APPENDIX F
WATER QUALITY STRUCTURAL CONTROLS

STORMWATER PONDS

Description: Constructed stormwater retention basin that has a permanent pool (or micropool). Runoff from each rain event is detained and treated in the pool primarily through settling and biological uptake mechanisms.

Advantages/Benefits:	Disadvantages/Limitations:
• Moderate to high removal rate of urban pollutants • High community acceptance • Opportunity for wildlife habitat	• Potential for thermal impacts/downstream warming • Dam height restrictions for areas with high relief terrain • Pond drainage can be a problematic for low relief terrain

Design Criteria:

- A sediment forebay or equivalent upstream pretreatment must be provided
- Minimum length to width ratio for the pond is 1.5:1
- Maximum depth of the permanent pool should not exceed 8 ft
- Side slopes to the pond should not exceed 3:1 (h:v)

Stormwater Management Capability:

- Reduction in peak rate of runoff discharge
- Water quality benefits can provide 80% TSS removal.

Land Use Considerations:

X	**Residential**
X	**Commercial**
X	**Industrial**

Maintenance:

- Remove debris from inlet and outlet structures
- Maintain side slopes / remove invasive vegetation
- Monitor sediment accumulation and remove periodically

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

SECTION 1. DESCRIPTION

Stormwater ponds (also referred to as *retention ponds*, *wet ponds*, *or wet extended detention ponds*) are constructed stormwater retention basins that have a permanent (dead storage) pool of water throughout the year. They can be created by excavating an already existing natural depression or through the construction of embankments.

In a stormwater 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 also serves to protect deposited sediments from resuspension. Above the permanent pool level, additional temporary storage (live storage) is provided for runoff quantity control. The upper stages of a stormwater pond are designed to provide extended detention of the 1-year storm for downstream channel protection, as well as normal detention of larger storm events.

Stormwater ponds are among the most cost-effective and widely used stormwater practices. A well-designed and landscaped pond can be an aesthetic feature on a development site when planned and located properly.

There are several different variants of stormwater pond design, the most common of which include the wet pond, the wet extended detention pond, and the micropool extended detention pond. In addition, multiple stormwater ponds can be placed in series or parallel to increase performance or meet site design constraints. Below are descriptions of each design variant:

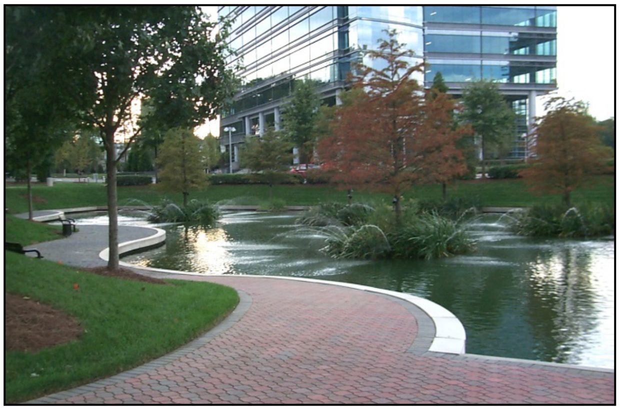
- Wet Pond – Wet ponds are stormwater basins constructed with a permanent (dead storage) pool of water equal to the water quality volume. Stormwater runoff displaces the water already present in the pool. Temporary storage (live storage) can be provided above the permanent pool elevation for larger flows.
- Wet Extended Detention (ED) Pond – A wet extended detention pond is a wet pond where the water quality volume is split evenly between the permanent pool and extended detention (ED) storage provided above the permanent pool. During storm events, water is detained above the permanent pool and released over 24 hours. This design has similar pollutant removal to a traditional wet pond, but consumes less space.
- 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 structure is sized to detain the water quality volume for 24 hours. The micropool prevents resuspension of previously settled sediments and also prevents clogging of the low flow orifice.
- 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 shows a number of examples of stormwater pond variants. Section 3 provides plan view and profile schematics for the design of a wet pond, wet extended detention pond, micropool extended detention pond, and multiple pond system.

Wet Pond

Wet ED Pond

Micropool ED Pond



Wet ED Pond

Figure 1.1. Stormwater Pond Examples.

SECTION 2. STORMWATER MANAGEMENT SUITABILITY

Stormwater ponds are designed to control both stormwater quantity and quality. Thus, a stormwater pond can be used to address Minimum Standards 1, 2, 3 and 4.

