CITY OF PORTAGE DRAINAGE AND STORMWATER MANAGEMENT – BEST MANAGEMENT PRACTICE MANUAL

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INTRODUCTION

Storm water runoff contains many types and forms of pollutants that lead to impairments in our Nation's waterways. Best Management Practices (BMPs) or storm water controls are an effective means of reducing the amount of pollutants in storm water. This Manual describes the most common but is not all inclusive of the BMPs applicable to the Portage area. This Manual should be used in conjunction with the Drainage and Storm Water Management Ordinance and Technical Guide.

The Manual is divided into three sections. The first section lists details of the storm water BMPs. The information provided for each BMP includes a description of the BMP and its purpose along with design criteria and guidelines, performance standards, and maintenance requirements. The second section describes the storm water BMP selection process with the usage of matrices to simplify the decision process. The matrices investigate land use settings, site considerations, and social factors for the BMPs. The third section provides guidance for landscaping including site considerations, plant selection, and other criteria to consider during landscaping.

The City of Portage has adopted a policy that the control of storm water runoff quality citywide will be based on the management of total suspended solids (TSS). This requirement is being adopted as the basis of the City's storm water quality management program for all areas of the City. It should also be noted that control of sediment is required for construction site runoff citywide.

This City of Portage follows the philosophy of removing pollutants to the "maximum extent practicable" through the use of a percentage removal performance goal. The target TSS removal rate is 80%. Thus, the City requires treatment of the first flush of runoff from a site to reduce post-development total suspended solids (TSS) loadings by 80%, as measured on an average annual basis. This performance goal is based upon U.S. EPA guidance and has been adopted nationwide by many local and statewide agencies.

TSS was chosen as the representative storm water pollutant for measuring treatment effectiveness for several reasons:

1. The use of TSS as an "indicator" pollutant is well established.
2. Sediment and turbidity, as well as other pollutants of concern that adhere to suspended solids, are a major source of water quality impairment due to urban development in Portage watersheds.
3. A large fraction of many other pollutants of concern are either removed along with TSS, or at rates proportional to the TSS removal.
4. The 80% TSS removal level is reasonably attainable using well-designed structural storm water controls (for typical ranges of TSS concentration found in storm water runoff).

TSS is an effective indicator for many storm water pollutants; however, the removal performance for pollutants that are soluble or that cannot be removed by settling will vary depending on the structural control practice. For pollutants of specific concern, individual analyses of specific pollutant sources and the appropriate removal mechanisms should be performed.

The BMPs described in this Manual are pre-approved BMPs that can be used in Portage for storm water quality management if designed according to the criteria set forth in the Manual. A key component to designing structural storm water controls is adequate sizing for water quality treatment.

All development projects requiring drainage and storm water management permits (approval) are required to treat on a volumetric basis or flow rate basis. Redevelopment projects are required to obtain Storm Water Management Board approval. The Board may, at their discretion, exempt development or redevelopment activities.

The runoff volume and peak runoff rate to be treated by a BMP shall be determined by the following:

The Water Quality Volume, denoted WQ_v, is the storage needed to capture and treat the runoff from the first one-inch of rainfall (first flush). The WQ_v is equivalent to an inch of rainfall multiplied by the volumetric runoff coefficient (R_v) and the site area. The following equation is used to calculate WQ_v:

$$WQv = \frac{(P)(Rv)(A)}{12}$$

where:

WQ_v = water quality volume (acre-feet)
P = 1 inch of rainfall
R_v = 0.05 + 0.009(I), where I is the percent of impervious cover (expressed as a percent value not a fraction or decimal)
A = area in acres

The peak water quality treatment rate shall be determined using hydrograph generation methods. The hydrograph shall use the Huff 1st Quartile, 50% distribution with a 1 inch rainfall and a one hour storm duration. The peak rate of this hydrograph shall be used as the minimum water quality treatment rate. Alternatively, the TR-55 Graphical Peak Discharge Method can be used to determine the peak water quality treatment rate. Similarly, a 1-inch rainfall shall be used.

Documentation for all proposed proprietary or manufactured BMPs shall be provided clearly demonstrating the BMP will remove 80% of the particles listed below at this peak flow rate.

Runoff Particle Distribution

Particle Size (μm)	% of TSS
250	20
125	40
75	40

There are two primary approaches for managing storm water runoff and addressing the storm water sizing criteria requirements on a development site:

1. The use of better site design practices to reduce the amount of storm water runoff and pollutants generated and/or provide for natural treatment and control of runoff; and
2. The use of structural storm water controls to provide treatment and control of storm water runoff

This Manual briefly describes site design practices while the use of structural storm water controls are highlighted throughout the Manual.

The first step in addressing storm water management begins with the site planning and design process. Development projects can be designed to reduce their impact on watersheds when careful efforts are made to conserve natural areas, reduce impervious cover and better integrate storm water treatment. By implementing a combination of these nonstructural approaches, collectively known as storm water better site design practices, it is possible to reduce the amount of runoff and pollutants that are generated from a site and provide for some nonstructural on-site treatment and control of runoff. The goals of better site design include:

- Managing storm water quantity and quality as close to the point of origin as possible and minimizing collection and conveyance;
- Preventing storm water impacts rather than mitigating them;
- Utilizing simple, nonstructural methods for storm water management that are lower cost and lower maintenance than structural controls;
- Creating a multifunctional landscape; and
- Using hydrology as a framework for site design.

Better site design for storm water management includes a number of site design techniques such as preserving natural features and resources, effectively laying out the site elements to reduce impact, reducing the amount of impervious surfaces, and utilizing natural features on the site for storm water management. The aim is to reduce the environmental impact while retaining and enhancing the owner/developer's purpose and vision for the site. Many of the better site design concepts can reduce the cost of infrastructure while maintaining or even increasing the value of the property.

Site design should be done in unison with the design and layout of storm water infrastructure in attaining storm water management goals. The first step in storm water better site design involves identifying significant natural features and resources on a site such as undisturbed forest areas, stream buffers and steep slopes that should be preserved to retain some of the original hydrologic function of the site through the preparation of a natural resources assessment. Next, the site layout is designed such that these conservation areas are preserved and the impact of the development is minimized. A number of techniques can then be used to reduce the overall imperviousness of the development site. Finally, natural features and conservation areas can be utilized to serve storm water quantity and quality management purposes.

Examples of storm water better site design practices and techniques are listed below in four categories:

1. Conservation of Natural Features and Resources

- Preserve Undisturbed Natural Areas
- Preserve Riparian Buffers
- Avoid Floodplains
- Avoid Steep Slopes
- Minimize Siting on Porous or Erodible Soils

2. Lower Impact Site Design Techniques

- Fit Design to the Terrain
- Locate Development in Less Sensitive Areas
- Reduce Limits of Clearing and Grading
- Utilize Open Space Development
- Consider Creative Development Design

3. Reduction of Impervious Cover

- Reduce Roadway Lengths and Widths
- Reduce Building Footprints
- Reduce the Parking Footprint
- Use Fewer or Alternative Cul-de-Sacs
- Create Parking Lot Storm Water "Islands"

4. Utilization of Natural Features for Storm Water Management

- Use Buffers and Undisturbed Areas
- Use Natural Drainageways Instead of Storm Sewers
- Use Vegetated Swale Instead of Enclosed Conduits
- Drain Rooftop Runoff to Pervious Areas

Reduction of adverse storm water runoff impacts through the use of better site design should be the first consideration of the design engineer. Operationally, economically, and aesthetically, the use of better site design practices offers significant benefits over treating and controlling runoff downstream. The reduction in runoff and pollutants using better site design can reduce the required runoff peak and volumes that need to be conveyed and controlled on a site and, therefore, the size and cost of necessary drainage infrastructure and structural storm water controls. Hence, better site design concepts can be viewed as both a water quantity and water quality management tool.

The use of storm water better site design can also have a number of other ancillary benefits including:

- Reduced construction costs
- Increased property values
- More open space for recreation
- More pedestrian friendly neighborhoods
- Protection of sensitive forests, wetlands, waterways, waterbodies and habitats
- More aesthetically pleasing and naturally attractive landscape

The following sections discuss in detail the use of structural storm water controls, the selection process for BMPs, and landscaping features of BMPs.

1.0 STORM WATER BMPS

Structural storm water controls, or structural BMPs, are constructed storm water management facilities designed to treat storm water runoff and/or mitigate the effects of increased storm water runoff peak rate, volume, and velocity due to urbanization.

This Manual recommends a number of structural storm water controls for meeting the storm water sizing criteria. The recommended controls are divided into two categories: general application and limited application controls.

General Application Controls

General application structural controls are recommended for use with a wide variety of land uses and development types. These structural controls have a demonstrated ability to effectively treat the Water Quality Volume (WQ_v) as they are estimated to be able to remove 80% of the total annual average TSS load in typical post-development urban runoff when designed, constructed, and maintained in accordance with recommended specifications. Several of the general application structural controls can also be designed to provide water quantity control. General application controls are the recommended storm water management facilities for a site wherever feasible or practical.

There are three types of general application controls, which are summarized below. Detailed descriptions of each structural control along with design criteria are provided in Section 1.1.

Storm Water Ponds

Storm water ponds are constructed storm water retention basins that have a permanent pool or micropool of water. Runoff from each rain event is detained and treated in the pool. Pond design variants include:

- Wet Pond
- Wet Extended Detention Pond
- Micropool Extended Detention Pond
- Multiple Pond Systems
- Pocket Pond

Bioretention Areas

Bioretention areas are shallow storm water basins or landscaped areas that utilize engineered soils and vegetation to capture and treat storm water runoff. Runoff may be returned to the conveyance system, or allowed to fully or partially infiltrate into the soil.

Water Quality Swales

Dry water quality swales are vegetated open channels that are explicitly designed and constructed to capture and treat storm water runoff within dry cells formed by check dams or other means.

Limited Application Controls

Limited application structural controls are those that are recommended only for limited use or for special site or design conditions. Generally, these practices cannot alone achieve the 80% TSS removal target, are intended to address hotspot or specific land use constraints or conditions, and/or may have high or special maintenance requirements that may preclude their use. Limited application controls are typically used for water quality treatment only. Some of these controls can be used as a pretreatment measure or in series with other structural controls to meet pollutant removal goals. Limited application structural controls should be considered primarily for commercial, industrial, or institutional developments.

The following limited application controls are provided for consideration in this Manual. Each is discussed in detail with appropriate application guidance in Section 1.2.

Biofilters

- Filter Strip
- Riparian buffer

Porous Surfaces

- Modular Porous Paver Systems
- Porous Concrete

Proprietary Systems

- Commercial Storm Water Controls

The maintenance and inspection of structural storm water controls are important components to ensuring the success of the BMPs. An operations and maintenance (O&M) manual is required for each BMP as part of the drainage and storm water maintenance plan with routine inspections and maintenance being the responsibility of the BMP owner. The maintenance plan and inspection forms provided in this Manual should be used as guidance for performing maintenance activities. Completed inspection forms must be maintained by the BMP owner and produced upon request by the City. The City must be notified of any changes in BMP ownership, major repairs, or BMP failure in writing within 30 days. The letter should be addressed to:

Storm Water BMP Modifications
City of Portage City Engineer
6070 Central Avenue
Portage, Indiana 46368

The City will perform periodic inspections of the BMPs and as such each BMP must have a storm water management easement obtained during the permit process. A copy of the easement should be included in the BMP operations and maintenance manual. If the City determines a BMP is in need of maintenance or repair, the City will notify the BMP owner and provide a timeframe for completing the maintenance and repairs. If the maintenance or repairs are not completed within the designated timeframe, the City shall perform the repairs or maintenance and bill the landowner for the actual costs for the work and/or impose fines as appropriate.

1.1 GENERAL APPLICATION CONTROLS

1.1.1 Ponds

1.1.1.1 General Description

Storm water ponds are small man-made surface waters designed to treat storm water runoff. The pond's natural physical, biological, and chemical processes work to remove the pollutants. In a storm water pond, runoff from each rain event is detained and treated in the pool through gravitational settling and biological uptake until it is displaced by runoff from the next storm. The permanent pool (dead storage) serves to protect deposited sediments from resuspension. Sedimentation processes remove particulates, organic matter, and metals, while dissolved metals and nutrients are removed through biological uptake. Above the permanent pool level, additional temporary storage (live storage) is provided for runoff quantity control.

Multiple variations of storm water ponds exist to control both storm water quantity and quality by capturing and retaining runoff during storm events. The ponds can be wet detention ponds, wet extended detention ponds, micropool extended detention ponds, multiple pond systems, and pocket ponds.

> ⚠ Conventional dry detention basins do not provide a permanent pool and are not recommended for general application use to meet water quality criteria, as they fail to demonstrate an ability to meet the majority of the water quality goals. In addition, dry detention basins are prone to clogging and resuspension of previously settled solids and require a higher frequency of maintenance than wet ponds if used for untreated storm water flows. These facilities can be used in combination with appropriate water quality controls to provide channel protection, and overbank and extreme flood storage.

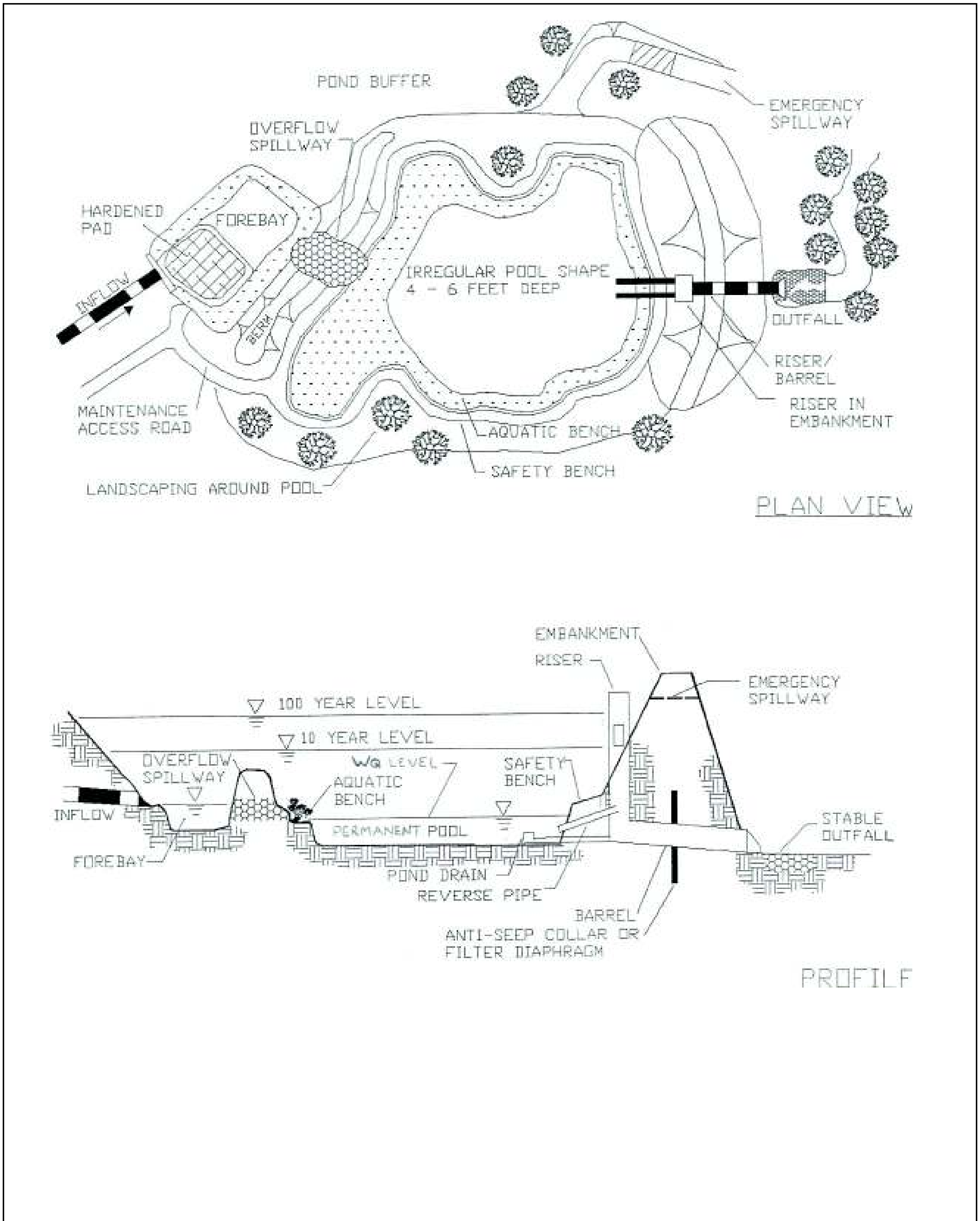
- **Wet Detention Ponds:** A wet detention pond provides all of the water quality volume storage in a permanent pool. The permanent pool of water is equal to the water quality volume. Figure 1.1.1-1 illustrates wet detention ponds.

  Advantages
  - Creation of aquatic and terrestrial habitat (particularly for waterfowl)
  - High community acceptance, landscaping, and amenity potential
  - High pollutant removal efficiency and downstream channel protection when properly designed and maintained
  - Permanent pool helps to prevent scour and resuspension of sediments
  - Can be designed for combined flood control and storm water quality control
  - Limited risk of groundwater quality impacts over the long term
  - Can provide uptake of soluble pollutants such as phosphorus, through biological activity
  - Can be used as a regional facility

Limitations

- Cannot be placed on steep unstable slopes
- Need base flow or supplemental water if water level is to be maintained
- Often infeasible in very dense urban areas due to space requirements
- Downstream warming can shift trophic status
- Upstream channels can be heavily impacted when wet ponds are “on line” and serve large drainage areas (> 250 acres)
- Potential loss of wetlands, forest and floodplain habitat associated with poor site selection for the pool
- May need liner in highly permeable soils
- Require a large drainage area (> 25 acres) to retain the permanent pool

Figure 1.1.1-1 Wet Detention Pond

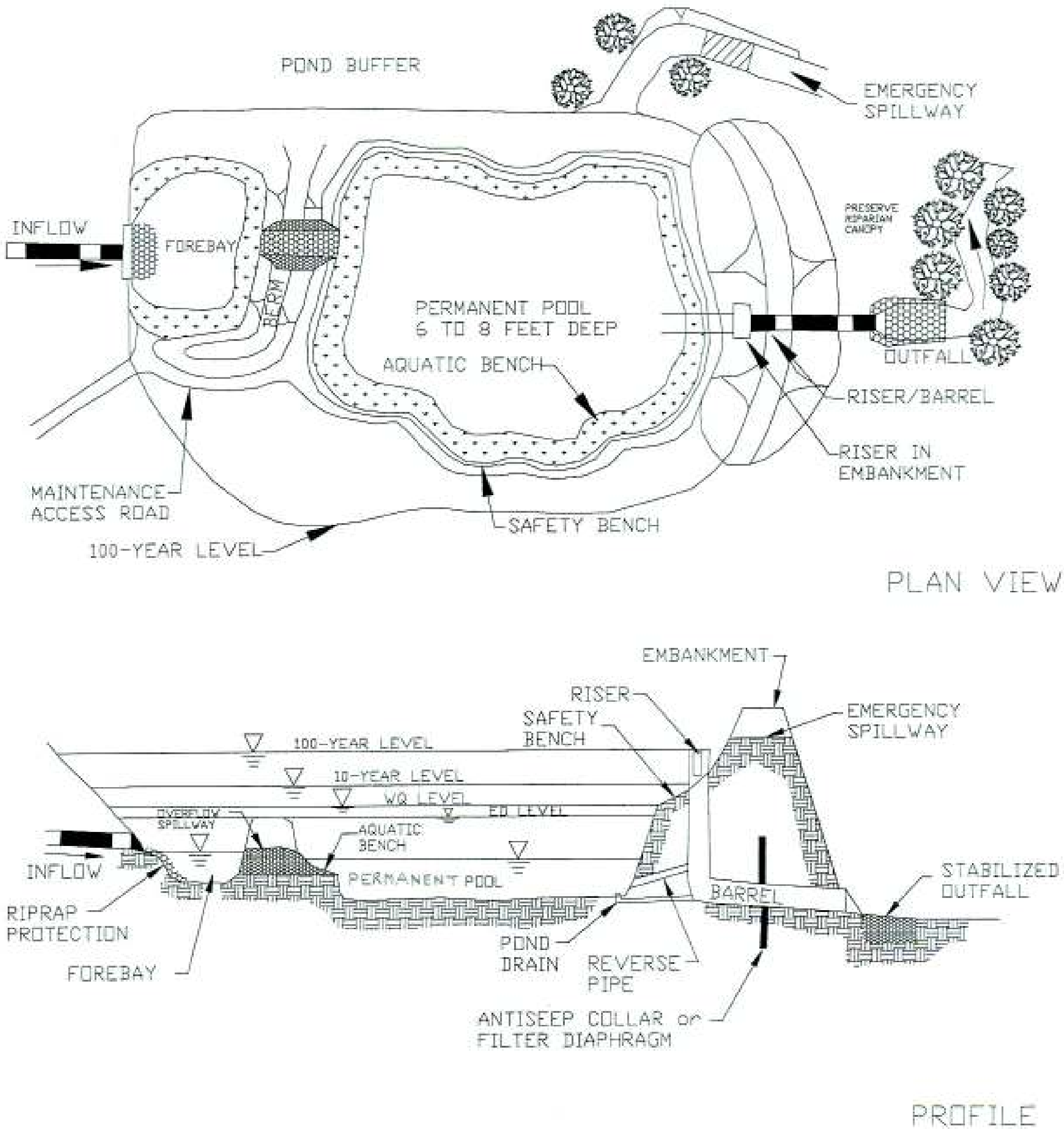


- **Wet Extended Detention (ED) Ponds:** A wet extended detention (ED) pond is a wet pond where the water quality volume is split evenly between the permanent pool and the extended detention storage provided above the permanent pool. These basins are generally characterized by a low flow channel with a minimum grade of 0.50%. The remainder of the basin should drain towards this channel at a minimum 1% slope. This low flow channel should end at the lip of the lower stage, where riprap or gabion baffles will be placed to prevent scour and resuspension. These ponds are suitable for any size tributary area from an individual commercial development to a large residential area. During storm events, water is detained above the permanent pool and released over 12 - 48 hours. This design has similar pollutant removal to a traditional wet pond, but consumes less space. Refer to Figure 1.1.1-2 for an example illustration of wet ED ponds.

