and brush, if desired, are acceptable on pond embankments other than the dam.

A maintenance plan shall be provided with the design that shall include a plan for sediment removal and disposal.

Maintenance responsibility for a pond and its buffer shall be vested with a responsible party by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

2.3 Infiltration Trenches

An infiltration trench is a gravel-filled trench designed to collect the first one-half inch(1/2") runoff. Gravel shall be clean washed material with a maximum size of 3 inches, and the trench should dewater in less than 7 days.

2.3.1 Storage Requirements

The equation for determining the volume of the trench for one-half (1/2)-inch runoff is:

$$V = I \times (1815/0.4)$$

Where:

V = minimum volume of trench in cubic feet
I = impervious surface area, acres
0.4 = pore space in gravel

Recommended dimensions of the trench are as follows:

	Minimum	Maximum
Width	2 feet	7 feet
Depth	1.5 feet	3 feet

The minimum width between trenches shall be ten feet (10') or the width x depth, whichever is greater. The equation above only determines the minimum volume of the trench. The next step is to select the dimensions of the trench, a site specific consideration and test for the 7-day drawdown or dewatering of the trench. Infiltration rates of selected soil textures are shown below.

Soil Texture	**Infiltration Rate** (CF/Hr/Sq. ft.)
Sandy loam	.085
Fine sandy loam, loam	.043
Silt loam	.023
Sandy clay loam	.014
Clay, 1:1 (kaolinite) and clay loam	.0075
Clay, 2:1 and mixed, saprolite and bottom of trench	.0017

The 7 day drawdown is checked by:

1. Multiply bottom area of trench (sq. ft.) by the appropriate infiltration rate from the Table above by 24 hours
2. Multiply one-half of surface area of trench side walls by appropriate infiltration rate from Table above by 24 hours
3. Multiply square footage of gravel surface by the evaporation rate (approximately .0083 CF/SF/day), assuming that the trench is exposed to the atmosphere.
4. Add Steps 1, 2 and 3 to determine the theoretical drawdown in the trench for 24 hours (D).
5. Divide V by D to determine if the trench will dewater in 7 days or less. If not, trench must be enlarged.

2.3.2 Maintenance Requirements

An infiltration trench depends on infiltration to succeed. If sediment or other trapped pollutants reduce the infiltration rate to the point the trench is no longer effective, the sediment will have to be removed.

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