Minimum Standard #1

Stormwater ponds treat incoming stormwater runoff by physical, biological, and chemical processes. The primary removal mechanism is gravitational settling of particulates, organic matter, metals, bacteria and organics as stormwater runoff resides in the pond. Another mechanism for pollutant removal is uptake by algae and wetland plants in the permanent pool—particularly of nutrients. Volatilization and chemical activity also work to break down and eliminate a number of other stormwater contaminants such as hydrocarbons.

Section 3 of this specification provides median pollutant removal efficiencies that can be used for planning and design purposes.

Minimum Standard #2

A portion of the storage volume above the permanent pool in a stormwater pond can be used to provide control of the channel protection volume. This is accomplished by releasing the 1-year, 24-hour storm runoff volume over 24 hours (extended detention).

Minimum Standards #3 and #4

A stormwater pond can also provide storage above the permanent pool to reduce the post-development peak flow of the 25-, and 100-year storms to pre-development levels (detention).

SECTION 3. POLLUTANT REMOVAL CAPABILITIES

All of the stormwater pond design variants are presumed to be able to remove 80% of the total suspended solids (TSS) load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed ponds can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or “treatment train” approach.

- Total Suspended Solids – 80%
- Total Phosphorus – 50%
- Total Nitrogen – 30%
- Fecal Coliform – 70% (if no resident waterfowl population present)
- Heavy Metals – 50%

For additional information and data on pollutant removal capabilities for stormwater ponds, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the National Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org