  Advantages
  - Can create both terrestrial and aquatic wildlife habitat with appropriate pondscaping and vegetation management
  - Small permanent pool allows sedimentation to occur in confined location; maintenance is relatively easier
  - Can be designed for combined flood control and storm water quality control
  - High pollutant removal efficiency and downstream channel protection when properly designed and maintained
  - Can provide uptake of soluble pollutants such as phosphorus, through plant uptake and other biological processes
  - Less hazardous than other storm water ponds with deeper permanent pools

  Limitations
  - Improper site selection can create wetland, forest and habitat conflicts
  - May need liner in highly permeable soils
  - Possible thermal and oxygen depleted discharge can impact downstream aquatic life
  - Need base flow or supplemental water if water level is to be maintained
  - May be inappropriate in dense urban areas due to space concerns
  - Requires a large drainage area (> 25 acres) to retain the permanent pool

Figure 1.1.1-2 Wet Extended Detention Pond

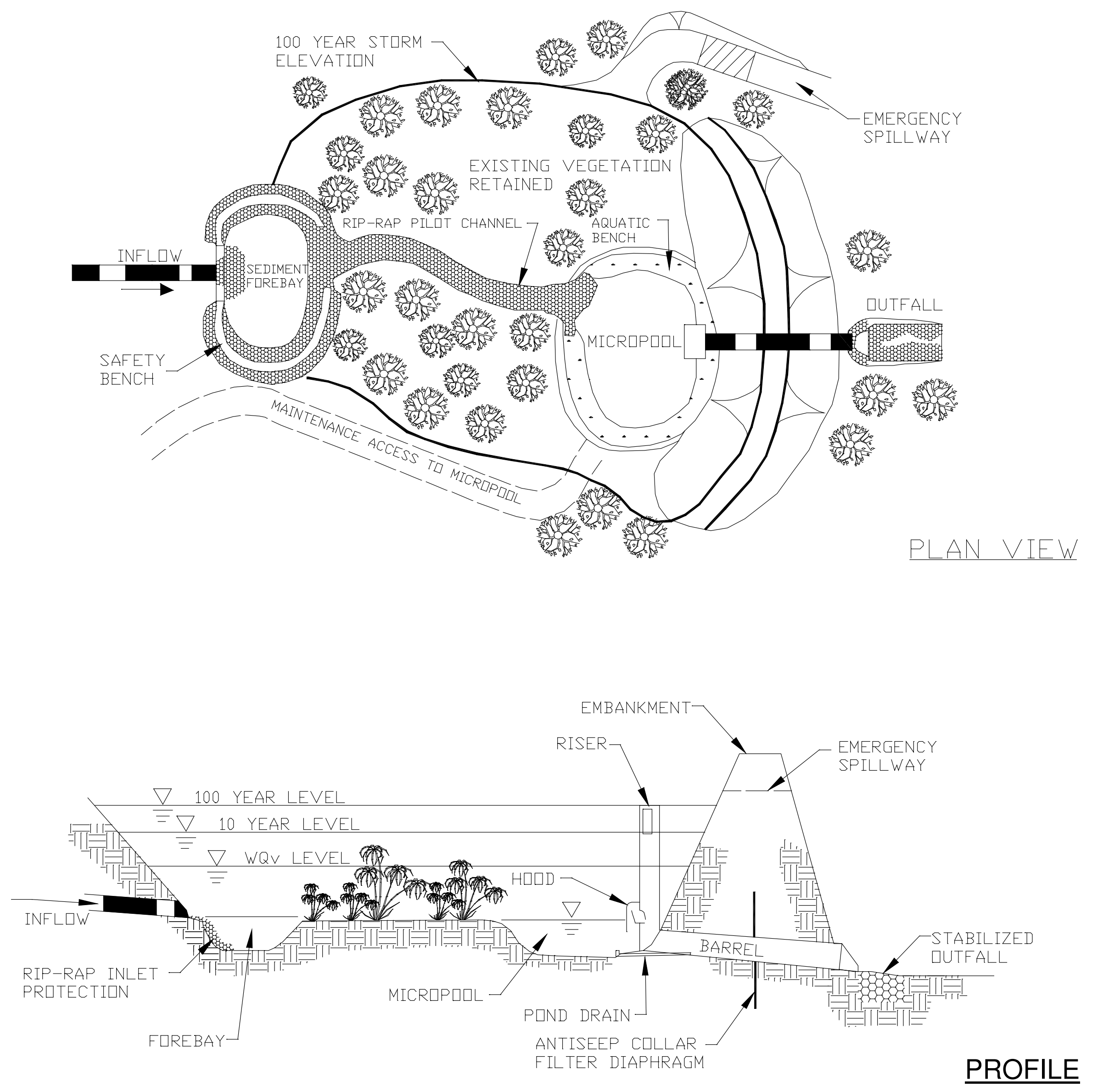


- **Micropool Extended Detention (ED) Pond:** The micropool extended detention pond is a variation of the wet ED pond where only a small micropool is maintained at the outlet to the pond. The outlet is sized to detain the water quality volume for 24 hours. The micropool prevents resuspension of previously settled sediments and prevents clogging of the low flow orifice. The permanent pool volume is typically sized for approximately 0.1 inch per impervious acre. Figure 1.1.1-3 illustrates a micropool extended detention pond.

  Advantages
  - Less expensive pond option
  - High pollutant removal efficiency and downstream channel protection when properly designed and maintained
  - Can be designed for combined flood control and storm water quality control

  Limitations
  - Inability to vegetate banks and bottom above permanent pool may result in erosion and resuspension of sediments
  - Limitation of the water quality orifice diameter may preclude use in small watersheds
  - May create mosquito breeding conditions and other nuisances if not properly constructed or maintained.

Figure 1.1.1-3 Micropool Extended Detention Pond

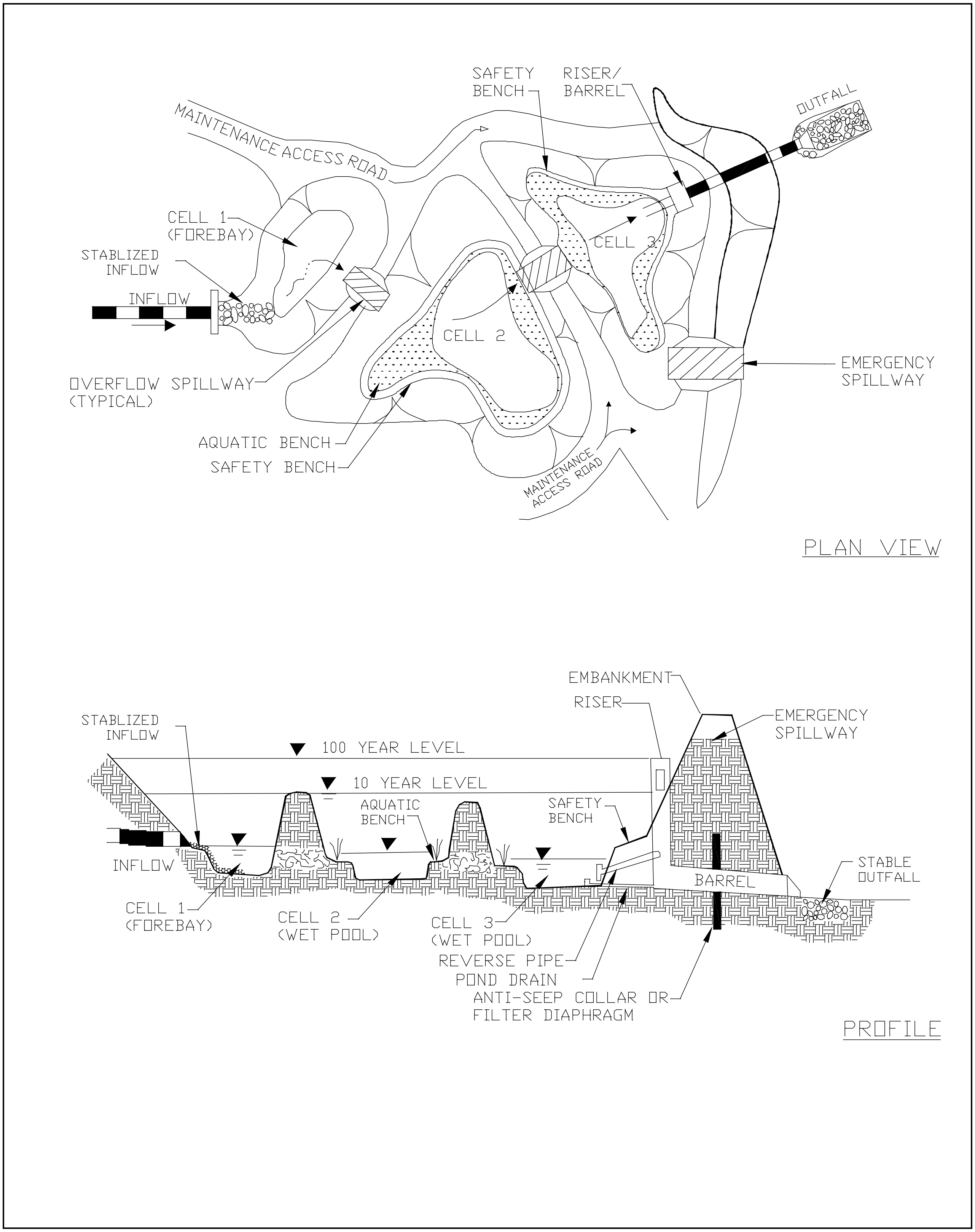


- **Multiple Pond Systems:** Multiple pond systems consist of constructed facilities that provide water quality and quantity volume storage in two or more cells. The additional cells can create longer pollutant removal pathways and improved downstream protection. Figure 1.1.1-4 illustrates a multiple pond system.

  Advantages
  - Provide higher and more consistent levels of urban pollutant removal than a single treatment system due to longer flow paths and increased retention time
  - Enhance habitat value
  - High pollutant removal efficiency and downstream channel protection when properly designed and maintained
  - Can be designed for combined flood control and storm water quality control

  Limitations
  - May need liner in highly permeable soils

Figure 1.1.1-4 Multiple Pond System

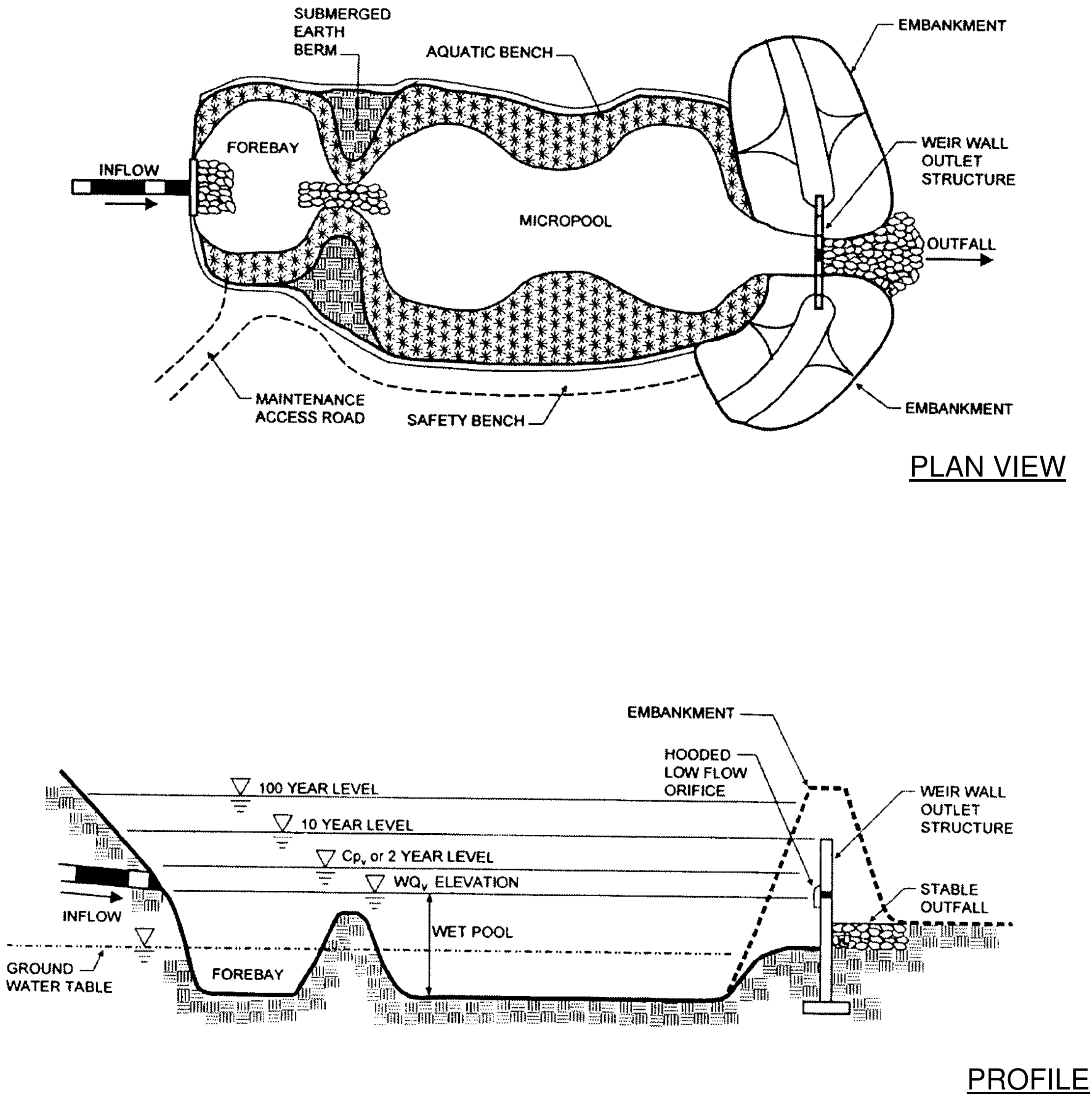


- **Pocket Pond:** A pocket pond drains a smaller area than a traditional wet pond and the permanent pool is maintained by intercepting the groundwater. Excavation to groundwater interception should be avoided where the land uses draining to the pond may contaminate drinking water supplies. Figure 1.1.1-5 illustrates a pocket pond.

  Advantages
  - Can be used on site where space is at a premium, or in a retrofit situation

  Limitations
  - Somewhat high maintenance requirements
  - Wet ground adjacent to the pond may provide a breeding ground for mosquitoes if not properly constructed or maintained
  - Low habitat and amenity value

Figure 1.1.1-5 Pocket Pond



1.1.1.2 Site and Design Considerations

The following design and site considerations must be followed when designing a storm water pond:

1. Design the pond with a minimum length to width ratio of 3:1 (preferably expanding outward toward the outlet). Irregular shorelines for larger ponds also provide visual variety.
2. Maximize flow length between the inlet and outlet structure. Use baffles if short-circuiting cannot be prevented with inlet-outlet placement. Long flow paths and irregular shapes are recommended.
3. When designing the BMP for the contributing drainage area, assume that the entire upstream watershed is fully developed. When designing the BMP for the effective drainage area where offsite areas bypass the BMP, the design shall only consider the drainage from the site.
4. Provide a sediment forebay or other pretreatment upstream from the wet pool.
   a. The forebay must be sized to contain 0.1 inches of runoff per impervious acre of contributing drainage. The forebay storage volume counts toward the total water quality storage requirements.
   b. Exit velocities from the forebay must be non-erosive (typically less than two feet per second).
   c. Direct maintenance access for appropriate equipment must be provided to the forebay.
   d. A fixed vertical sediment depth marker must be installed in the forebay to measure sediment deposition over time.
   e. Sediment removal in the forebay shall occur when 50% of the total capacity has been lost.
5. Side slopes shall be no greater than 3:1 if mowed.
6. Riprap protection must be provided (or other suitable erosion control means) for the outlet and all inlet structures into the pond.
7. A safety ledge 4 to 6 feet in width should be installed in all ponds approximately 30 to 36 inches below the permanent water level. In addition, a similar maintenance ledge 12 to 18 inches above the permanent water line shall be provided. The slope between the two ledges should be stable and prevent erosion due to wave action.
8. Flow control from a storm water pond is typically accomplished with the use of a concrete or corrugated metal riser and barrel. The riser is a vertical pipe or inlet structure that is attached to the base of the pond with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment . The riser should be located within the embankment for maintenance access, safety and aesthetics.
9. A number of outlets at varying depths in the riser provide internal flow control for routing of the water quality, channel protection, and overbank flood protection runoff volumes. In the case of a wet ED pond or micropool ED pond, there is generally a need for an additional outlet (usually an orifice) that is sized to pass the extended detention water quality volume that is surcharged on top of the permanent pool. Flow will first pass through this orifice, which is sized to release the water quality ED volume in 24 hours. The preferred design is a reverse slope pipe attached to the riser, with its inlet submerged

1 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the pond. The next outlet is sized for the release of the channel protection storage volume. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention water quality volume and is sized to release the channel protection storage volume over a 24-hour period (12-hour extended detention may be warranted in some cold water streams). Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular, V-notch, proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.

10. Anti-seep collars or filter diaphragms must be provided for the barrel of the principal spillway to reduce the potential for pipe failure.
11. If reinforced concrete pipe is used for the principal spillway, O-ring gaskets (ASTM C361) shall be used to create watertight joints.
12. Provide a one (1) foot minimum freeboard above the maximum anticipated flow depth through the emergency spillway.
13. Design and install an emergency drain (i.e. sluice gate or drawdown pipe) capable of draining within 24 hours. The pond drain should be sized one pipe size greater than the calculated design diameter. The drain valve is typically a handwheel activated knife or gate valve. Valve controls shall be located inside of the riser at a point where they will not normally be inundated and can be operated in a safe manner.
14. The emergency spillway must be designed to pass 1.25 times the peak discharge and peak flow velocity from the 100-year storm event for the entire contributing drainage area (unless bypassed), assuming post-development conditions.
15. Provide trash racks, filters, hoods or other debris control.
16. All facilities must be constructed within a storm water easement either platted or legally described and recorded as a perpetual storm water easement with a minimum of 20 feet horizontally outside of the top of bank or design 100-year flood water elevation of the basin. Provide a 10’ foot wide permanent access easement for all local ponds for long-term maintenance. A copy of the easement should be included in the copy of the BMP operations and maintenance manual.
17. The principal spillway/riser system must incorporate anti-floatation, anti-vortex, and trash-rack designs.
18. To prevent drawdown of the permanent pool, an impervious soil boundary may be needed.
19. Orifice-type outlets are not allowed below the permanent pool elevation of wet ponds and micropools.
20. Construction debris cannot be disposed of within the facility or used as fill in the embankment.
21. If the pond is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the pond and elevations and grades have been reestablished as noted in the approved storm water management plan for post-construction runoff control.

1.1.1.3 Performance Standards

Wet ponds and variations designed, constructed and maintained as noted above provide the following pollutant reductions:

Table 1.1.1-2 Performance Standards for Wet Ponds

Pollutant	Percent Reduction
BOD	30%
TSS	85%
Total P	50%
Total N	30%
Metals	30%

1.1.1.4 Advantages

1. High pollutant removal.
2. High community acceptance, if designed and maintained correctly.
3. Opportunity for wildlife habitat.
4. Multi-objective use for water quality and quantity control.
5. Decreased potential for downstream flooding and stream bank erosion.

1.1.1.5 Disadvantages

1. Potential for thermal impacts downstream.
2. Berm height restrictions.
3. Must evaluate potential for groundwater contamination.

1.1.1.6 Maintenance

An operations and maintenance (O&M) manual is required for each BMP as part of the drainage and storm water maintenance plan with routine inspections and maintenance being the responsibility of the BMP owner. The plan must be approved by the City, and maintained and updated by the BMP owner. Refer to the checklist provided in Figure 1.1.1-6 for operation, maintenance and inspection of storm water ponds. The checklist is for the use of the BMP owner in performing routine inspections. At a minimum, the owner must complete the following tasks, but is not limited to:

1. Provide adequate access for inspection and maintenance.
2. Remove debris from inlet and outlet structures.
3. Remove invasive vegetation from all side slopes.
4. Remove sediment accumulation from the forebay and permanent pool area when it is 50% full.
5. Remove woody vegetation from the embankment.

> ⚠ Regular maintenance is critical to the effective operation of storm water ponds as designed. Maintenance responsibility for a pond and its buffer should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

The following table further describes the typical maintenance requirements associated with wet ponds.

Table 1.1.1-3 Typical Maintenance Activities for Wet Ponds

Activity	Schedule
• Clean and remove debris form inlet and outlet structures. • Mow side slopes.	Monthly
• If wetland components are included, inspect for invasive vegetation.	Semiannual Inspection
• Inspect for damage, paying particular attention to the control structure. • Check for signs of eutrophic conditions. • Note signs of hydrocarbon build-up, and remove appropriately. • Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and operational. • Check all control gates, valves, or other mechanical devices.	Annual Inspection
• Repair undercut or eroded areas.	As Needed
• Perform wetland plant management and harvesting.	Annually (if needed)
• Removal of sediment from the forebay. .	5 to 7 years or after 50% of the total forebay capacity has been lost
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, or the pond becomes eutrophic.	10 to 20 years or after 25% of the permanent pool volume has been lost

Figure 1.1.1-6 Private Operation, Maintenance & Management – Storm Water Ponds

Storm Water Pond Operation, Maintenance, and Management Inspection Checklist for BMP Owners

Project: ______________________________ Owner Change since last inspection? Y N

Owner Name, Phone: ______________________________

Owner Address: ______________________________

Location: ______________________________

Site Status: ______________________________

Date: ______________________________ Time: ______________

Inspector: ______________________________

Maintenance Item	**Satisfactory/ Unsatisfactory**	**Comments**
I. Embankment and Emergency Spillway (Inspect annually and after major storms)		
1. Vegetation/Ground cover adequate		
2. Embankment erosion		
3. Animal burrows		
4. Cracking, bulging, or sliding of dam		
a. Location (upstream, downstream, toe)		
b. Description		
5. Drains clear and functioning		
6. Seeps or leaks		
7. Slope protection failure		
8. Vertical/horizontal alignment of top of dam		
9. Emergency spillway clear of obstructions		
10. Other (describe)		

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
II. Riser and Principal Spillway (Inspect annually)		
Type: Reinforced concrete __________ Corrugated pipe __________ Masonry __________		
1. Low flow orifice blocked		
2. Trash rack		
a. Debris removal necessary		
b. Corrosion detected		
3. Weir trash rack		
a. Debris removal necessary		
b. Corrosion detected		
4. Excessive sediment accumulation in riser		
5. Concrete/Masonry condition		
a. Cracks or displacement		
b. Spalling		
c. Joint failures		
6. Metal pipe condition		
7. Control valve operational		
8. Pond drain valve operational		
9. Outfall channels functioning		
10. Other (describe)		
III. Permanent Pool (Inspect monthly)		
1. Undesirable vegetative growth		
2. Floatable removal necessary		
3. Visible pollution		
4. Shoreline problem		
5. Other (describe)		

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
IV. Sediment Forebays		
1. Sedimentation noted		
2. Sediment cleanout necessary (50%+ full)		
V. Dry Pond Areas		
1. Vegetation/Ground cover adequate		
2. Low flow channels clear of obstructions		
3. Standing water or wet spots		
4. Sediment and/or trash accumulation		
5. Other (describe)		
VI. Other (Inspect monthly)		
1. Erosion at outfalls		
2. Endwalls and headwalls		
3. Encroachment into pond or easement area		
4. Complaints from residents		
5. Public hazards		

Additional Comments

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Actions to be taken: **Timeframe:**

1.1.2 Bioretention

1.1.2.1 General Description

Bioretention areas, or rain gardens, are structural storm water controls developed in the early 1990's that capture and temporarily store the water quality volume using soils and vegetation in landscaped areas to remove pollutants from storm water runoff. Bioretention areas are engineered facilities in which runoff is conveyed as sheet flow to the "treatment area," consisting of a grass buffer strip, ponding area, organic or mulch layer, planting soil, and vegetation. An optional sand bed can be included in the design to provide aeration and drainage of the planting soil. The filtered runoff is typically collected and returned to the conveyance system, though it can be exfiltrated into the surrounding soil in areas with acceptable porous soils. The practice of exfiltration may not be permitted in Wellfield Zoning Districts.

There are numerous design applications, both on- and off-line, for bioretention areas. These include use on single-family residential lots, small subdivisions, as off-line facilities adjacent to parking lots, along highways and road drainage swales, within larger landscaped pervious areas, and as landscaped islands in impervious or high-density environments. However, the structures are not suitable as regional storm water quality or quantity BMPs.

Bioretention facilities can provide a limited amount of water quantity control, with the storage provided by the facility included in the design of any downstream detention structures. Bioretention areas are designed for intermittent flow and to drain and aerate between rainfall events. Sites with continuous flow from groundwater, sump pumps or other areas must be avoided.

Bioretention areas consist of:

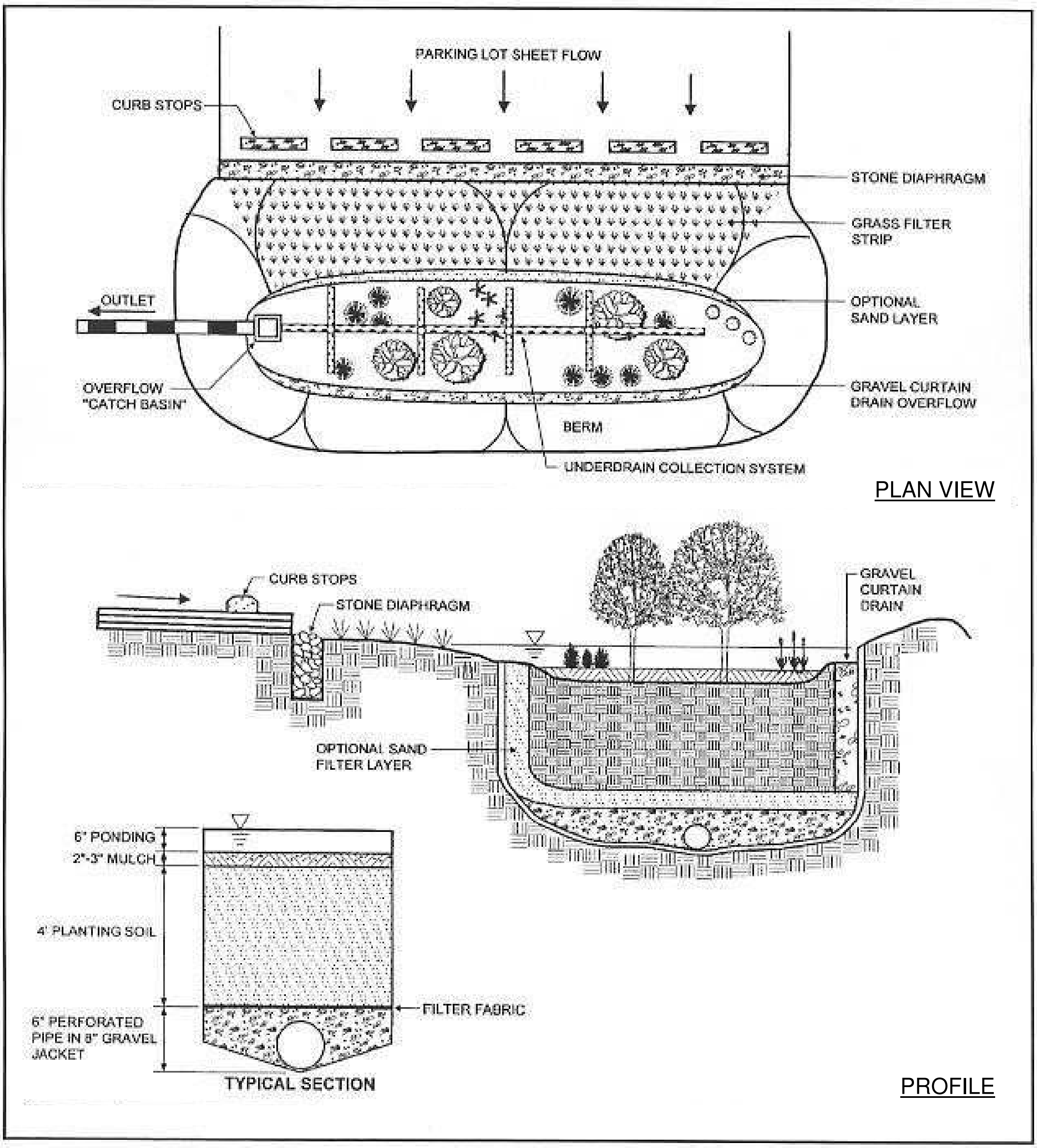
1. Grass filter strip between the contributing drainage area and the ponding area;
2. Ponding areas containing vegetation with a planting soil bed,
3. Organic/mulch layer, and
4. Gravel and perforated pipe underdrain system to collect runoff that has filtered through the soil layers (bioretention areas can optionally be designed to infiltrate into the soil).

Optional design components include:

1. Sand filter layer to spread flow, filter runoff and aid in aeration and drainage of the planting soil;
2. Stone diaphragm at the beginning of the grass filter strip to reduce velocities and spread flow into the grass filter;
3. Inflow diversion or an overflow structure.

Figure 1.1.2-1 provides an example of a bioretention area.

Figure 1.1.2-1 Bioretention Area



1.1.2.2 Site and Design Considerations

The following design and site considerations must be incorporated into the BMP plan including bioretention areas:

1. The drainage area (contributing or effective) must be 5 acres or less, though 0.5 to 2 acres is preferred.
2. The minimum size for the facility is 200 ft^2, with a length to width ratio of 2:1. The slope of the site can be no more than 6%.
3. Planting soil filter bed is sized using a Darcy's Law equation with a filter bed drain time of 48 hours and a coefficient of permeability (k) of 0.5 ft/day. The planting soil bed must be at least 4 feet deep. Planting soils must be sandy loam, loamy sand or loam texture with a clay content rating from 10 to 25 percent. The soil must have an infiltration rate of at least 0.5 inches per hour and a pH between 5.5 and 6.5. In addition, the planting soil should have a 1.5 to 3 percent organic content and a maximum 500-ppm concentration of soluble salts.
4. The maximum ponding depth in bioretention areas is 6 inches.
5. Filter strip design for pre-treatment must follow the requirements outlined in Section 1.2.1 and provide treatment to 25% of the WQ_v.
6. The mulch layer must consist of 2-3 inches of commercially available fine shredded hardwood mulch or shredded hardwood chips.
7. The sand bed must be 12-18 inches thick. Sand must be clean and have less than 15% silt or clay content.
8. Pea gravel for the diaphragm and curtain, where used, must be ASTM D 448 size No. 6 (1/8" to 1/4").
9. The underdrain collection system must be equipped with a 6 inch perforated PVC pipe in an 8-inch gravel layer. The pipe must have 3/8-inch perforations, spaced on 6-inch centers with a minimum of 4 holes per row. The pipe is spaced at a maximum of 10 feet on center, and a minimum grade of 0.5% must be maintained. A permeable filter fabric is placed between the gravel layer and the planting soil bed.
10. The required elevation difference needed from the inflow to the outflow is 5 feet.
11. The depth from the bottom of the bioretention facility to the seasonally high water table must be a minimum of 2 feet.
12. Runoff captured by facility must be sheet flow to prevent erosion of the organic or mulch layer. Velocities entering the mulch layer must be between 1-2 fps.
13. Continuous flow from groundwater, sump pumps or other areas to the bioretention area is prohibited.
14. An overflow structure and a non-erosive overflow channel must be provided to safely pass the flow from the bioretention area that exceeds the storage capacity to a stabilized downstream area. The high flow structure within the bioretention area can consist of a yard drain catch basin, with the throat of the catch basin inlet typically 6 inches above the elevation of the shallow ponding area.
15. All components of the BMP must be located within an easement. Access to the BMP must be located within the BMP, if needed.
16. If the bioretention area is used as a sediment control measure during active construction, the performance sureties will not be released until sediment has been cleaned out of the

bioretention area and elevations and grades have been reestablished as noted in the approved storm water management plan for post-construction runoff control.

1.1.2.3 Performance Standards

Bioretention areas designed, constructed and maintained as noted in this manual provide the following pollutant reductions:

Table 1.1.2-1 Performance Standards for Bioretention Areas

Pollutant	Percent Reduction
TSS	81%
Total P	29%
Total N	49%
Metals	61%

1.1.2.4 Advantages

1. Applicable to small drainage areas.
2. Often located in landscape islands.
3. High pollutant removal.
4. High community acceptance, if designed and maintained correctly.
5. Able to provide shade, wind break, absorb noise, and improve landscape.

1.1.2.5 Disadvantages

1. Requires extensive landscaping.
2. Not recommended for areas with steep slopes.
3. Not appropriate for areas where water table is within 6 feet of the ground surface.
4. Potential for freezing can prevent runoff from infiltrating into the planting soil.

1.1.2.6 Maintenance

An operations and maintenance (O&M) manual is required for each BMP as part of the drainage and storm water maintenance plan with routine inspections and maintenance being the responsibility of the BMP owner. The plan must be approved by the City, and maintained and updated by the BMP owner. Refer to Figure 1.1.2-2 for a checklist for BMP owners for the routine operation, maintenance and inspection of bioretention areas.

When bioretention basins are first placed into use, they should be inspected on a monthly basis, and more frequently if a large storm occurs in between that schedule. Once it is determined that the basin is functioning in a satisfactory manner and that there are no potential sediment problems, inspection can be reduced to a semi-annual basis with additional inspections following the occurrence of a large storm.

The facility should be observed after storms to ensure adequate drainage. Water standing longer than 4 days will severely limit the growth of most plants. Mosquitoes and other insects may start to breed as well. The microbial processes of the planting soil, which remove nutrients, will not work as well if the facility becomes waterlogged and anaerobic.

Trees and shrubs should be inspected twice per year. Any dead or severely diseased vegetation should be removed. Prune and weed to maintain the bioretention area's appearance. Spot mulch when bare spots appear. Every two to three years the entire area should be remulched. One to two times a year, limestone should be applied to counteract soil acidity resulting from the treated runoff.

Soil should be tested annually to detect toxic concentrations of pollutants. As toxins accumulate, they may impair plant growth and bioretention effectiveness, soil replacement may be required.

Figure 1.1.2-2 Private Operation, Maintenance & Management – Bioretention Areas

Bioretention Operation, Maintenance, and Management Inspection Checklist for BMP Owners

Site Name:________________________________ Owner Change since last inspection? Y N

Owner Name, Phone: ____

Owner Address: ____

Location: ____

Site Status: ____

Date: ______________________________ Time: ________________

Inspector: ____

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
I. Debris Cleanout (Inspect monthly)		
1. Debris in bioretention area and contributing areas		
2. Litter (branches, etc.) removed		
II. Vegetation (Inspect monthly)		
1. Plant height not less than design water depth		
2. Fertilized per specifications		
3. Plant composition according to approved plan		
4. Grass height no greater than 6 inches		
5. No evidence of erosion		
III. Dewatering (Inspect monthly)		
1. Dewaters between storms		
2. No evidence of standing water		

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
IV. Sediment Deposition (Inspect annually)		
1. Swale clean of sediments		
2. Sediments should be no more than 20% of the swale design depth		
V. Outlet/Overflow Spillway (Inspect annually and after major storms)		
1. No need for repair		
2. No evidence of erosion		
3. No evidence of any blockages		
VI. Integrity of Filter Bed (Inspect Annually)		
1. Filter bed not blocked or filled		

Additional Comments:

Actions to be taken: **Timeframe:**

1.1.3 Water Quality Swales

1.1.3.1 General Description

Dry water quality swales are channels designed and constructed to capture and treat storm water runoff within dry cells formed by check dams or other means. Dry water quality swales are also described as biofiltration swales. These swales are designed with a limited slope for slow, shallow flow to allow particulates to settle out and to promote infiltration. Water quality swales are limited to areas with low impervious acreage, such as residential and industrial developments.

Dry swales are channels designed with a filter bed and underdrain system. They are designed to filter and infiltrate the entire WQv through the bottom of the swale. Runoff is collected by a perforated pipe and discharged at the outlet. Water quality swales are dry most of the time and are therefore well suited for residential areas. Refer to Figure 1.1.3-1 for a schematic of a dry swale.

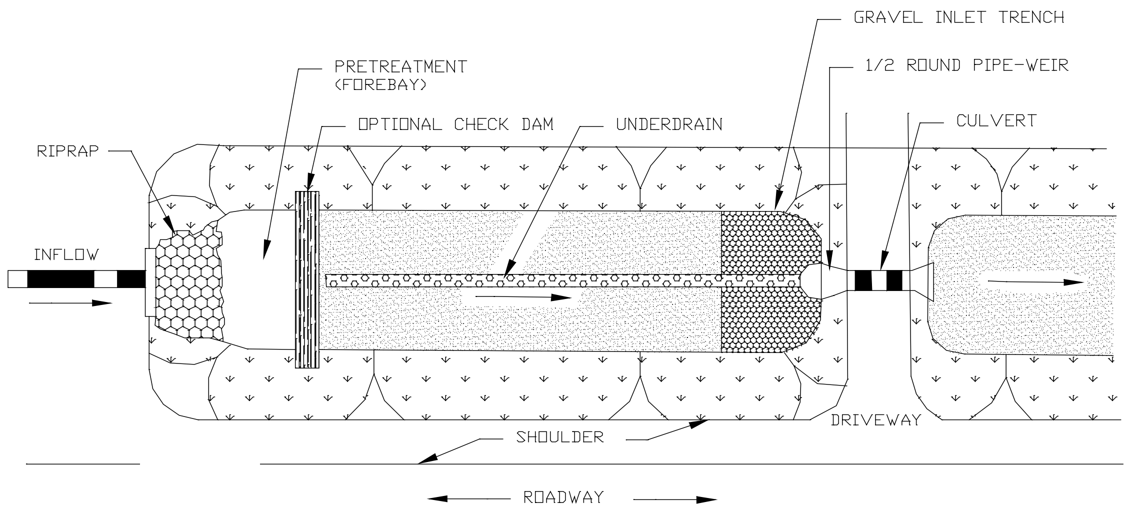
1.1.3.2 Site and Design Considerations

The following site and design criteria must be followed:

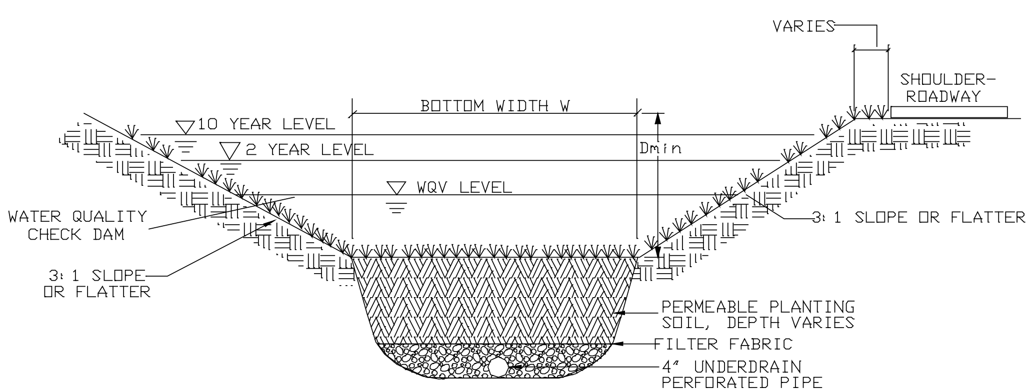
1. Water quality swales treat only the water quality volume. An additional measure is needed to provide detention in conjunction with the water quality swale. The swales can be designed as on-line or off-line structures. Larger storms pass non-erosively through the channels.
2. Water quality swales are limited to peak discharges generally less than 5 to 10 cfs and runoff velocities less than 2.5 ft/sec. The maximum drainage area is 5 acres. The maximum ponding time must be less than 48 hours, and a minimum ponding time of 30 minutes is recommended.
3. Pretreatment of 10% of the water quality volume should be provided. This pretreatment may be obtained by providing check dams at pipe inlets and / or driveway crossings. Additionally, all direct discharges of concentrated flow (e.g. by pipe) shall be pretreated.
4. The maximum design flow depth is 1 foot, with a ponding depth of 18 inches at the end of the channel.
5. Swale cross-section must have side slopes of 3:1 (h:v) or flatter. Bottom widths must be between 2-8 feet wide.
6. Underlying soils shall have a high permeability (fc > 0.5 inches per hour). Seasonally high water table must be greater than 3 feet below the bottom of the swale.
7. Water quality swales must have a minimum length of 100 feet.
8. Provide a sediment forebay at the inlet to the swales.
9. Locate the swale and all of its components within a drainage easement. The easement should include access to the BMP.
10. The maximum allowable length of a swale within a residential subdivision is 300 feet.
11. Swales must be completely sodded, well vegetated, and follow the natural, pre-development drainage path when possible.
12. Vegetation should be uniform with fine, turf-forming water-resistant grasses. Wetland vegetation should be used in areas with high groundwater and/or little slope. Vegetation examples include Big Bluestem Grass, Cardinal Flower, and Arrowhead.

13. Check dams may be used to enhance water quality and reduce velocities. Anti-clogging devices and / or skimmers shall be provided on each check dam and / or outlet to prevent clogging.

Figure 1.1.3-1 Dry Swale



PLAN VIEW



PROFILE

1.1.3.3 Performance Standards

Water quality swales designed, constructed and maintained (on a 4% or flatter slope) as noted in this manual provide the following pollutant reductions:

Table 1.1.3-1 Performance Standards for Water Quality Swales

Pollutant	Percent Reduction
BOD	10%
TSS	80%
Total P	83%
Total N	92%
Metals	75%

1.1.3.4 Advantages

1. Typically well accepted in residential settings.
2. Inexpensive.
3. Combines water quality treatment with runoff conveyance.
4. Reduces runoff velocities.
5. Low maintenance.

1.1.3.5 Disadvantages

1. Can provide a limited amount of storm water quantity control.

1.1.3.6 Maintenance

An operations and maintenance (O&M) manual is required for each BMP as part of the drainage and storm water maintenance plan with routine inspections and maintenance being the responsibility of the BMP owner. The plan must be approved by the City, and maintained and updated by the BMP owner. Refer to Figure 1.1.3-2 for a checklist for BMP owner routine operation, inspection and maintenance of water quality swales. At a minimum, the owner must complete the following tasks, but is not limited to:

1. Provide adequate access for inspection and maintenance.
2. Dry swales shall be maintained to keep grass cover dense and vigorous.
3. At a minimum, maintenance shall include periodic mowing, occasional spot reseeding, and weed control. Swale grasses must never be mowed close to the ground. Grass heights in the 4 to 6 inch range are recommended.
4. Fertilization of grass swale shall be done when needed to maintain the health of the grass, with care not to over-apply the fertilizer.
5. Remove sediment accumulated in forebay when it is 50% full.

Figure 1.1.3-2 Private Operation, Maintenance & Management – Water Quality Swale

Water Quality Swale Operation, Maintenance, and Management Inspection Checklist for BMP Owners

Site Name: ______________________ Owner Change since last inspection? Y N

Owner Name, Phone: ______________________

Owner Address: ______________________

Location: ______________________

Site Status: ______________________

Date: ______________________ Time: ______________________

Inspector: ______________________

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
I. Debris Cleanout (Inspect monthly)		
1. Contributing areas free of debris		
II. Check Dams or Energy Dissipators (Inspect annually and after major storms)		
1. No evidence of flow going around structures		
2. No evidence of erosion at downstream toe		
3. Soil permeability		
III. Vegetation (Inspect monthly)		
1. Minimum mow depth not exceeded		
2. No evidence of erosion		
3. Fertilized per specification		
IV. Dewatering (Inspect monthly)		
1. Dewaters between storms		

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
V. Sediment Deposition (Inspect annually)		
1. Clean of sediment		

Additional Comments:

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Actions to be taken:	**Timeframe:**

1.2 LIMITED APPLICATION CONTROLS

1.2.1 Biofilters

1.2.1.1 General Description

Biofilters are densely vegetated sections of land, designed to treat runoff from and remove pollutants through vegetative filtering and infiltration. Biofilters must receive runoff from adjacent areas as sheet flow. The vegetation slows the runoff and filters out sediment and other pollutants. However, the TSS removal provided is less than 80 percent. Therefore, biofilters must be used in a treatment train in conjunction with other management practices to provide the 80 percent performance goal.