SECTION 4: TYPICAL SCHEMATIC DETAILS

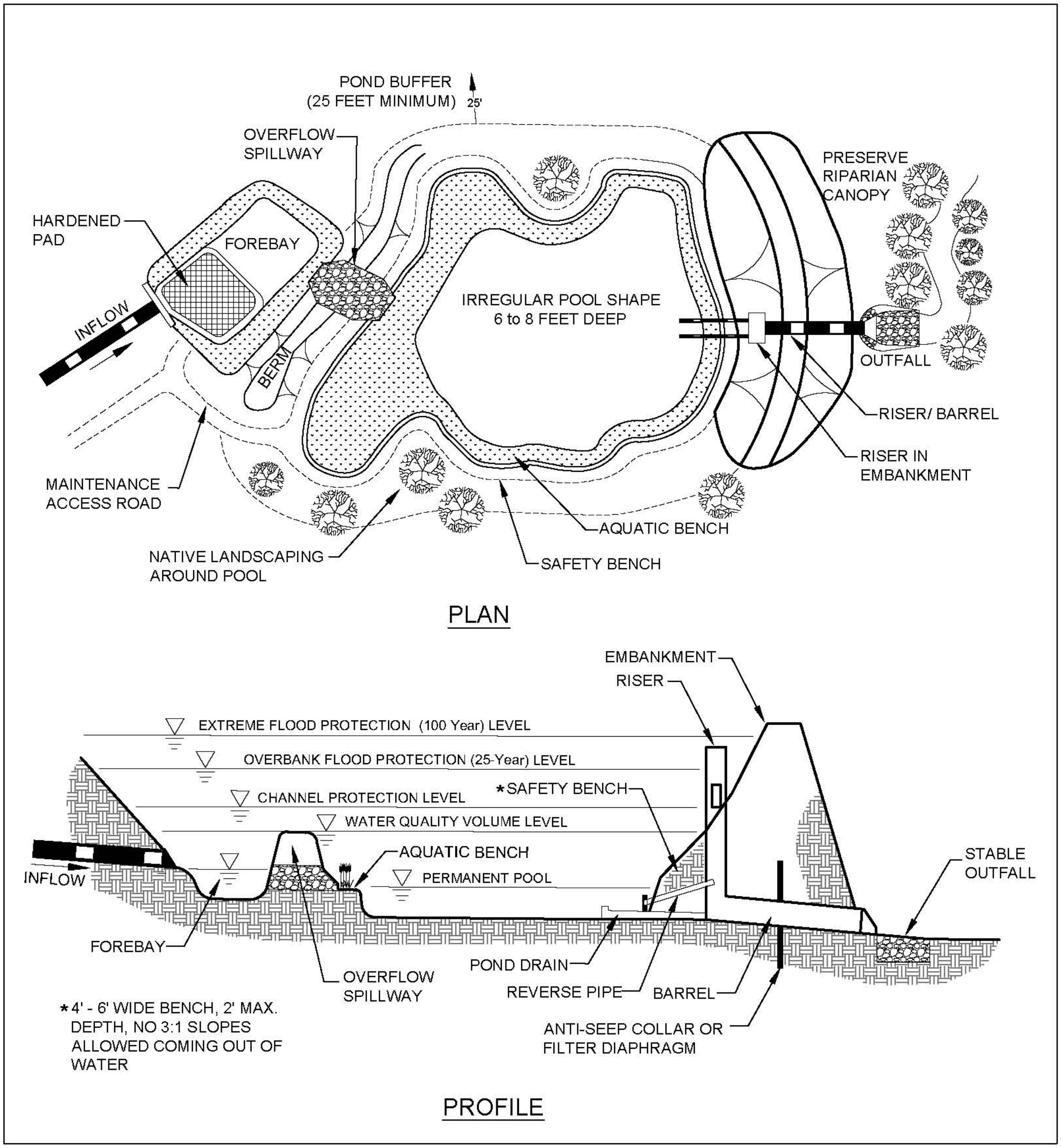


Figure 1.2. Schematic of Wet Pond
(Source: Center for Watershed Protection).