Biofilters are best suited to treating runoff from roadways, rooftops, small parking areas and pervious areas. They can be easily incorporated into residential development as land-use buffers and setbacks.

Allowable biofilter variations are filter strips and riparian buffers.

- **Filter strip**: A filter strip is a uniformly graded and densely vegetated strip of land. The vegetation can be grasses or a combination of grass and woody plants. Pollutant removal efficiencies are based upon a 50-foot wide strip. Refer to Figure 1.2.1-1 for a schematic of a filter strip. Uniform sheet flow must be maintained through the filter strip to provide pollutant reduction and to avoid erosion.

- **Riparian buffer**: A riparian buffer is a strip of land with natural, woody vegetation along a stream or other watercourse. Besides the undergrowth of grasses and herbaceous vegetation, the riparian buffer includes deep rooted trees. The buffer area consists of three parts; an inner core buffer zone, a middle zone, and an outer buffer zone. The inner core buffer zone shall extend 25 feet from each side of a natural drainage way and 50 feet from each bank of a legal drain. The middle zone shall extend an additional 25 feet from either side of the inner core zone, the outward limit of the defined 100-year floodplain limit, or the outward limit of jurisdictional wetland habitat, whichever is greater. The outer buffer zone shall consist of an additional 20-foot setback to structures. The inner core buffer zone is to remain undisturbed during and after construction. The middle zone can be maintained by mowing or other maintenance; tree removal is allowed by permit. The outer buffer zone may consist of forest or maintained turf. Uniform sheet flow must be maintained through the filter strip to provide pollutant reduction and to avoid erosion. Refer to Figure 1.2.1-2 for a schematic of a riparian buffer.

Figure 1.2.1-1 Filter Strip

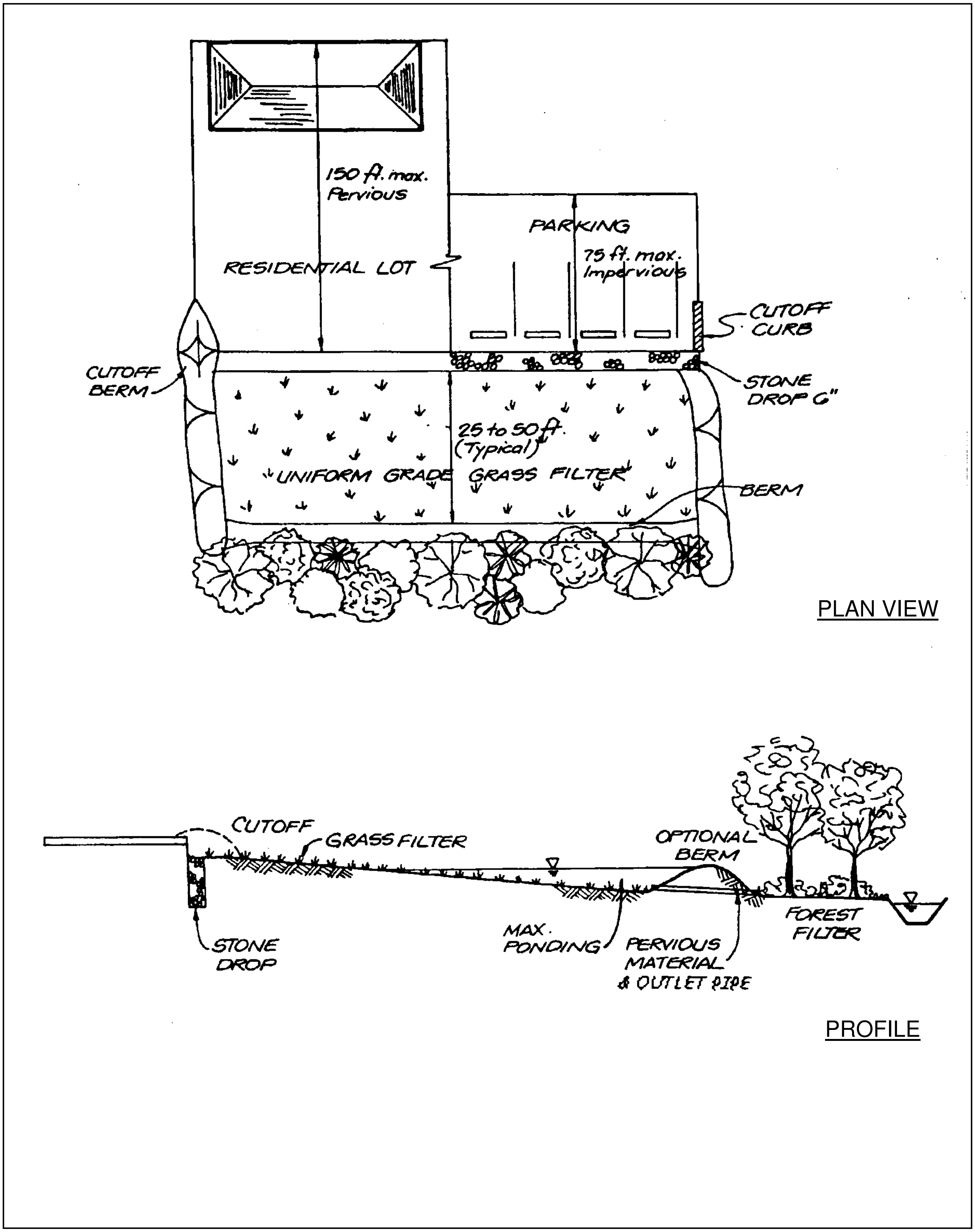
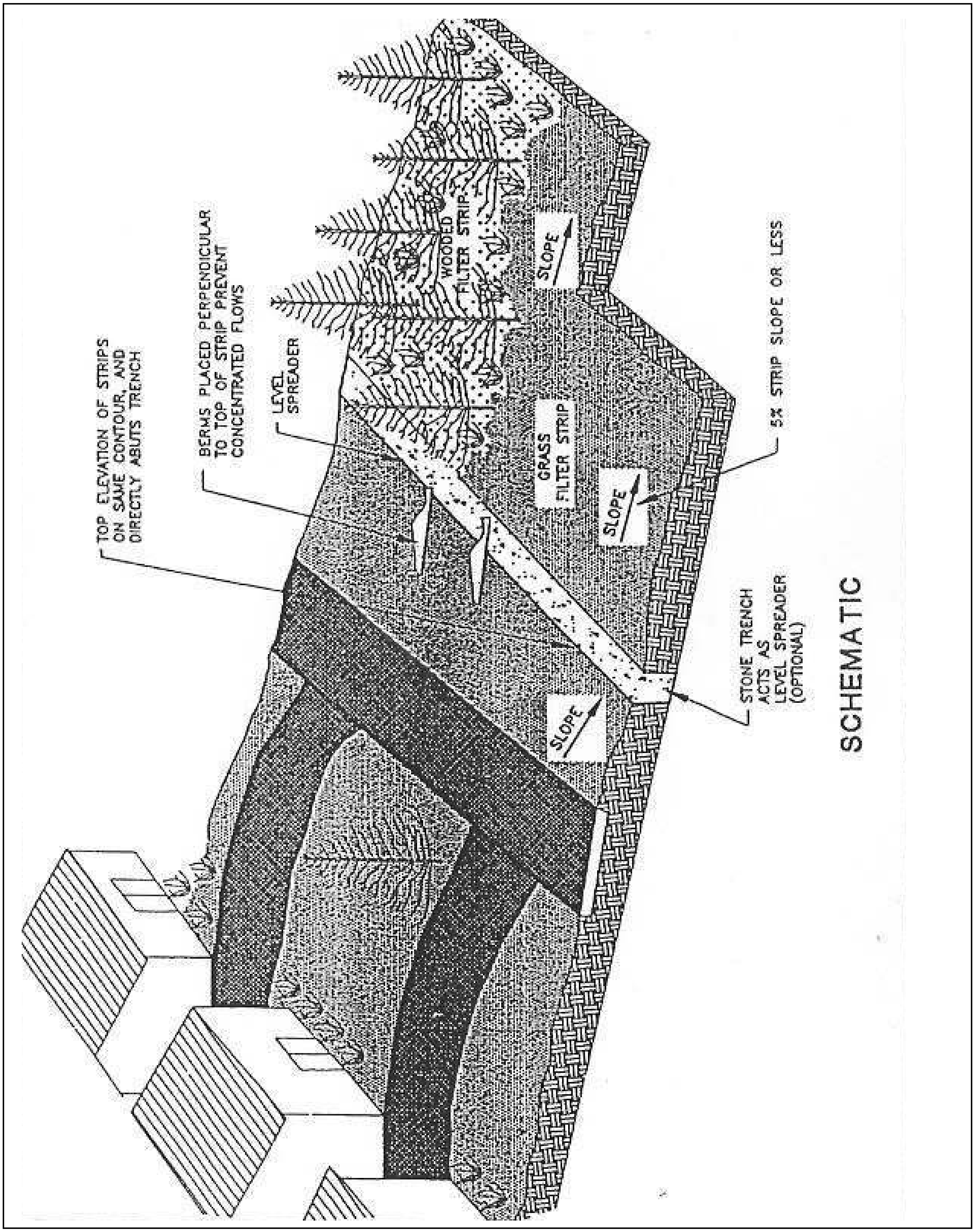


Figure 1.2.1-2 Buffer Area



1.2.1.2 Site and Drainage Considerations

The following site and drainage considerations must be included in the BMP plan:

1. To ensure sheet flow into the filter strips and riparian buffers, flow spreaders or level spreaders must be designed and installed where concentrated runoff flows into filter strips or riparian buffers.
2. Level Spreader: The grade of a level spreader shall be 0%. Stone trenches shall use 6 to 8 inch stone with a geotextile underlay. The channel grade for the last 20 feet of the dike or diversion entering the level spreader must be less than or equal to 1% and designed to provide a smooth transition into spreader. The depth of a level spreader as measured from the lip must be at least 6 inches. The level spreader lip must be constructed on undisturbed soil (not fill material) to uniform height and zero grade over length of the spreader. The maximum drainage area to the level spreader shall be 10 acres or less with the optimal size being less than 5 acres. The maximum flow into the level spreader must be 30 cfs or less.
3. Appropriate length, width, and depth of level spreaders shall be selected from the following table.

Design Flow (cfs)	Entrance Width (ft)	Depth (ft)	End Width (ft)	Length (ft)
0-10	10	0.5	3	10
10-20	16	0.6	3	20
20-30	14	0.7	3	30

4. Capacity of the spreader, filter strip and riparian buffer length (perpendicular to flow) must be determined by estimating the volume of flow that is diverted to the spreader for water quality control.
5. The released runoff to the outlet must be on undisturbed stabilized areas in sheet flow and not allowed to re-concentrate below the structure.
6. Slope of the filter strip from a level spreader must not exceed 10 percent.
7. All disturbed areas must be vegetated immediately after construction.
8. The minimum filter strip width is 20 feet.
9. Filter strips must be designed for slopes between 2 percent and 6 percent.
10. Ensure that flows in excess of design flow move across and around the filter strip without damaging it.
11. Filter strips can be used effectively as pretreatment measures. The minimum sizing criteria are as follows:

Parameters	Impervious Area				Pervious Area (lawns, etc.)			
Maximum Inflow Approach Length (ft)	35		75		75		100	
Filter Strip Slope (max = 6%)	<2%	>2%	<2%	>2%	<2%	>2%	<2%	>2%
Filter Strip Minimum Length	10	15	20	25	10	12	15	18

12. Riparian buffers: The use of buffers is limited to drainage areas of 10 acres or less with the optimal size being less than 5 acres.
13. Slope of the buffer from a level spreader cannot exceed 10 percent.

14. Top edge of buffer must directly abut the contributing impervious area and follow the same elevation contour line.
15. Biofilters and level spreaders must be located within a drainage easement. A copy of the easement should be included with the BMP operations and maintenance manual.
16. A conservation easement shall be provided across the buffer area to prevent development on top of the buffer area.

1.2.1.3 Performance Standards

Biofilters designed, constructed and maintained as noted in this manual provide the following pollutant reductions:

Table 1.2.1-1 Performance Standards for Biofilters

Pollutant	Percent Reduction (riparian buffer/filter strip)
BOD	40/10%
TSS	60/30%
Total P	35/10%
Total N	25/10%
Metals	70/30%

1.2.1.4 Advantages

1. Filter strips and riparian buffers can easily be incorporated into new development design.
2. Low maintenance once a dense ground cover is established in filter strips and level spreaders and once trees and other woody vegetation is established in riparian buffers.
3. Riparian buffers provide wildlife habitat.
4. Ideal for use near waterbodies and streams.

1.2.1.5 Disadvantages

1. Filter strips, riparian buffers and level spreaders have limited drainage areas.
2. Constructing a level lip on a level spreader can be difficult. Failure to construct a level lip makes the level spreader ineffective.

1.2.1.6 Maintenance

An operations and maintenance (O&M) manual is required for each BMP as part of the drainage and storm water maintenance plan with routine inspections and maintenance being the responsibility of the BMP owner. The plan must be approved by the City, and maintained and updated by the BMP owner. Refer to Figure 1.2.1-3 for a BMP owner's routine checklist for inspection and maintenance of filter strips and riparian buffers.

Figure 1.2.1-3 Private Operation, Maintenance & Management – Biofilters and Buffers

Biofilter and Buffer Operation, Maintenance, and Management Inspection Checklist for BMP Owners

Site Name: ______________________ Owner Change since last inspection? Y N

Owner Name, Phone: ______________________

Owner Address: ______________________

Location: ______________________

Site Status: ______________________

Date: ______________________ Time: ______________

Inspector: ______________________

Maintenance Item	**Satisfactory/ Unsatisfactory**	**Comments**
I. Debris Cleanout (Inspect monthly)		
1. Plant composition according to approved plan		
2. Vegetation is healthy		
3. Grass height not more than 6 inches		
4. No evidence of erosion		

Additional Comments:

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Actions to be taken: **Timeframe:**

1.2.2 Porous Surfaces

1.2.2.1 General Description

Porous surfaces such as modular porous paver systems and porous concrete systems are permeable pavement surfaces with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil. Porous concrete is the term for a mixture of course aggregate, portland cement and water that allows for rapid infiltration of water. Modular porous paver systems consist of open void paver units laid on a gravel subgrade. Both porous concrete and porous paver systems provide water quality and quantity benefits, but have high workmanship and maintenance requirements, as well as high failure rates.

Porous concrete is a subset of a broader family of pervious pavements including porous asphalt, and various kinds of grids and paver systems. Porous concrete is a formulated mixture of coarse aggregate, portland cement, and water that allows for rapid infiltration of water and overlays a stone aggregate reservoir. The concrete layer has a high permeability, often many times that of the underlying permeable soil layer, and allows rapid percolation of rainwater through the surface into the layers beneath. The void space in porous concrete is in the 15% to 22% range compared to three to five percent for conventional pavements. The permeable surface is placed over a layer of open-graded gravel and crushed stone. The void spaces in the stone act as a storage reservoir for runoff. This reservoir provides temporary storage as runoff infiltrates into underlying permeable soils and or out through an underdrain system.

Modifications or additions to the standard porous concrete design have been used to pass flows and volumes in excess of the water quality volume, or to increase storage capacity or treatment. These include:

- Placing a perforated pipe near the top of the crushed stone reservoir to pass excess flows after the reservoir is filled
- Providing surface detention storage in a parking lot, adjacent swale, or detention pond with suitable overflow conveyance
- Connecting the stone reservoir layer to a stone filled trench
- Adding a sand layer and perforated pipe beneath the stone layer for filtration of the water quality volume
- Placing an underground detention tank or vault system beneath the layers.

Modular porous paver systems are structural units, such as concrete blocks, bricks, or reinforced plastic mats, with regularly interdispersed void areas to create a load-bearing pavement surface. The void areas are filled with pervious materials, such as gravel, sand, or grass turf, to create a system that allows for the infiltration of storm water runoff. Modular porous pavers are typically placed on gravel base course. As runoff infiltrates through the porous paver surface into the gravel, the gravel acts as a storage reservoir as it exfiltrates to the underlying soil.

Porous surfaces such as porous concrete and porous pavers are typically used in low-traffic areas such as the following types of applications:

- Parking pads in parking lots
- Overflow parking areas
- Residential street parking lanes
- Recreational trails
- Golf cart and pedestrian paths
- Emergency vehicle and fire access lanes

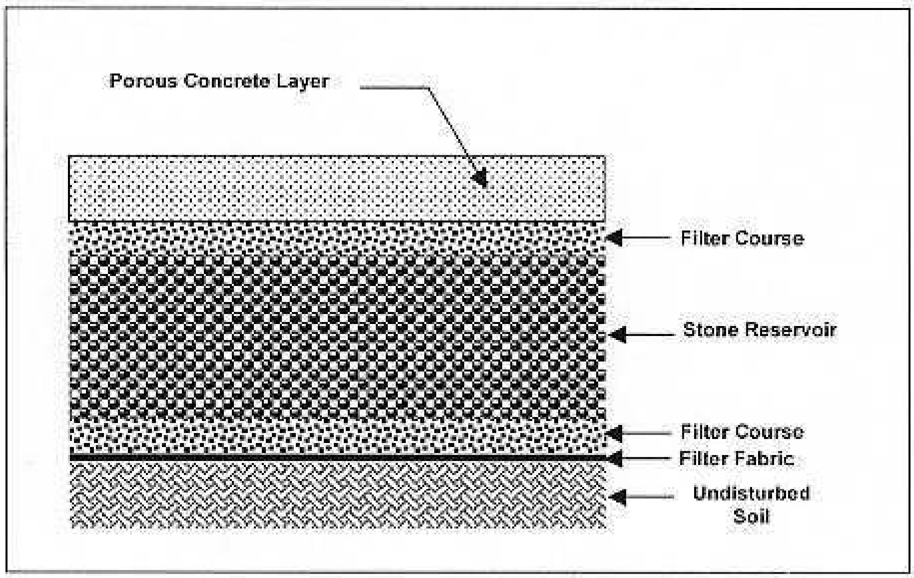
1.2.2.2 Site and Design Considerations

1. Porous paver systems can be used where the underlying in-situ subsoils have an infiltration rate of between 0.5 and 3.0 inches per hour. Porous concrete systems can be used where the underlying in-situ subsoils have an infiltration rate greater than 0.5 inches per hour. Therefore, porous surfaces are not suitable on sites with hydrologic group D or most group C soils, or soils with a high (>30%) clay content. During construction and preparation of the subgrade, special care must be taken to avoid compaction of the soils.
2. Porous surfaces should typically be used in applications where the pavement receives tributary runoff only from impervious areas. Actual pervious surface area sizing will depend on achieving a 24 hour minimum and 48 hour maximum draw down time for the design storm volume. The ratio of the contributing impervious area to the porous paver surface area should be no greater than 3:1.
3. If runoff is coming from adjacent pervious areas, it is important that those areas be fully stabilized to reduce sediment loads and prevent clogging of the porous surface.
4. Pretreatment using filter strips or vegetated swales for removal of course sediments is recommended. (see sections 1.2.1 and 1.1.3)
5. Porous concrete systems should not be used on slopes greater than 5% with slopes of no greater than 2% recommended. For slopes greater than 1%, barriers perpendicular to the direction of drainage should be installed in sub-grade material to keep it from washing away, or filter fabric should be placed at the bottom and sides of the aggregate to keep soil from migrating into the aggregate and reducing porosity.
6. Porous paver systems are not recommended on sites with a slope greater than 2%.
7. A minimum of four feet of clearance for porous concrete and two feet of clearance for porous pavers is recommended between the bottom of the gravel base course or the seasonally high groundwater table.
8. Porous surfaces should be sited at least 10 feet down-gradient from buildings and 100 feet away from drinking water wells.
9. To protect groundwater from potential contamination, runoff from designated hotspot land uses or activities must not be infiltrated. Porous concrete should not be used for manufacturing and industrial sites, where there is a potential for high concentrations of soluble pollutants and heavy metals. In addition, porous concrete should not be considered for areas with a high pesticide concentration.
10. Porous surface designs must use some method to convey larger storm event flows to the conveyance system. One option is to use storm drain inlets set slightly above the elevation of the pavement. This would allow for some ponding above the surface, but

would accept bypass flows that are too large to be infiltrated by the porous surface, or if the surface clogs.

11. For the purpose of sizing downstream conveyance and structural control system, porous surfaces can be assumed to be 35% impervious.
12. For treatment control, the design volume should be, at a minimum, equal to the water quality volume. The water quality storage volume for porous concrete is contained in the surface layer, the aggregate reservoir, and the sub-grade above the seasonal high water table – if the sub-grade is sandy.
13. The storm duration (fill time) is normally short compared to the infiltration rate of the sub-grade, a duration of two hours can be used for design purposes. The total storage volume in a layer is equal to the percent of voids times the volume of the layer. Alternately storage may be created on the surface through temporary ponding, though this would tend to accelerate clogging if course sediment or mud settles out on the surface.
14. The cross-section of porous concrete typically consists of four layers, as shown in Figure 3.3.7-1.

Figure 1.2.2-1 Porous Concrete System Section



The aggregate reservoir can sometimes be avoided or minimized if the sub-grade is sandy and there is adequate time to infiltrate the necessary runoff volume into the sandy soil without by-passing the water quality volume. Descriptions of each of the layers is presented below:

<u>Porous Concrete Layer</u> – The porous concrete layer consists of an open-graded concrete mixture usually ranging from depths of 2 to 4 inches depending on required bearing strength and pavement design requirements. Porous concrete can be assumed to contain 18 percent voids (porosity = 0.18) for design purposes. Thus, for example, a 4 inch thick porous concrete layer would hold 0.72 inches of rainfall. The omission of the fine aggregate provides the porosity of the porous pavement. To provide a smooth riding

surface and to enhance handling and placement a coarse aggregate of 3/8 inch maximum size is normally used.

Top Filter Layer – Consists of a 0.5-inch diameter crushed stone to a depth of 1 to 2 inches. This layer serves to stabilize the porous asphalt layer. It can be combined with reservoir layer using suitable stone.

Reservoir Layer – The reservoir gravel base course consists of washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from two to four feet. The layer must have a minimum depth of nine inches, it should be designed to drain completely in 48 hours, and should be designed to store at a minimum the water quality volume (WQv). Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 should be used in calculations unless aggregate specific data exist.

Bottom Filter Layer – The surface of the subgrade should be a 6 inch layer of sand or a 2 inch thick layer of 0.5 inch crushed stone, and be completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.

Filter Fabric – It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves a very important function by inhibiting soil from migrating into the reservoir layer and reducing storage capacity.

Underlying Soil – The underlying soil should have an infiltration capacity of at least 0.5 in/hr, but preferably greater than 0.50 in/hr. as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility). Infiltration trenches cannot be used in fill soils. Soils at the lower end of this range may not be suited for a full infiltration system. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability. Often a double-ring infiltrometer test is done at subgrade elevation to determine the impermeable layer, and, for safety, one-half the measured value is allowed for infiltration calculations.

15. The pit excavation should be limited to the width and depth specified in the design. Excavated material should be placed away from the open trench as not to jeopardize the stability of the trench sidewalls. The bottom of the excavated trench should not be loaded so as to cause compaction, and should be scarified prior to placement of sand. The sides of the trench shall be trimmed of all large roots. The sidewalls shall be uniform with no voids and scarified prior to backfilling. All infiltration trench facilities should be

protected during site construction, and should be constructed after upstream areas have been stabilized.

16. An observation well consisting of perforated PVC pipe 4 to 6 inches in diameter should be placed at the downstream end of the facility and protected. The well should be used to determine actual infiltration rates.
17. A warning sign should be placed at porous concrete facilities that states, "Porous Paving used on this site to reduce pollution. Do not resurface with non-porous material. Any construction without prior written approval from the City of Portage Storm Water Board will result in the violation of City Ordinance 92-5 and possible subsequent fines. Call 219-762-1815 for more information."
18. A minimum of 40% of the porous paver surface area should consist of open void spaces. If it is a load-bearing surface, then the pavers should be able to support the maximum load.
19. The different layers for porous pavers should meet the following requirements:

    Porous Paver Infill – The porous paver infill is selected based upon the intended application and required infiltration rate. Masonry sand has a high infiltration rate and should be used in applications where no vegetation is desired. A sandy loam soil has a substantially lower infiltration rate, but will provide for growth of a grass ground cover.

    Top Filter Layer – A 1-inch top course (filter layer) of sand underlain by filter fabric is placed under the porous pavers and above the gravel base course.

    Reservoir Layer – The gravel base course should be designed to store at a minimum the WQv. The stone aggregate should be washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40%. Aggregate contaminated with soil shall not be used. A porosity value (void space/total volume) of 0.32 should be used in calculations unless aggregate specific data exist.

    The gravel base course must have a minimum depth of 9 inches. The following equation can be used to determine if the depth of the storage layer (gravel base course) needs to be greater than the minimum depth:

    $$D = WQ_v / A * n$$

    Where:

    D = Gravel Layer Depth (feet)
    WQ_v = Water Quality Volume or Total Volume to be Infiltrated
    A = Surface Area (square feet)
    N = Porosity (use n=0.32)

    Bottom Filter Layer – The surface of the subgrade should be lined with filter fabric or an 8-inch layer of sand and be completely flat to promote infiltration across the entire surface.

1.2.2.3 Performance Standards

Porous surfaces have a high removal of both soluble and particulate pollutants, where they become trapped, absorbed, or broken down in the underlying soil layers. Porous surfaces pollutant removal mechanisms include absorption, straining, and microbiological decomposition in the soil. Porous surfaces can provide the following pollutant reductions:

Table 1.2.2-1 Performance Standards for Porous Surfaces

Pollutant	Percent Reduction
TSS	95%
Total P	65%
Total N	82%
Metals	98-99%

Some key factors to increase pollutant removal include:

- Routine vacuum sweeping and high pressure washing (with proper disposal of removed material).
- Drainage time of at least 24 hours.
- Highly permeable soils.
- Pretreatment of runoff from site.
- Organic matter in subsoils.
- Clean-washed aggregate.

1.2.2.4 Advantages

1. Volume reduction due to infiltration and groundwater recharge.
2. Blends into the normal urban landscape.
3. Allows a reduction in the cost of other storm water infrastructure.

1.2.2.5 Disadvantages

1. Cost and complexity of porous concrete systems compared to conventional pavements.
2. High level of construction workmanship to ensure they function as designed.
3. High failure rate if not designed, constructed, and maintained properly.

1.2.2.6 Maintenance

An operations and maintenance (O&M) manual is required for each BMP as part of the drainage and storm water maintenance plan with routine inspections and maintenance being the responsibility of the BMP owner. The plan must be approved by the City, and maintained and updated by the BMP owner. Refer to the checklist provided in Figure 1.2.2-2 for operation, maintenance and inspection of porous surfaces. The checklist is for the use of the BMP owner in performing routine inspections. The tables below also list examples of typical maintenance activities for porous concrete systems and porous paver systems.

Table 1.2.2-2 Typical Maintenance Activities for Porous Concrete Systems

Activity	Schedule
• Initial inspection.	Monthly for three months after installation
• Ensure that the porous paver surface is free of sediment.	Monthly
• Ensure that the contributing and adjacent area is stabilized and mowed, with clippings removed.	As needed, based on inspection
• Vacuum sweep porous concrete surface followed by high pressure hosing to keep pores free of sediment	Four times a year
• Inspect the surface for deterioration or spalling. • Check to make sure that the system dewaters between storms.	Annually
• Spot clogging can be handled by drilling half-inch holes through the pavement every few feet. • Rehabilitation of the porous concrete system, including the top and base course as needed. .	Upon failure

Table 1.2.2-3 Typical Maintenance Activities for Porous Paver Systems

Activity	Schedule
• Ensure that the porous paver surface is free of sediment. • Check to make sure that the system dewaters between storms.	Monthly
• Ensure that contributing area and porous paver surface are clear of debris. • Ensure that the contributing and adjacent area is stabilized and mowed, with clippings removed.	As needed, based on inspection
• Vacuum sweep porous paver surface to keep free of sediment.	Typically three to four times a year
• Inspect the surface for deterioration or spalling.	Annually
• Spot clogging can be handled by drilling half-inch holes through the pavement every few feet. • Totally rehabilitate the porous paver system, including the top and base course, as needed. .	Upon failure

Figure 1.2.2-2 Private Operation, Maintenance & Management – Porous Surfaces

Porous Surfaces Operation, Maintenance, and Management Inspection Checklist for BMP Owners

Project: ________________________ Owner Change since last inspection? Y N

Owner Name, Phone: ________________________

Owner Address: ________________________

Location: ________________________

Site Status: ________________________

Date: ________________________ Time: ____________

Inspector: ________________________

Maintenance Item	Satisfactory/ Unsatisfactory	Comments
I. Debris on Infiltration Paving Parking Area (Inspect monthly)		
1. Paving area clean of debris		
II. Vegetation (buffer areas or pervious areas in drainage area) (Inspect monthly)		
1. Mowing done when needed		
2. Fertilized per specifications		
3. No evidence of erosion		
III. Dewatering (Inspect monthly)		
1. Infiltration paving dewaters between storms		
IV. Sediments (Inspect monthly)		
1. Area clean of sediments		
2. Area vacuum swept on a periodic basis		
V. Structural Condition (Inspect annually)		
1. No evidence of surface deterioration		
2. No evidence of rutting or spalling		

Additional Comments

Actions to be taken: **Timeframe:**

1.2.3 Proprietary Systems

1.2.3.1 General Description

There are many types of commercially available proprietary storm water structural controls available for both water quality treatment and quantity control. These include:

- Hydrodynamic systems such as gravity and vortex separators
- Filtration systems
- Chemical treatment systems
- Package treatment plants
- Prefabricated detention structures
-

Many proprietary systems are useful on small sites and space-limited areas where there is not enough land or room for other structural control alternatives. Proprietary systems can often be used in pretreatment applications in a treatment train. However, proprietary systems are often more costly than other alternatives and may have high maintenance requirements. Perhaps the largest difficulty in using a proprietary system is the lack of adequate independent performance data, particularly for use in Indiana conditions. Below are general guidelines that should be followed before considering the use of a proprietary commercial system.

1.2.3.2 Guidelines for Using Proprietary Systems

Proprietary systems or manufactured BMPs must be professionally certified and approved by the City Engineer prior to any construction or installation. ASTM standard methods must be followed when verifying performance of new measures. New BMPs must have low to medium maintenance requirements as directed by the City Engineer. In order for use as a limited application control, a proprietary system must have a demonstrated capability of meeting the storm water management goals for which it is being intended. This means that the system must provide:

1. Independent third-party scientific verification of the ability of the proprietary system to meet water quality treatment objectives and/or to provide water quantity control (channel or flood protection). The following monitoring criteria should be met for supporting studies:
   - At least 15 storm events must be sampled
   - The study must be independent or independently verified (i.e., may not be conducted by the vendor or designer without third-party verification)
   - The study must be conducted in the field, as opposed to laboratory testing
   - Field monitoring must be conducted using standard protocols which require proportional sampling both upstream and downstream of the device
   - Concentrations reported in the study must be flow-weighted
   - The propriety system or device must have been in place for at least one year at the time of monitoring
2. Proven record of longevity in the field
3. Proven ability to function in Indiana conditions (e.g., climate, rainfall patterns, soil types, etc.).

Although local data is preferred, data from other regions can be accepted as long as the design accounts for the local conditions. A poor performance record or high failure rate is valid justification for not allowing the use of a proprietary system or device.

A BMP operations and maintenance plan will be required for each BMP. The plan must be submitted to the City Engineer for approval and maintained and updated by the BMP owner. The maintenance covenant must require the owner of the proprietary system to periodically clean the unit. Routine inspections and maintenance are the responsibility of the BMP owner. An easement must be acquired to provide adequate access for inspection and maintenance. All easements should be included in the operations and maintenance plan.

1.2.3.3 Oil / Water Separators

Certain site uses within the City of Portage, such as high-use or high-risk parking lots, may require additional treatment for oil and grease. To be considered for use as an oil/water separator, a manufactured technology must demonstrate adequate performance. Adequate performance needs to include: the removal of oil droplets from 50 to 60 microns in size, and the ability to achieve effluent efficiencies of 10 ppm or mg/L for influent concentrations exceeding 50 ppm or mg/L.

2.0 STORM WATER BMP SELECTION

The City of Portage offers this section to assist in the selection of storm water quality BMPs for use with its corporate boundaries. This section presents matrices that can be used as a screening process to select the best BMP or group of BMPs for a development or redevelopment site. The BMPs listed in the matrices have been determined to be widely accepted by the City Engineer and should be considered to be pre-approved for use within the City of Portage if all necessary and appropriate design criteria and guidelines are met.

The matrices presented below can be used to screen practices in a step-wise fashion. The screening factors include:

1. Land Use
2. Physical Feasibility
3. Community and Environmental Factors

The three matrices presented here are not exhaustive. Specific additional criteria may be incorporated or considered depending on enhanced local design knowledge, experience and resource protection goals. Caveats for the application of each matrix are included in the detailed description of each.

More detail on the proposed step-wise screening process is provided below.

2.1 LAND USE FACTORS

In this step, the designer/engineer makes an initial screen of practices most appropriate for a given land use. The different types of land use are described as follows:

Rural. This column identifies BMPs best suited to treat runoff in rural or very low-density areas (e.g., typically at a density of less than ½ dwelling unit per acre).

Residential. This column identifies the best treatment options in medium to high-density residential developments.

Commercial Development. This column identifies practices that are suitable for new commercial development.

Downtown Sites. This column identifies BMPs that work well in an ultra-urban environment, where space is limited and original soils have been disturbed. These BMPs are also frequently used at redevelopment sites.

Table 2.1-1 Land Use Selection Matrix

BMP Group	BMP Design	Rural	Residential	Commercial/ High Density	Downtown
Pond	Micropool ED	❍	❍	⊙	⊗
	Wet Pond	❍	❍	⊙	⊗
	Wet Pond ED	❍	❍	⊙	⊗
	Multiple Pond	❍	❍	⊙	⊗
	Pocket Pond	❍	⊙	⊙	⊗
Filters	Bioretention	⊙	⊙	❍	❍
	Filter Strip	⊙	⊙	⊙	⊗
	Riparian Buffer	❍	❍	❍	❍
	Porous Surface	❍	❍	⊗	⊙
Open Channels	Dry Swale	❍	⊙	❍	⊙
Proprietary System		⊙	⊙	❍	❍

❍: Yes. Good option in most cases.
⊙: Depends. Suitable under certain conditions, or may be used to treat a portion of the site.
⊗: No. Seldom or never suitable.

2.2 PHYSICAL FEASIBILITY FACTORS

In this step, the designer/engineer screens the BMP list to determine if the soils, water table, drainage area, slope or head conditions present at a particular development site might limit the use of the BMP. The five primary physical conditions are described as follows:

Soils. The key evaluation factors are based on an initial investigation of the NRCS hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors.

Water Table. This column indicates the minimum depth to the seasonally high water table from the bottom elevation, or floor, of a BMP.

Drainage Area. This column indicates the minimum or maximum drainage area that is considered optimal for a practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway is warranted where a practice meets other management objectives. Likewise, the minimum drainage areas indicated for ponds should not be considered inflexible limits, and may be increased or decreased depending on water availability (baseflow or groundwater), mechanisms employed to prevent clogging, or the ability to assume an increased maintenance burden.

Slope. This column evaluates the effect of slope on the practice. Specifically, the slope guidance refers to how flat the area where the practice is installed must be and/or how steep the contributing drainage area or flow length can be.

Head. This column provides an estimate of the elevation difference needed for a practice (from the inflow to the outflow) to allow for gravity operation.

Table 2.2-1 Physical Feasibility Matrix

BMP Group	BMP Design	Soils	Water Table	Drainage Area (acres)	Site Slope	Head
Pond	Micropool ED	May require a pond liner	2 foot separation if hotspot or aquifer	10 min[1]	No more than 15%	6 to 8 ft
	Wet Pond			25 min[1]		
	Wet ED Pond					
	Multiple Pond					
	Pocket Pond	OK	Below WT	5 max[2]		4 ft
Filters	Bioretention	OK	2 feet[3]	5 max[2]	No more than 6%	5 ft
	Filter Strip	OK	Above WT	5 max	2% – 6%	Concentrated Depth no more than 2.5 in
	Riparian Buffer	OK	Above WT	10 max	No more than 10% from level spreader	Sheet flow
	Porous Surface	OK	Above WT	5 max	2%-5%	Site specific
Open Channels	Dry Swale	Made Soil	Above WT	5 max[2]	No more than 6%	3 to 5 ft
Proprietary System		OK	Structure specific	Structure specific	Structure specific	Structure specific

Notes:
1: Unless adequate water balance and anti-clogging device installed.
2: Drainage area can be larger in some instances.
3: If designed with a permeable bottom, must meet the depth requirements for infiltration practices.

2.3 COMMUNITY AND ENVIRONMENTAL FACTORS

In this step, a matrix is used to compare the BMP options with regard to maintenance, community acceptance and habitat considerations. These community and environmental factors are described as follows:

Ease of Maintenance. This column assesses the relative maintenance effort needed for an BMP, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging) and reported failure rates. It should be noted that all BMPs require routine inspection and maintenance.

*Community Acceptanc*e. This column assesses community acceptance, as measured by three factors: market and preference surveys, reported nuisance problems, and visual orientation (i.e., is it prominently located or is it in a discrete underground location). It should be noted that a low rank could often be improved by a better landscaping plan.

Habitat. BMPs are evaluated on their ability to provide wildlife or wetland habitat, assuming that an effort is made to landscape them appropriately. Objective criteria include size, water features, wetland features and vegetative cover of the BMP and its buffer.

Table 2.3-1 Community and Environmental Factors

BMP Group	BMP List	Ease of Maintenance	Community Acceptance	Habitat
Ponds	Micropool ED	⊙	⊙	⊙
	Wet Pond	❍	❍	❍
	Wet ED Pond	❍	❍	❍
	Multiple Pond	❍	❍	❍
	Pocket Pond	⊗	⊙	⊗
Filters	Bioretention	⊙	⊙	⊙
	Filter Strip	⊙	❍	⊙
	Riparian Buffer	⊙	❍	❍
	Porous Surface	⊙	❍	⊗
Open Channels	Dry Swale	❍	❍	⊙
Proprietary System		❍	❍	⊗

❍: Yes. Good option in most cases.
⊙: Depends. Suitable under certain conditions, or may be used to treat a portion of the site.
⊗: No. Seldom or never suitable.

Other aspects to consider in BMP selection include safety.

3.0 LANDSCAPING GUIDANCE

Below are general guidelines that should be followed in the landscaping of any storm water control or conveyance facility.

DO NOT:

- Plant trees and shrubs within 15 feet of the toe of slope of a dam.
- Plant trees or shrubs known to have long tap roots within the vicinity of the earthen dam or embankment, or subsurface drainage facilities.
- Plant trees and shrubs within 25 feet of a principal spillway structure (e.g., riser)
- Plant trees and shrubs within 25 feet of perforated pipes.
- Block maintenance access to structures with trees or shrubs.

DO:

- Take into account site characteristics and plant selection guidelines when selecting plants for storm water facilities.
- Consider how plant characteristics will affect the landscape and the performance of a structural storm water control or conveyance.
- Carefully consider the long-term vegetation management strategy for the structural control, keeping in mind the maintenance legacy for the future owners.
- Preserve existing natural vegetation when possible.
- Avoid the overuse of any plant materials.
- Have soils tested to determine if there is a need for amendments.
- Select plants that can thrive in on-site soils with no additional amendments or a minimum of amendments.
- Consider water availability, particularly for wetland and water-intensive plantings.
- Decrease the areas where turf is used. Use low maintenance ground cover to absorb run-off.
- Plant stream and edge of water buffers with trees, shrubs, ornamental grasses, and herbaceous materials where possible, to stabilize banks and provide shade.
- Provide slope stabilization methods for slopes steeper than 2:1, such as planted erosion control mats. Also, use seed mixes with quick germination rates in this area. Augment temporary seeding measures with container crowns or root mats of more permanent plant material.
- Utilize erosion control mats and fabrics to protect in channels that are subject to frequent wash outs.
- Stabilize all water overflows with plant material that can withstand strong current flows. Root material should be fibrous and substantial but lacking a tap root.
- Sod area channels that are not stabilized using erosion control mats.
- Divert flows temporarily from seeded areas until stabilized.
- Check water tolerances of existing plant materials prior to inundation of area.
- Stabilize aquatic and safety benches with emergent wetland plants and wet seed mixes.
- Provide a 15-foot clearance from a non-clogging, low flow orifice.

- Limit herbaceous embankment plantings to 10 inches in height, to allow visibility for the inspector who is looking for burrowing rodents that may compromise the integrity of the embankment.
- Shade inflow and outflow channels, as well as the southern exposures of pond, to reduce thermal warming
- Avoid plantings that will require routine or intensive chemical applications (i.e. turf area).
- Maintain and frame desirable views. Be careful not to block views at entrances, exits, or difficult road curves. Screen or buffer unattractive views into the site.
- Use plants to prohibit pedestrian access to pools or slopes that may be unsafe.
- Keep maintenance area open to allow future access for pond maintenance.
- Provide a planting surface that can withstand the compaction of vehicles using maintenance access roads.
- Make sure the facility maintenance agreement includes a maintenance requirement of designated plant material.
- Provide signage for:
  - Storm water management facilities to help educate the public
  - Wildflower areas to designate limits of mowing
  - Preserving existing natural vegetation

The sections below describe the landscaping process in detail based upon site considerations, the plant selection process, and the type of storm water facility.

3.1 SITE CONSIDERATIONS

A development site's characteristics often will help to determine which plant materials and planting methods the site designer should select and will help improve plant establishment.

Primary site considerations include:

1. Soil Characteristics
2. Drainage
3. Slope
4. Orientation

3.1.1 Soil Characteristics

Plant establishment and growth can be limited by a number of different soil characteristics including:

- Soil texture
- pH - whether acid, neutral, or alkali (base)
- Nutrient levels - nitrogen, phosphorus, potassium
- Minerals - such as chelated iron, lime
- Salinity
- Toxicity

Soils are made up of four basic ingredients: mineral elements, pore space, organic matter and other items consisting mainly of living organisms including fungi, bacteria, and nematodes. One classification of soils is based upon the mineral part of soil and consists of four sizes of particles. Clay particles are the smallest, followed by silt, sand, and gravel. The USDA has devised another system of classifying soil particles. In this system soil is divided into seven categories: clay, silt, and five sizes of sand.

Soil texture is determined by the percentage of sand, silt, and clay in the soil. The structure of a soil is influenced by soil texture and also by the aggregation of small soil particles into larger particles. The amount of aggregation in a soil is strongly influenced by the amount of organic matter present.

Soil samples should be analyzed by experienced and qualified individuals who can explain the results and provide information on any soil amendments that are required. Soil fertility can often be corrected by applying fertilizer or by increasing the level of organic matter in the soil. Soil pH can be corrected with applications of lime. Where poor soils can't be amended, seed mixes and plant material must be selected to establish ground cover as quickly as possible.