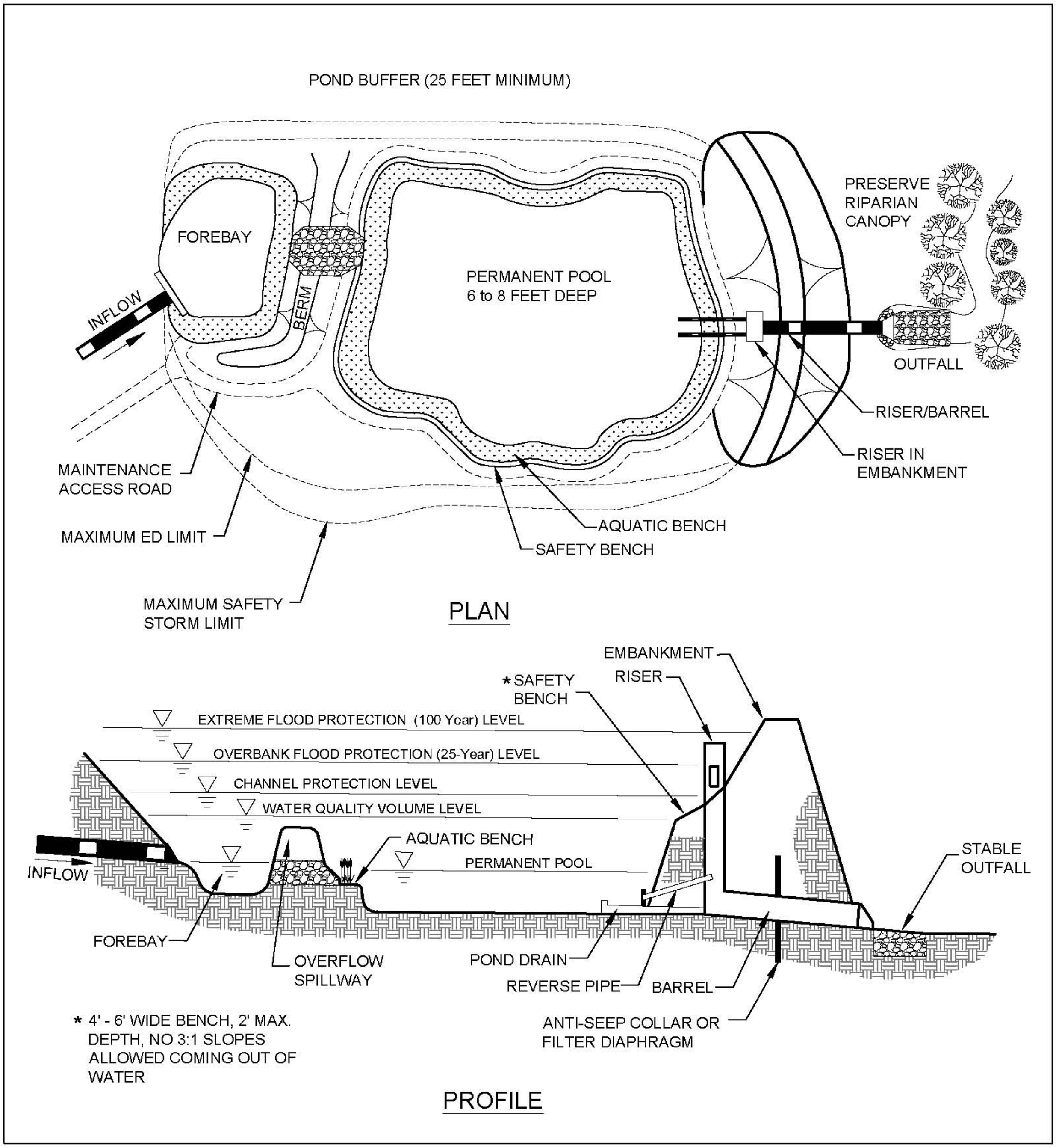


Figure 1.3. Schematic of Wet Extended Detention Pond (Source: Center for Watershed Protection).

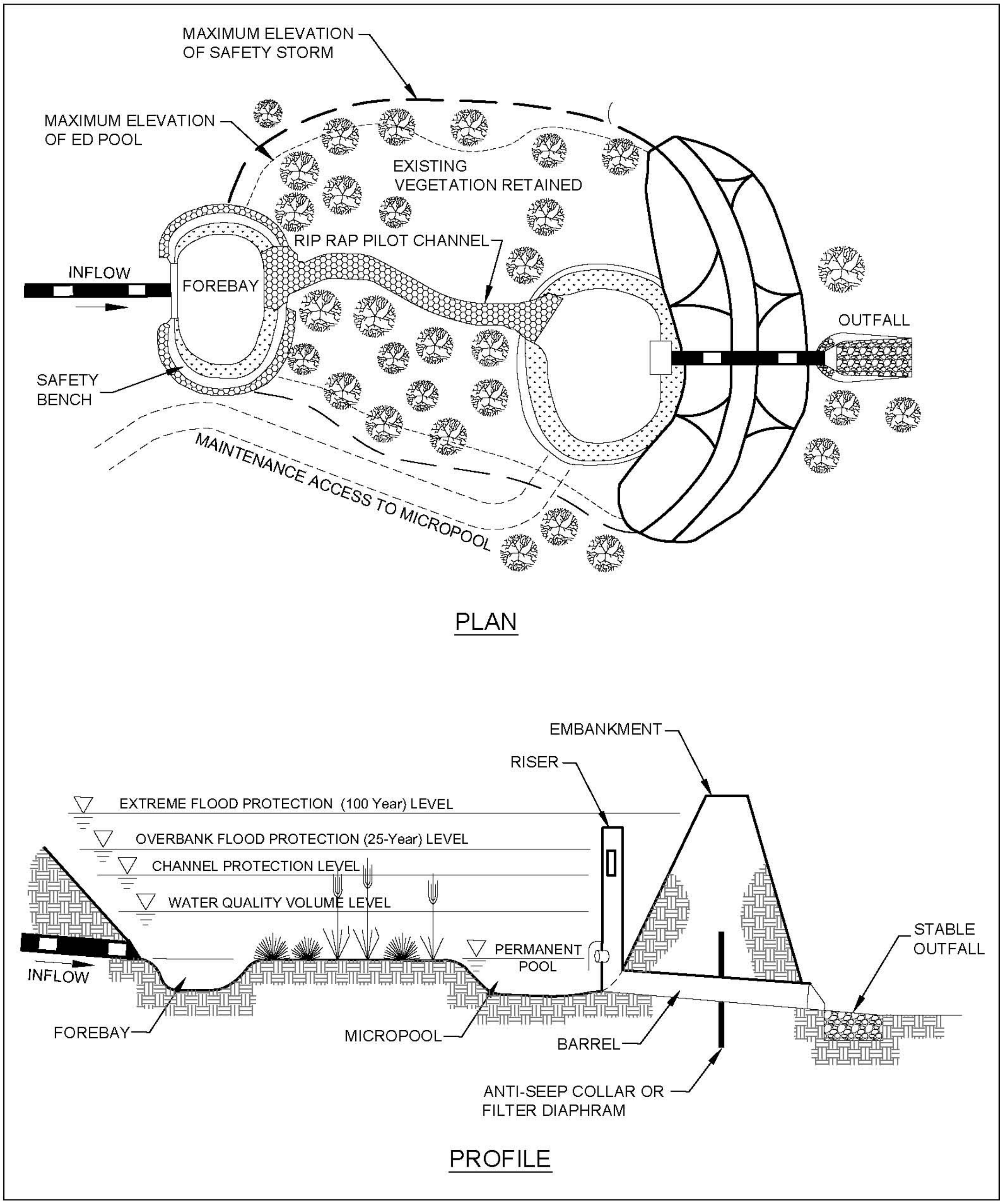


Figure 1.4. Schematic of Micropool Extended Detention Pond (Source: Center for Watershed Protection).