Areas that have recently been involved in construction can become compacted so that plant roots cannot penetrate the soil. Seeds lying on the surface of compacted soils can be washed away or be eaten by birds. Soils should be loosened to a minimum depth of two inches, preferably to a four-inch depth. Hard soils may require discing to a deeper depth. Loosening soils will improve seed contact with the soil, provide greater germination rates, and allow the roots to penetrate into the soil. If the area is to be sodded, discing will allow the roots to penetrate into the soil.

Whenever possible, topsoil should be spread to a depth of four inches (two inch minimum) over the entire area to be planted. This provides organic matter and important nutrients for the plant material. This also allows the stabilizing materials to become established faster, while the roots are able to penetrate deeper and stabilize the soil, making it less likely that the plants will wash out during a heavy storm. If topsoil has been stockpiled in deep mounds for a long period of time, it is desirable to test the soil for pH as well as microbial activity. If the microbial activity has been destroyed, it may be necessary to inoculate the soil after application.

3.1.2 Drainage

Soil moisture and drainage have a direct bearing on the plant species and communities that can be supported on a site. Factors such as soil texture, topography, groundwater levels and climatic patterns all influence soil drainage and the amount of water in the soil. Identifying the topography and drainage of the site will help determine potential moisture gradients. The following categories can be used to describe the drainage properties of soils on a site:

Flooded - Areas where standing water is present most of the growing season.
Wet - Areas where standing water is present most of the growing season, except during times of drought. Wet areas are found at the edges of ponds, rivers, streams, ditches, and low spots. Wet conditions exist on poorly drained soils, often with a high clay content.
Moist - Areas where the soil is damp. Occasionally, the soil is saturated and drains slowly. These areas usually are at slightly higher elevations than wet sites. Moist conditions may exist in sheltered areas protected from sun and wind.
Well-drained - Areas where rain water drains readily, and puddles do not last long. Moisture is available to plants most of the growing season. Soils usually are medium textures with enough sand and silt particles to allow water to drain through the soil.
Dry - Areas where water drains rapidly through the soil. Soils are usually coarse, sandy, rocky or shallow. Slopes are often steep and exposed to sun and wind. Water runs off quickly and does not remain in the soil.

3.1.3 Slope

The degree of slope can also limit the site's suitability for certain types of plants. Plant establishment and growth requires stable substrates for anchoring root systems and preserving propagules such as seeds and plant fragments, and slope is a primary factor in determining substrate stability. Establishing plants directly on or below eroding slopes is not possible for most species. In such instances, plant species capable of rapid spread and anchoring soils should be selected or bioengineering techniques should be used to aid the establishment of a plant cover.

In addition, soils on steep slopes generally drain more rapidly than those on gradual slopes. This means that the soils may remain saturated longer on gradual slopes. If soils on gradual slopes are classified as poorly drained, care should be taken that plant species are selected that are tolerant of saturation.

Site topography also affects maintenance of plant species diversity. Small irregularities in the ground surface (e.g., depressions, etc.) are common in natural systems. More species are found in areas with many micro-topographic features than in areas without such features. Raised sites are particularly important in wetlands because they allow plants that would otherwise die while flooded to escape inundation.

In wetland plant establishment, ground surface slope interacts with the site hydrology to determine water depths for specific areas within the site. Depth and duration of inundation are principal factors in the zonation of wetland plant species. A given change in water levels will expose a relatively small area on a steep slope in comparison with a much larger area exposed on a gradual or flat slope. Narrow planting zones will be delineated on steep slopes for species tolerant of specific hydrologic conditions, whereas gradual slopes enable the use of wider planting zones.

3.1.4 Orientation

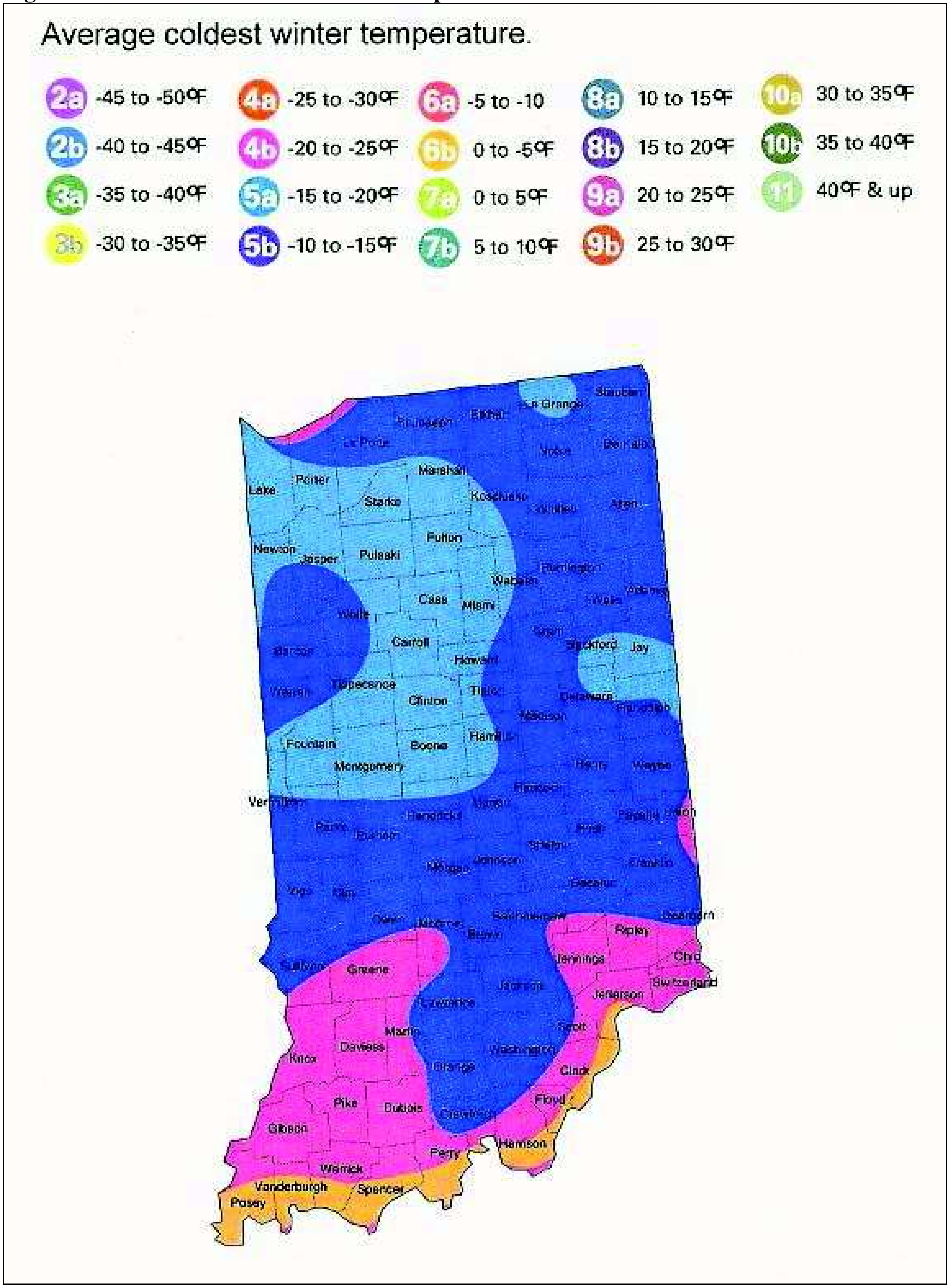
Slope exposure should be considered for its effect on plants. A southern-facing slope receives more sun and is warmer and drier, while the opposite is true of a northern slope. Eastern- and western-facing slopes are intermediate, receiving morning and afternoon sun, respectively. Western-facing slopes tending to receive more wind.

3.2 PLANT SELECTION PROCESS

3.2.1 Plant Hardiness Map

Hardiness zones are based on historical annual minimum temperatures recorded in an area. The 1990 USDA Plant Hardiness Zones divide the United States and southern Canada into 11 areas based on a 10 degree Fahrenheit difference in the average annual minimum temperature. A site's location in relation to plant hardiness zones is important to consider first because plants differ in their ability to withstand very cold winters. It is best to recommend plants known to thrive in specific hardiness zones. It should be noted, however, that certain site factors can create microclimates or environmental conditions which permit the growth of plants not listed as hardy for that zone. By investigating numerous references and based on personal experience, a designer should be able to confidently recommend plants that will survive in microclimates. Porter County contains Zones 5a, 5b, 6a. It appears as if the City of Portage is contained within 5b and 6a.

Figure 3.2.1-1 USDA Plant Hardiness Map for Indiana



3.2.2 Other Considerations

3.2.2.1 Use or Function

In selecting plants, consideration must be given to their desired function in the storm water management facility. For instance, it needs to be determined if the plant is needed as a ground cover, soil stabilizer, biofilter or source of shade; if the plant will be placed for functional or aesthetic purposes; if the adjacent use provides conflict or potential problems and requires a barrier, screen, or buffer.

3.2.2.2 Plant Characteristics

The size and shape of the plant must be considered to determine how the plant will work today and in the future. For example, tree limbs, after several years, can grow into power lines. A wide growing shrub may block maintenance access to a storm water facility.

Other plant characteristics must be considered to determine how the plant grows and functions seasonally, and whether the plant will meet the needs of the facility today and in the future. Some of these characteristics are:

- Growth Rate
- Regeneration Capacity
- Maintenance Requirements (e.g. mowing, harvesting, leaf collection, etc.)
- Aesthetics

In urban or suburban settings, a plant's aesthetic interest may be of greater importance. Residents living next to a storm water system may desire that the facility be appealing or interesting to look at throughout the year. Aesthetics is an important factor to consider in the design of these systems. Failure to consider the aesthetic appeal of a facility to the surrounding residents may result in reduced value to nearby lots. Careful attention to the design and planting of a facility can result in maintained or increased values of a property.

3.2.2.3 Availability and Cost

Often overlooked in plant selection is the availability from wholesalers and the cost of the plant material. Plants that are listed in landscape books may not be readily available from the nurseries. Without knowledge of what is available, time spent researching and finding the one plant that meets all the needs will be wasted, if it is not available from the growers. It may require shipping, therefore, making it more costly than the budget may allow. Some planting requirements, however, may require a special effort to find the specific plant that fulfills the needs of the site and the function of the plant in the landscape.

3.2.2.4 Native versus Nonnative Species

This Manual encourages the use of native plants in storm water management facilities, since they are best suited to thrive under the physiographic and hardiness conditions encountered at a site. Unfortunately, not all native plants provide the desired landscape or appearance, and may not always be available in quantity from local nurseries. Therefore, naturalized plants that are not native species, but can thrive and reproduce in the new area may be a useful alternative.

Because all landscaping needs may not be met by native or naturalized plants, some ornamental and exotic species are provided in this guide that can survive under difficult conditions encountered in a storm water management facility. Since many storm water facilities are adjacent to residential areas, the objectives of the storm water planting plan may shift to resemble the more controlled appearance of nearby yards, or to provide a pleasing view. Great care should be taken; however, when introducing plant species so as not to create a situation where they may become invasive and take over adjacent natural plant communities.

3.2.2.5 Moisture Status

In landscaping storm water management facilities, hydrology plays a large role in determining which species will survive in a given location. For areas that are to be planted within a storm water management facility it is necessary to determine what type of hydrologic zones will be created within the facility.

The six zones shown in Table 3.3.1-1 in the next section describe the different conditions encountered in storm water management facilities. Every facility does not necessarily reflect all of these zones. The hydrologic zones designate the degree of tolerance the plant exhibits to differing degrees of inundation by water. Each zone has its own set of plant selection criteria based on the hydrology of the zone, the storm water functions required of the plant and the desired landscape effect.

3.3 FACILITY SPECIFIC LANDSCAPING CRITERIA

3.3.1 Storm Water Ponds

Storm water ponds are engineered basins designed to control and treat storm water runoff. Aquatic vegetation plays an important role in pollutant removal in storm water ponds. In addition, vegetation can enhance the appearance of a pond, stabilize side slopes, serve as wildlife habitat, and can temporarily conceal unsightly trash and debris. Wetland plants should be encouraged in a pond design, along the aquatic bench, the safety bench and side slopes (ED ponds), and within shallow areas of the pool itself. The best elevations for establishing wetland plants, either through transplantation or volunteer colonization, are within 6 inches of the normal pool elevation.

A couple items to consider are as follows:

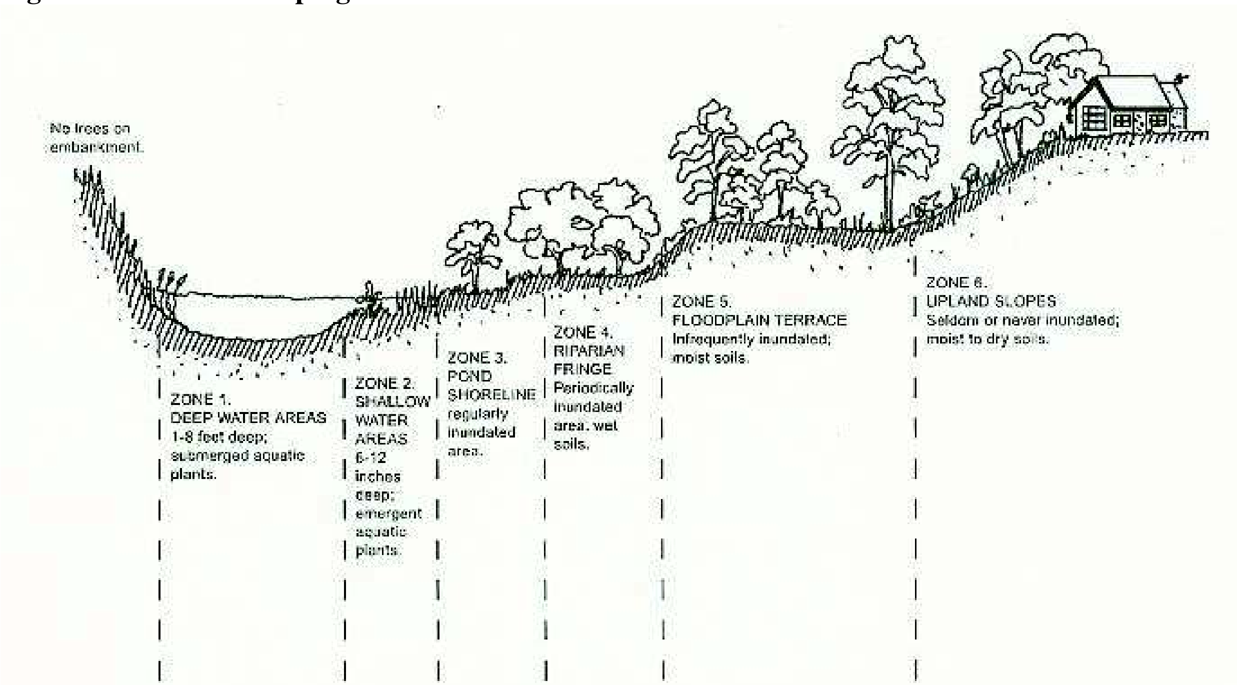
1. Woody vegetation may not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
2. A pond buffer should be provided that extends 25 feet outward from the maximum water surface elevation of the pond.
3. Existing trees should be preserved in the buffer area during construction. It is desirable to locate forest conservation areas adjacent to ponds. To discourage resident geese populations, the buffer can be planted with trees, shrubs, and native ground covers.
4. 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. It is advisable to excavate large and deep holes around the proposed planting sites and backfill these with uncompacted topsoil.

Within a storm water pond, there are various hydrologic zones as shown in Table 3.3.1-1 and Figure 3.3.1-1 that must be considered in plant selection. These hydrologic zones designate the degree of tolerance a plant must have to differing degrees of inundation by water. Hydrologic conditions in an area may fluctuate in unpredictable ways; thus the use of plants capable of tolerating wide varieties of hydrologic conditions greatly increases the successful establishment of a planting. Plants suited for specific hydrologic conditions may perish when those conditions change, exposing the soil, and therefore, increasing the chance for erosion. Each of the hydrologic zones is described in more detail below along with examples of appropriate plant species.

Table 3.3.1-1 Hydrologic Zones

Zone	Zone Description	Hydrologic Conditions
Zone 1	Deep Water Pool	1-6 feet depth (permanent pool)
Zone 2	Shallow Water Bench	Normal pool elevation to 1 foot depth
Zone 3	Shoreline Fringe	Regularly inundated
Zone 4	Riparian Fringe	Periodically inundated
Zone 5	Floodplain Terrace	Infrequently inundated
Zone 6	Upland Slopes	Seldom or never inundated

Figure 3.3.1-1 Landscaping Zones for Storm water Ponds



3.3.1.1 Zone 1: Deep Water Area *(1- 6 Feet)*

Ponds have deep pool areas that comprise Zone 1. These pools range from one to six feet in depth, and are best colonized by submergent plants, if at all. This pondscaping zone is *not* routinely planted for several reasons. First, the availability of plant materials that can survive and grow in this zone is limited, and it is also feared that plants could clog the storm water facility outlet structure. In many cases, these plants will gradually become established through natural recolonization (e.g., transport of plant fragments from other ponds via the feet and legs of waterfowl). If submerged plant material is commercially available and clogging concerns are addressed, this area can be planted. The function of the planting is to reduce resedimentation and improve oxidation while creating a greater aquatic habitat.

- Plant material must be able to withstand constant inundation of water of one foot or greater in depth.
- Plants may be submerged partially or entirely.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, desirable insects, and other aquatic life.

Some suggested emergent or submergent species include, but are not limited to: Water Lily, Common Pondweed, Lotus, and Pickerel Weed.

3.3.1.2 Zone 2: Shallow Water Bench *(Normal Pool To 1 Foot)*

Zone 2 includes all areas that are inundated below the normal pool to a depth of one foot, and is the primary area where emergent plants will grow in storm water wetlands. Zone 2 also coincides with the aquatic bench found in storm water ponds. This zone offers ideal conditions for the growth of many emergent wetland species. These areas may be located at the edge of the pond or on low mounds of earth located below the surface of the water within the pond. When planted, Zone 2 can be an important habitat for many aquatic and nonaquatic animals, creating a diverse food chain. This food chain includes predators, allowing a natural regulation of mosquito populations, thereby reducing the need for insecticidal applications.

- Plant material must be able to withstand constant inundation of water to depths between six inches and one foot deep.
- Plants will be partially submerged.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, desirable insects and other aquatic life.

Plants will stabilize the bottom of the pond, as well as the edge of the pond, absorbing wave impacts and reducing erosion, when water level fluctuates. In addition to slowing water velocities and increasing sediment deposition rates, plants can also reduce resuspension of sediments caused by the wind. Plants can also soften the engineered contours of the pond, and can conceal drawdowns during dry weather.

Common emergent wetland plant species used on the aquatic benches of storm water ponds include, but are not limited to: Arrowhead, various Sedges, Hard-stemmed Bulrush, Great Bulrush, Dark Green Rush, Arrow Arum, Sweet Flag, Cattail, Blue-Flag Iris, Swamp Rose Mallow, and Water Willow.

3.3.1.3 Zone 3: Shoreline Fringe *(Regularly Inundated)*

Zone 3 encompasses the shoreline of a pond and extends vertically about one foot in elevation from the normal pool. This zone includes the safety bench of a pond, and may also be periodically inundated if storm events are subject to extended detention. This zone occurs in a wet pond or shallow marsh and can be the most difficult to establish since plants must be able to withstand inundation of water during storms, when wind might blow water into the area, or the occasional drought during the summer. In order to stabilize the soil in this zone, Zone 3 must have a vigorous cover.

- Plants should stabilize the shoreline to minimize erosion caused by wave and wind action or water fluctuation.
- Plant material must be able to withstand occasional inundation of water. Plants will be partially submerged partially at this time.
- Plant material should, whenever possible, shade the shoreline, especially the southern exposure. This will help to reduce the water temperature.
- Plants should be able to enhance pollutant uptake.
- Plants may provide food and cover for waterfowl, songbirds, and wildlife. Plants could also be selected and located to control overpopulation of waterfowl.
- Plants should be located to reduce human access, where there are potential hazards, but should not block the maintenance access.
- Plants should have very low maintenance requirements, since they may be difficult or impossible to reach.
- Plants should be resistant to disease and other problems which require chemical applications (since chemical application is not advised in storm water ponds).

Many of the emergent wetland plants that perform well in Zone 2 also thrive in Zone 3. Some other species that do well include Wild Rye, Common Rush, and Cardinal Flower. If shading is needed along the shoreline, the following tree species are suggested: Red Maples, Redbud, and Green Ash.

3.3.1.4 Zone 4: Riparian Fringe *(Periodically Inundated)*

Zone 4 extends from one to four feet in elevation above the normal pool. Plants in this zone are subject to periodic inundation after storms, and may experience saturated or partly saturated soil inundation. Nearly all of the temporary extended detention (ED) storage area is included within this zone.

- Plants must be able to withstand periodic inundation of water after storms, as well as occasional drought during the warm summer months.
- Plants should stabilize the ground from erosion caused by run-off.
- Plants should shade the low flow channel to reduce the pool warming whenever possible.
- Plants should be able to enhance pollutant uptake.
- Plant material should have very low maintenance, since they may be difficult or impossible to access.
- Plants may provide food and cover for waterfowl, songbirds and wildlife. Plants may also be selected and located to control overpopulation of waterfowl.
- Plants should be located to reduce pedestrian access to the deeper pools.

Some frequently used plant species in Zone 4 include Sedge, Ironweed, Joe-Pye Weed, and Black-eyed Susan.

3.3.1.5 Zone 5: Floodplain Terrace *(Infrequently Inundated)*

Zone 5 is periodically inundated by floodwaters that quickly recede in a day or less. Operationally, Zone 5 extends from the maximum two-year water surface elevation up to the 25 or 100-year maximum water surface elevation. Key landscaping objectives for Zone 5 are to stabilize the steep slopes characteristic of this zone, and establish a low maintenance, natural vegetation.

- Plant material should be able to withstand occasional but brief inundation during storms, although typical moisture conditions may be moist, slightly wet, or even swing entirely to drought conditions during the dry weather periods.
- Plants should stabilize the basin slopes from erosion.
- Ground cover should be very low maintenance, since they may be difficult to access on steep slopes or if the frequency of mowing is limited. A dense tree cover may help reduce maintenance and discourage resident geese.
- Plants may provide food and cover for waterfowl, songbirds, and wildlife.
- Placement of plant material in Zone 5 is often critical, as it often creates a visual focal point and provides structure and shade for a greater variety of plants.

Some commonly planted species in Zone 5 include many wildflowers or native grasses, many Fescues, many Viburnums, and Red Oak.

3.3.1.6 Zone 6: Upland Slopes *(Seldom or Never Inundated)*

The last zone extends above the maximum 100-year water surface elevation, and often includes the outer buffer of a pond. Unlike other zones, this upland area may have sidewalks, bike paths, retaining walls, and maintenance access roads. Care should be taken to locate plants so they will not overgrow these routes or create hiding places that might make the area unsafe.

- Most common plant material are capable of surviving the particular conditions of this area;thus, it is not necessary to select plant material that will tolerate any inundation. Rather, plant selections should be made based on soil condition, light, and function within the landscape.
- Ground covers should emphasize infrequent mowing to reduce the cost of maintaining this landscape.
- Placement of plants in Zone 6 is important since they are often used to create a visual focal point, frame a desirable view, screen undesirable views, serve as a buffer, or provide shade to allow a greater variety of plant materials. Particular attention should be paid to seasonal color and texture of these plantings.

Some frequently used plant species in Zone 6 include most ornamentals as long as soils drain well and many wildflowers or native grasses.

Table 3.3.1-2 provides a list of selected wetland plants for storm water ponds for hydrologic zones 1-4.

Table 3.3.1-2 Wetland Plants (Herbaceous Species) for Storm Water Facilities

Scientific Name	Common Name	Hydrologic Zone
Acorus calumus	Sweet Flag	2
Andropogon virginicus	Broom Sedge	4
Carex spp.	Caric Sedges	2
Elymus canadensis	Canada Wild Rye	3
Eupatorium fistulosum	Joe-Pye Weed	4
Hibiscus palustris	Swamp Rose Mallow	2
Iris virginica shrevei	Blue Flag Iris	2
Juncus effusus	Common Rush	3
Justicia americana	Water Willow	2
Lobelia cardinalis	Cardinal Flower	3
Nelumbo lutea	Lotus	1
Nymphaea odorata	Fragrant Water Lily	1
Peltandra virginica	Arrow Arum	2
Polygonum hydropiperoides	Smartweed	2
Pontederia cordata	Pickerel Weed	1
Potamogeton natans	Common Pondweed	1
Rudbeckia hirta	Black-eyed Susan	4
Sagittaria latifolia	Common Arrowhead	2
Scirpus acutus	Hard-stemmed Bulrush	2
Scirpus atrovirens	Dark Green Rush	2
Scirpus validus creber	Great Bulrush	2
Typha spp.	Cattail	2
Vernonia spp.	Ironweed	4

3.3.2 Bioretention Areas

Bioretention areas are structural storm water controls that capture treat runoff using soils and vegetation in shallow basins or landscaped areas. Landscaping is therefore critical to the performance and function of these facilities. Below are guidelines for soil characteristics, mulching, and plant selection for bioretention areas.

3.3.2.1 Planting Soil Bed Characteristics

The characteristics of the soil for the bioretention facility are perhaps as important as the facility location and size. The soil must be permeable enough to allow runoff to filter through the media, while having characteristics suitable to promote and sustain a robust vegetative cover crop. In addition, much of the nutrient pollutant uptake (nitrogen and phosphorus) is accomplished through adsorption and microbial activity within the soil profile. Therefore, the soils must balance soil chemistry and physical properties to support biotic communities above and below ground.

The planting soil should contain a minimum 35% to 60% sand, by volume. The clay content for these soils should be less than 25% by volume. A permeability of at least 1.0 foot per day or 0.5 inch per hour is required with a conservative value of 0.5 feet per day used for design. The soil should be free of stones, stumps, roots, or other woody material over 1-inch in diameter. Placement of the planting soil should be in lifts of 12 to 18 inches, loosely compacted.

3.3.2.2 Mulch Layer

The mulch layer plays an important role in the performance of the bioretention system. The mulch layer helps maintain soil moisture and avoids surface sealing which reduces permeability. Mulch helps prevent erosion, and provides a micro-environment suitable for soil biota at the mulch/soil interface. It also serves as a pretreatment layer, trapping the finer sediments which remain suspended after the primary pretreatment. The mulch layer should be standard landscape style, single or double, shredded hardwood mulch or chips. The mulch layer should be stockpiled or stored for at least 12 months, uniform in color, and free of other materials, such as weed seeds, soil, roots, etc. The mulch should be applied to a maximum depth of three inches. Grass clippings should not be used as a mulch material.

3.3.2.3 Planting Plan Guidance

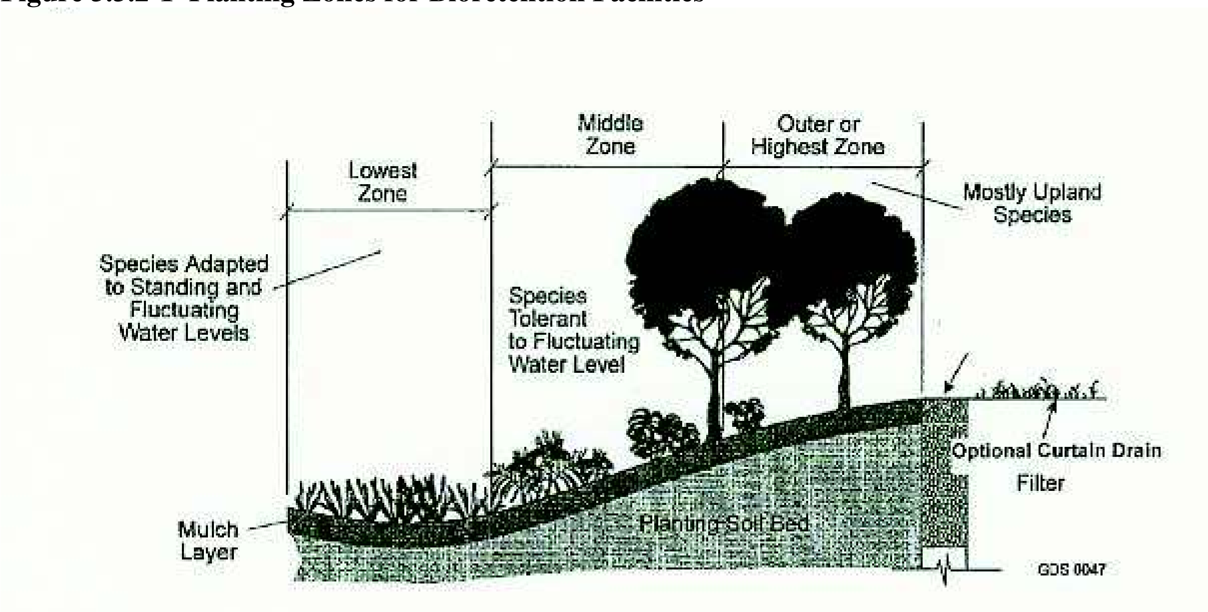
Plant material selection should be based on the goal of simulating a terrestrial forested community of native species. Bioretention simulates an ecosystem consisting of an upland-oriented community dominated by trees, but having a distinct community, or sub-canopy, of understory trees, shrubs and herbaceous materials. The intent is to establish a diverse, dense plant cover to treat storm water 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: (1) lowest zone, (2) middle zone, and (3) outer or highest zone (Figure 3.3.2-1). 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. A sample of appropriate plant materials for bioretention facilities is included in Table 3.3.2-1.

Table 3.3.2-1 Commonly Used Species for Bioretention Areas

Trees	Shrubs	Herbaceous Species
Acer rubrum Red Maple	*Aesculus pariviflora* Bottlebrush Buckeye	*Andropogon virginicus* Broom Sedge
Platanus occidentalis Sycamore	*Lindera benzoin* Spicebush	*Eupatorium maculatum* Spotted Joe-Pye Weed
Quercus palustris Pin Oak	*Virburnum lentago* Nannyberry	*Lobelia cardinalis* Cardinal Flower
		Panicum virgatum Switch Grass
		Rudbeckia laciniata Wild Golden Glow
		Scirpus cyperinus Wool Grass

Figure 3.3.2-1 Planting Zones for Bioretention Facilities



The layout of plant material should be flexible, but should follow the general principals described below. The objective is to have a system that resembles a random and natural plant layout, while maintaining optimal conditions for plant establishment and growth.

- Native plant species should be specified over exotic or foreign species.
- Appropriate vegetation should be selected based on the zone of hydric tolerance
- Species layout should generally be random and natural.
- The tree-to-shrub ratio should be 2:1 to 3:1. On average, the trees should be spaced 8 feet apart.
- Plants should be placed at regular intervals to replicate a natural forest.
- Woody vegetation should not be specified at inflow locations.
- A canopy should be established with an understory of shrubs and herbaceous materials.
- Woody vegetation should not be specified in the vicinity of inflow locations.
- Trees should be planted primarily along the perimeter of the bioretention area.
- Urban stressors (e.g., wind, sun, exposure, insect and disease infestation, drought) should be considered when laying out the planting plan.
- Noxious weeds should not be specified.
- Aesthetics and visual characteristics should be a prime consideration.
- Traffic and safety issues must be considered.
- Existing and proposed utilities must be identified and considered.

Planting specifications should be prepared by the designer and should include a sequence for construction, a description of the contractor's responsibilities, a planting schedule and installation specifications, initial maintenance, and a warranty period and expectations of plant survival.

Table 3.3.2-2 presents some typical issues for planting specifications.

Table 3.3.2-2 Planting Plan Specification Issues for Bioretention Areas

Specification Element	Elements
Sequence of Construction	Describe site preparation activities, soil amendments, etc.; address erosion and sediment control procedures; specify step-by-step procedure for plant installation.
Contractor's Responsibilities	Specify the contractors responsibilities, such as watering, care of plant material during transport, timeliness of installation, repairs due to vandalism, etc.
Planting Schedule And Specifications	Specify the materials to be installed, the type of materials (e.g., B&B, bare root, containerized); time of year of installations, sequence of installation of types of plants; fertilization, stabilization seeding, if required; watering and general care.
Maintenance	Specify inspection periods; mulching frequency; removal and replacement of dead and diseased vegetation; treatment of diseased trees; watering schedule after initial installation (once per day for 14 days is common); repair and replacement of staking and wires.
Warranty	Specify warranty period, the required survival rate, and expected condition of plant species at the end of the warranty.

3.3.3 Enhanced Swales, Grass Channels, and Filter Strips

Table 3.3.3-1 provides a number of grass, wildflower, and sedge species that perform well in the stressful environment of an open channel structural control such as an enhanced swale or grass channel, or for grass filter strips.

Table 3.3.3-1 Common Species for Swales and/or Grass Channels

Scientific Name	Common Name
Agrostis alba	Redtop
Andropogon gerardii	Big Bluestem Grass
Carex hystericina	Porcupine Sedge
Lobelia caradinalis	Cardinal Flower
Panicum virgatum	Switch Grass
Sagittaria latifolia	Common Arrowhead
Scirpus cyperinus	Wool Grass

Where possible one or more of the grasses should be included in the seed mix. Typical maintenance will include mowing to maintain a height of 4 to 6 inches, occasional spot reseeding, and weed control.

APPENDIX – DESIGN EXAMPLES

Design Example #1: Wet Extended Detention Pond

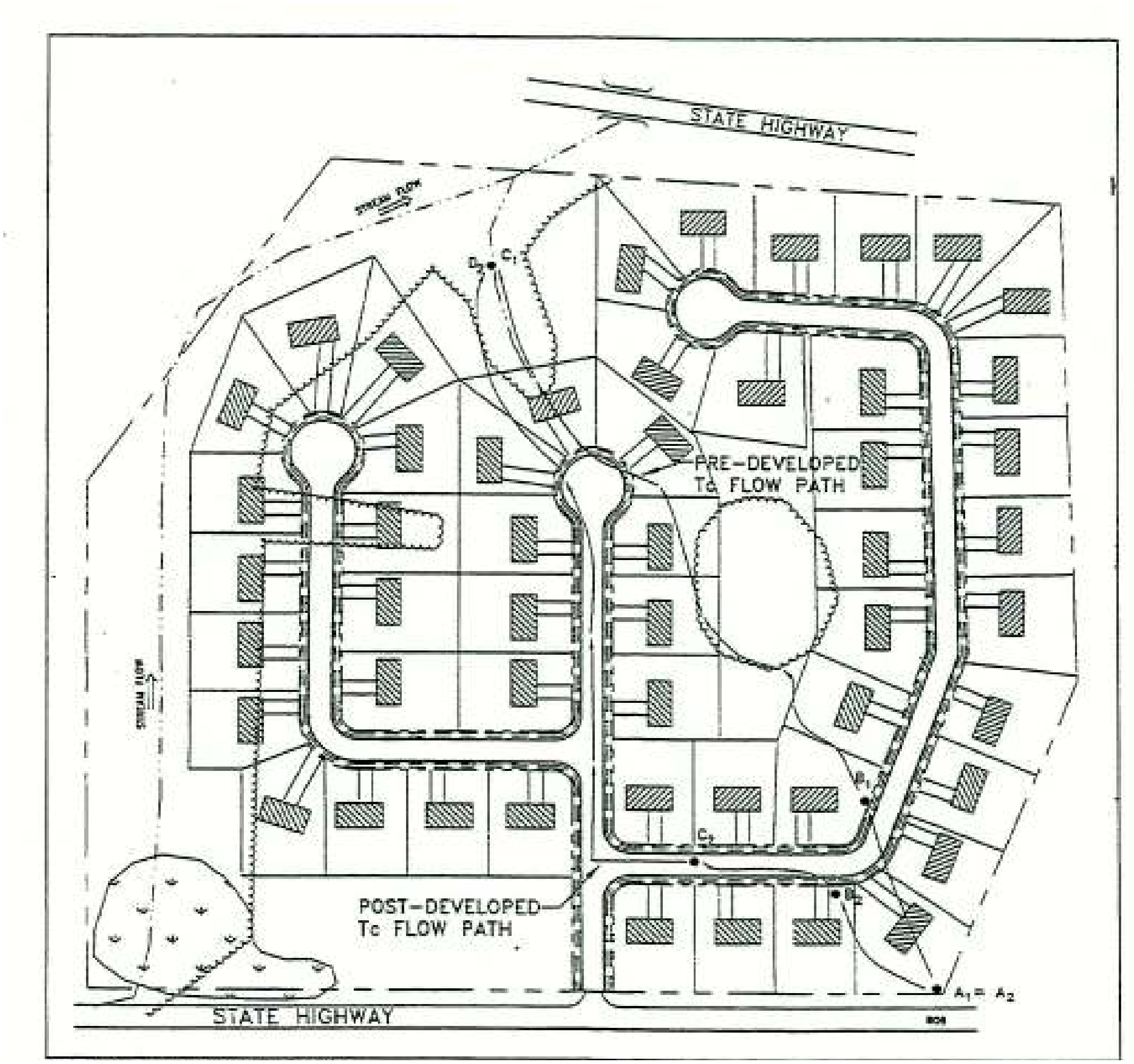


Figure A-1 Site Layout for Wet Extended Detention Pond Design Example

This example is not intended to show all required calculations necessary for the development of a wet extended detention pond; however, it is intended to show the basic calculations necessary for the computation of water quality components.

Base Data		**Hydrologic Data**	
Location: Portage, IN		Pre	Post
Site Area = Total Drainage Area (A) = 38.0 ac	CN	65	78
Measured Impervious Area = 13.8 ac;	t_c	.32 hr	.17 hr

I = 13.8/38 = 36.3%
Soils Types: 60% "B", 40% "A"
Zoning: Residential (1/2 acre lots)

Compute Storm Water Volumes and Peak Discharges

Step 1: Compute the WQ_v
Runoff coefficient $R_v = 0.05 + 0.009(I)$
$0.05 + (0.009)(36.3) = 0.38$

$$WQ_v = \frac{(P)(R_v)(A)}{12}$$

$(1)(0.38)(38)/12 = 1.2$ ac-ft

Step 2: Compute Peak Discharges and Required Detention Volume (This Example Utilizes TR-55)

Detention Requirements:
Q_{100} post-development outflow = Q_{10} pre-development outflow

Q_{10} pre-development flow rate = 41 cfs (per TR-55)
Q_{100} post-development flow rate = 243 cfs (per TR-55)

Required 100-Year detention volume (6.92 ac-ft)

Step 3: Determine Feasibility of an Extended Detention Wet Pond.

The total drainage to the pond is 38 acres. Soil borings found that the seasonably high water table is 1 foot below the depth of the pond and the soils are sandy/loamy. The wet pond will require a liner.

Step 4: Determine pretreatment volume for the sediment forebay

Size forebay to contain 0.1 inches of runoff per impervious acre. Forebay volume will be included in WQ_v as part of the permanent pool volume.
(13.8 ac)(0.1 inch)(1' / 12 inches) = 0.12 ac-ft

Step 5: Determine permanent pool volume and water quality extended detention volume (ED).

Size permanent pool volume to contain 50% of WQ_v.
(0.5)(1.2 ac-ft) = 0.6 ac-ft (includes 0.12 ac-ft of storage in forebay)

Design ED volume to contain 50% of the WQ_v = 0.6 ac-ft

Step 6: Determine pond location and preliminary geometry.

This step involves establishing contours and determining the stage-storage relationships for the pond. Storage must be provided for the permanent pool and to meet the detention requirements.

Elevation	Average Area, ft^2	Depth, ft	Volume, ft^3	Cumulative Volume, ft^3	Cumulative Volume, ac-ft	Volume Above Permanent Pool, ac-ft
620.0						
621.0	7838	1	7838	7838	0.18	
623.0	11450	2	22900	30738	0.71	
624.0	14538	1	14538	45275	1.04	0
625.0	15075	1	15075	60350	1.39	0.035
625.5	16655	0.5	8328	68678	1.58	0.54
626.0	17118	0.5	8559	77236	1.77	0.73
626.5	21000	0.5	10500	87736	2.01	0.97
627.0	25000	0.5	12500	100236	2.30	1.26
627.5	30000	0.5	15000	115236	2.65	1.61
628.0	36000	0.5	18000	133236	30.6	2.02
628.5	38000	0.5	19000	152236	3.49	2.46
629.0	41000	0.5	20500	172736	3.97	2.93
629.5	43000	0.5	21500	194236	4.46	3.42
630.0	45000	0.5	22500	216736	4.98	3.94
630.5	47000	0.5	26500	240236	5.52	4.48
631.0	49000	0.5	24500	264736	6.08	5.04
631.5	52000	0.5	26000	290736	6.67	5.64
632.0	55000	0.5	27500	318236	7.31	6.27
632.5	58000	0.5	29000	347236	7.97	6.93
633.0	61000	0.5	30500	377736	8.67	7.63
633.5	65000	0.5	32500	410236	9.42	8.38
634.0	69000	0.5	34500	444736	10.21	9.17

Set pond basics.

- Pond bottom elevation = 620
- Set barrel outlet at 619

Set water surface and other elevations.

- Required permanent pool volume 50% WQ_v = 0.6 ac-ft. At elevation 624, the storage provided is 1.04 ac-ft, which is adequate for the WQ_v
- Forebay volume in 2 pools with average volume = 0.08 ac-ft, exceeding the required 0.12 ac-ft
- Required extended detention volume (WQ_v-ED) = 0.6 ac-ft. Elevation 626 provided 0.73 ac-ft of storage, exceeding the required storage. Set ED water surface elevation =

626. Note that the total storage provided at elevation 626 = 1.77 ac-ft, exceeding the required WQ_v of 1.2 ac-ft.

Calculate the required WQ_v-ED orifice diameter to release 0.6 ac-ft over 24 hours.

- Average release rate = (0.6 ac-ft)(43,560 ft^2/acre) / (24 hrs)(3600 sec/hr) = 0.30cfs
- Average head = (626-624) / 2 = 1'
- Use orifice equation to compute cross sectional area and diameter
  - $Q=CA(2gh)^{0.5}$ for Q = 0.30 cfs, h = 1.0 ft., C = 0.6 = discharge coefficient
  - A = 0.06 ft^2; $A = \pi d^2 / 4$; diameter = 0.27 ft or 3.3"

Calculate outlet hydraulics

- At elevation 632.5, detention basin provides required 6.92 acre-feet of storage
- Try setting outlet pipe with 25.5 inch diameter orifice at elevation 626.0
  - H = 632.5 – (626 + ½(2 ft dia)) = 5.5 feet
  - $A = \pi d^2 / 4 = 3.55\ ft^2$
  - $Q=CA(2gh)^{0.5} = 0.6(3.55)(2 \times 32.2 \times 5.5)^{0.5}$ = 40.1 cfs (from control structure)
- Now, compute flow from WQ_v-ED orifice with water surface elevation at 632.5
  - H = 632.5 – 626.0 = 6.5 feet
  - $Q=CA(2gh)^{0.5} = 0.6(0.06)(2 \times 32.2 \times 6.5)^{0.5}$ = 0.7 cfs
- Note the sum of the flow from each orifice is less than the allowable release rate of 41 cfs.

Design Example #2: Bioretention

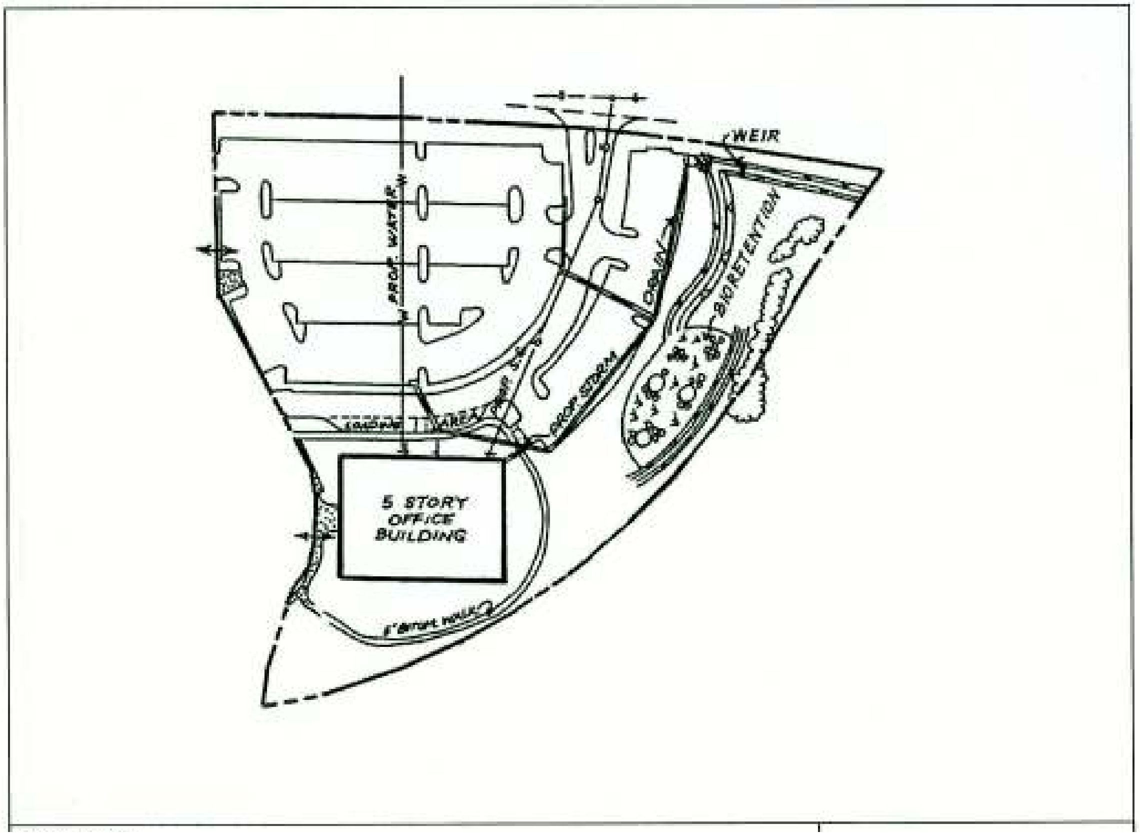


Figure A-2 Site Layout for Bioretention Design Example

Base Data

Location: Portage, IN
Site Area = Total Drainage Area (A) = 4.5 acre
Impervious Area = 3.05 acre; or I = 3.05/4.50 = 68%
R_v = 0.05 + (68)(0.009) = 0.66
Soils Type "B"

Hydrologic Data

	Pre	Post
CN	58	83
t_c	.44	.10

This design example focuses on the design of a bioretention area for a 4.5 acre watershed of a commercial site. A five-story office building and associated parking are proposed within this watershed. The watershed has 3.05 acres of impervious cover, resulting in 68% impervious cover. The pre-developed site is a mixture of forest and meadow. On-site soils are predominately HSG "B" soils.

This example focuses on the design of a bioretention area to meet the water quality treatment requirements of the site. Channel protection and overbank flood control is not addressed in this example other than quantification of preliminary storage volume and peak discharge requirements. It is assumed that the designer can refer to the previous wet extended detention pond example in order to extrapolate the necessary information to determine and design the required storage and outlet structures to meet these criteria. In general, the primary function of bioretention areas is to provide water quality treatment and groundwater recharge and not large storm attenuation. As such, flow in excess of the water quality volume are typically routed to bypass the facility. Where quantity control is required, the bypassed flows can be routed to conventional detention basins (or some other facility such as underground storage vaults) that are designed to meet detention requirements.

Computation of Preliminary Storm Water Storage Volumes and Peak Discharges

The layout of the site is shown in Figure A-2.

Step 1: Compute Water Quality Volume, WQ_v

WQ_v = (1")(R_v)(A) / 12

= (1")(0.66)(4.5 acre)(43,560 ft^2/acre) (1 ft/12 inch)

= 10,781.1 ft^3

Step 2: Determine if the development site and conditions are appropriate for the use of a bioretention area.

Site Specific Data

Existing ground elevation at practice location is 621.0 feet, mean sea level. Soil boring observations reveal that the seasonally high water table is at 611.0 feet and underlying soil is loamy. Adjacent channel invert is at 613 feet. It appears as if the site is acceptable.

Step 3: Determine size of bioretention filter area

Darcy's Law: $A_f = (WQ_v)(d_f) / [(k)(h_f + d_f)(t_f)]$

Where:
- A_f = surface area of filter bed (ft^2)
- d_f = filter bed depth (ft)
- k = coefficient of permeability of filter media (ft/day)
- h_f = average height of water above filter bed (ft)
- t_f = design filter bed drain time (days) (2 days is recommended)

A_f = (10,781 ft^3)(5') / [(0.5'/day)(0.25' + 5') (2 days)] (With k = 0.5'day, h_f = 0.25', t_f = 2 days)

A_f = 10,267 ft^2

Step 4: Set design elevations and dimensions

Assume a roughly 2 to 1 rectangular shape. Given a filter area requirement of 10,267 ft^2, say facility is roughly 70' by 150'. Set top of facility at 619.0 feet, with the berm at 620.0 feet. The facility is 5' deep, which will allow 3' of separation distance over the seasonally high water table.

Step 5: Size overflow channel

Use a 4’ weir set 0.63’ above the base of the overflow channel. The overflow channel will flow to the adjacent drainage channel, while the water quality storm will be diverted to the bioretention cell.

Step 6: Design Pretreatment

Size pretreatment to treat ¼ of the WQv. Therefore, treat 10,781 ft^3 x 0.25 = 2,695 ft^3
Use a grass channel to provide pretreatment. The channel has a 4’ width, 2% slope and 3:1 side slopes. During the water quality event, water flows at 1.3 fps, and at a depth of 0.6’. Adjust the length to be 25% of the length required to accommodate the WQ_v for 10 minutes as follows:

L = (1.3 fps)(600 s)(0.25) = 195 feet

Step 7: Size underdrain area

As a rule of thumb, the length of underdrain should be based on 10% of the A_f or 1,027 sq ft and a three-foot wide zone of influence. Using 6” perforated plastic pipes surrounded by a three-foot wide gravel bed, 10’ on center, yields the following length of pipe:

(1,027 sq ft)/3’ per foot of underdrain = 342’ of perforated underdrain

Step 8: Create overdrain design

Size a square catch basin drop inlet to convey storms up to the peak discharge of the water quality event (4.6 cfs). Assume a 2’ square, which is equivalent to an 8’ weir. Rearrange the weir equation to calculate the depth of flow as follows:

$$H = [Q/(CL)]^{2/3}$$

Where,

Q = 4.6 cfs (flow)
C = 3.1
H = (depth of flow in feet)
L = Weir Length (feet)

Using this equation:

$$H = [4.6 \text{ cfs} / (3.1) / (8 \text{ ft})]^{2/3}$$
$$= 0.33 \text{ feet or } 4''$$

Allow for a 6” freeboard above the top of the catch basin. Therefore, set the elevation of the berm at 10” above the top of the catch basin.

Step 9: Choose plants for planting area

Choose plants based on factors such as whether native or not, resistance to drought and inundation, cost, aesthetics, maintenance, etc. Select species locations (i.e. on center planting distances) so species will not "shade out" one another. Do not plant trees and shrubs with extensive root systems (e.g. willows) near pipe work.

Design Example #3: Storm Water Swale

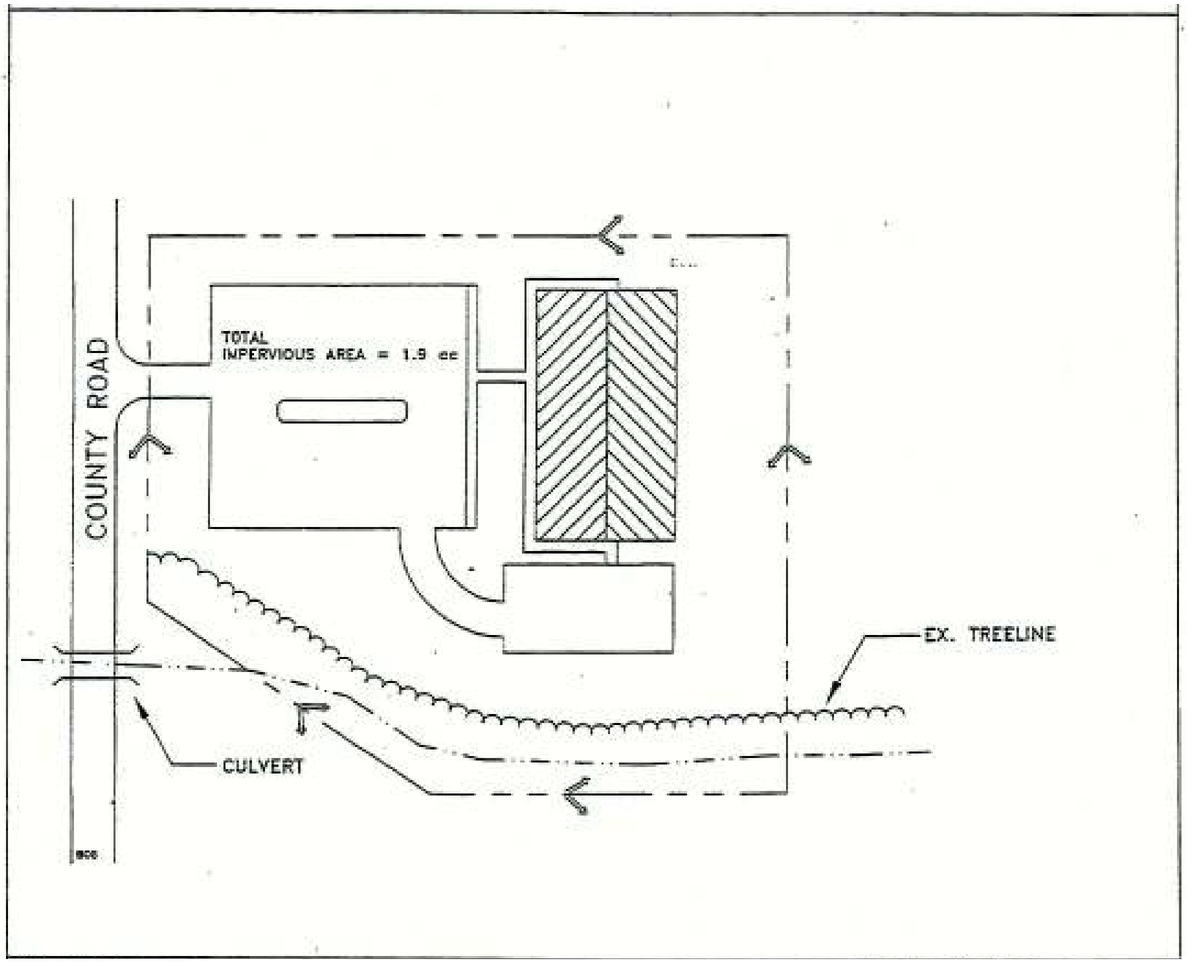


Figure A-3 Site Layout for Storm Water Swale Design Example

Base Data		**Hydrologic Data**	
Location: Portage, Indiana		Pre	Post
Site Area = Total Drainage Area (A) = 3.0 ac	CN	70	88
Impervious Area = 1.9 ac; or I = 1.9/3.0 = 63.3%	t_c	.39	.20
R_v = 0.05 + (63.3)(0.009) = 0.62			
Soils Type "B"			

This example focuses on the design of a dry swale to meet the water quality treatment requirements of the site. Channel protection and overbank flood control is not addressed in this example other than quantification of preliminary storage volume and peak discharge requirements. It is assumed that the designer can refer to the previous wet extended detention pond example in order to extrapolate the necessary information to determine and design the required storage and outlet structures to meet these criteria. In general, the primary function of dry swales is to provide water quality treatment and groundwater recharge and not large storm attenuation. As such, flow in excess of the water quality volume are typically routed to bypass the facility. Where quantity control is required, the bypassed flows can be routed to conventional detention basins (or some other facility such as underground storage vaults) that are designed to meet detention requirements.

Computation of Preliminary Storm Water Storage Volumes and Peak Discharges

The layout of the site is shown in Figure A-3.

Step 1: Compute Water Quality Volume, WQ_v

$$WQ_v = (1")(R_v)(A) / 12$$
$$= (1")(0.62)(3.0\text{ acre})(43{,}560\text{ ft}^2/\text{acre})\ (1\text{ ft}/12\text{ inch})$$
$$= 6751.8\text{ ft}^3$$

Step 2: Compute the design flow

NRCS TR-55 methodology was used to calculate the peak design flow discharge. The peak flow will later be routed through the channel to ensure channel capacity.

Per TR-55

Condition	**CN**	**Design Flow (cfs)**
Pre-developed	70	5
Post-developed	88	10

Step 3: Analyze for Safe Passage of the Design Flow:

At final design, prove that discharge conveyance channel is adequate to convey the design flow event and discharge to receiving waters.

Summary of General Design Information for Example

Step No.	**Category**	**Volume Required (cubic feet)**	**Notes**
1	Water Quality (WQ_v)	6,752	
2	Design Flow	N/A	Provide safe passage for the design flow event in final design while limiting peak discharges to less than 10 cfs

Site Specific Data:

Existing ground elevation at BMP location is 622.0 feet. Soil boring observations reveal that the seasonally high water table is at 613.0 feet and underlying soils are loamy. Adjacent creek invert is at 612.0 feet.

Step 4: Compute Pretreatment

Pretreatment shall be equal to 10% of the water quality volume. Size two shallow forebays at the head of the swales equal to 0.05" per impervious acre of drainage (each). (Note, total recommended pretreatment requirement is 0.1"/imp acre). (1.9 acre)(0.05")(1 ft/12")(43,560 ft^2/acre) = <u>344.9 ft^3</u>

Use a 2' deep pea gravel drain at the head of the swale to reduce velocities and to assist in the distribution of the inflow.

Step 5: Identify swale dimensions

Required: bottom width, depth, length, and slope necessary to store WQ_v with less than 18" of ponding (see Figure A-5 for representative site plan).

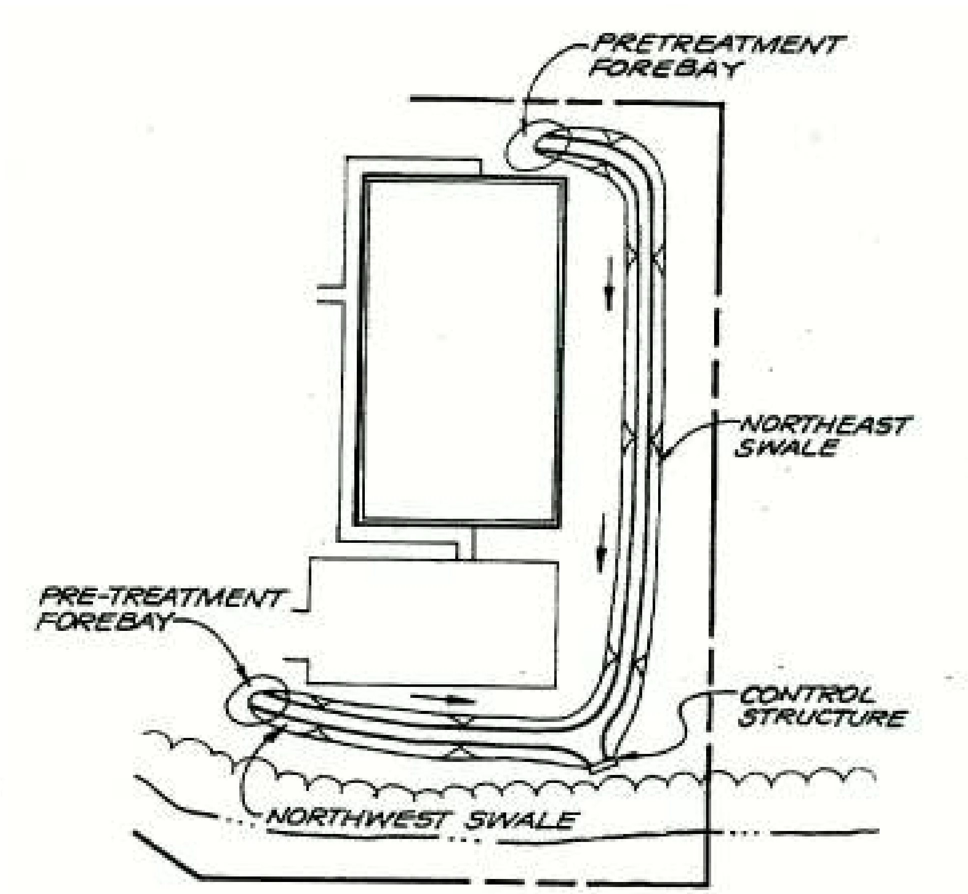


Figure A-4 Dry Swale Site Plan

Assume a trapezoidal channel with a maximum WQ_v depth of 18". Control for this swale will be shallow concrete wall with a low flow orifice, trash rack. Per the site plan in Figure A-4, we have about 1,100' of swale available, if the swale is put in with two tails. The outlet control will be set at the existing invert minus three feet (622.0 – 3.0 = 619.0). The existing uphill invert for the northwest fork is 624.0 (length of 500'), the invert for the northeast fork is 628.0 (at a length of 600').

Slope of northwest fork is (624 – 619)/500' = 0.01 or 1.0%
Slope of northeast fork is (628 – 619)/600' = 0.01 or 1.0%
Minimum slope is 1.0% [okay]

For a trapezoidal section with a bottom width of 6', a WQ_v average depth of 9", 3:1 side slopes, compute a cross sectional area of (6')(0.75')(2.25') = 6.2 ft^2

(6.2 ft^2)(1,100 ft) = 6820 ft^3 [> WQ_v of 6752 ft^3; okay]

Step 6: Compute number of check dams (or similar structure) required to detain WQ_v

For the northwest fork, 500 ft @ 1.0% slope, and maximum depth of 18", place checkdams at 1.5'/0.01 = 150'   <u>place at 150', 4 required</u>

For the northeast fork, 600 ft @ 1.0% slope, and maximum depth at 18", place checkdams at 1.5'/0.01 = 150'   <u>place at 150', 4 required</u>

Step 7: Calculate draw-down time

In order to ensure that the swale will draw down within 24 hours, the planting soil will need to pass a maximum rate of 1.5' in 24 hours (<u>k = 1.5' per day</u>). Provide 6" perforated underdrain pipe and gravel system below soil bed

Step 8: Check erosion potential and freeboard:

From TR-55 information, the design flow is 10 cfs, assume that 30% goes through northwestern swale (3 cfs) and 70% goes through the northeastern swale (7 cfs). Design for the larger amount (7 cfs). From separate computer analysis, with a slope of 1.0%, the design flow velocity will be 2.3 feet per second at a depth of 0.4 feet. The velocity is non-erosive.

Find the design flow overflow weir length required: (weir eq. $Q = CLH^{3/2}$), where C = 3.1, Q = 10 cfs, H = 1.2

Rearranging the equation yields:

$L = 10 \text{ cfs} / (3.1 \times 1.2^{1.5}) = 2.5'$ <u>Use 3 ft</u>

Step 9: Specify vegetation
Use tall fescue grass or other appropriate vegetation

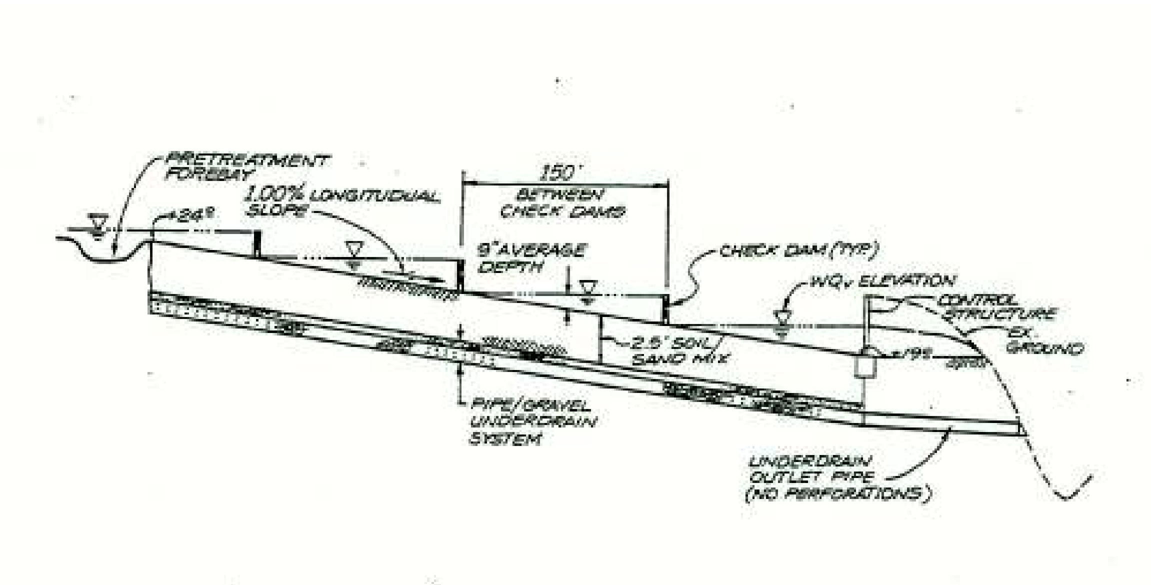


Figure A-5 Profile of Northwest Fork Dry Swale

Step 10: Design low flow orifice at headwall

Design orifice to pass 6,752 cubic feet in 6 hours.

6,752 cubic feet / [(6 hours)(3600 sec/hour)] = 0.3 cfs

use orifice equation: $Q = CA(2gh)^{1/2}$

assume h = 1.5'

$A = (0.3 \text{ cfs}) / [(0.6)\ ((2)\ (32.2 \text{ ft/sec}^2)\ (1.5'))^{1/2}]$

A = 0.05 sq ft, dia = 0.01 feet or >0.5" use 0.5" orifice

Provide 3" v-notch slot in each check dam to prevent erosion at structure's abutment.