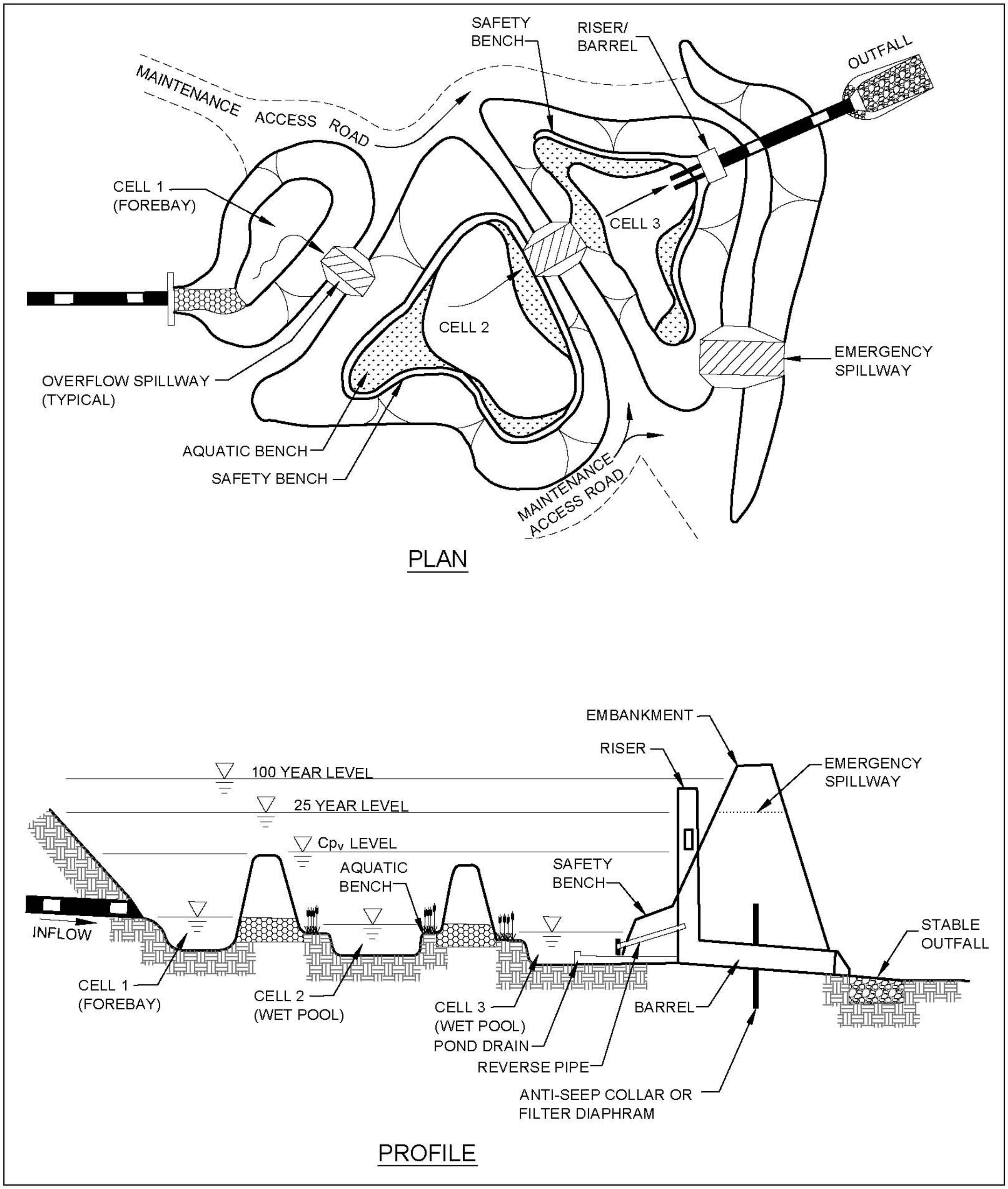


Figure 1.5. Schematic of Multiple Pond System (Source: Center for Watershed Protection).

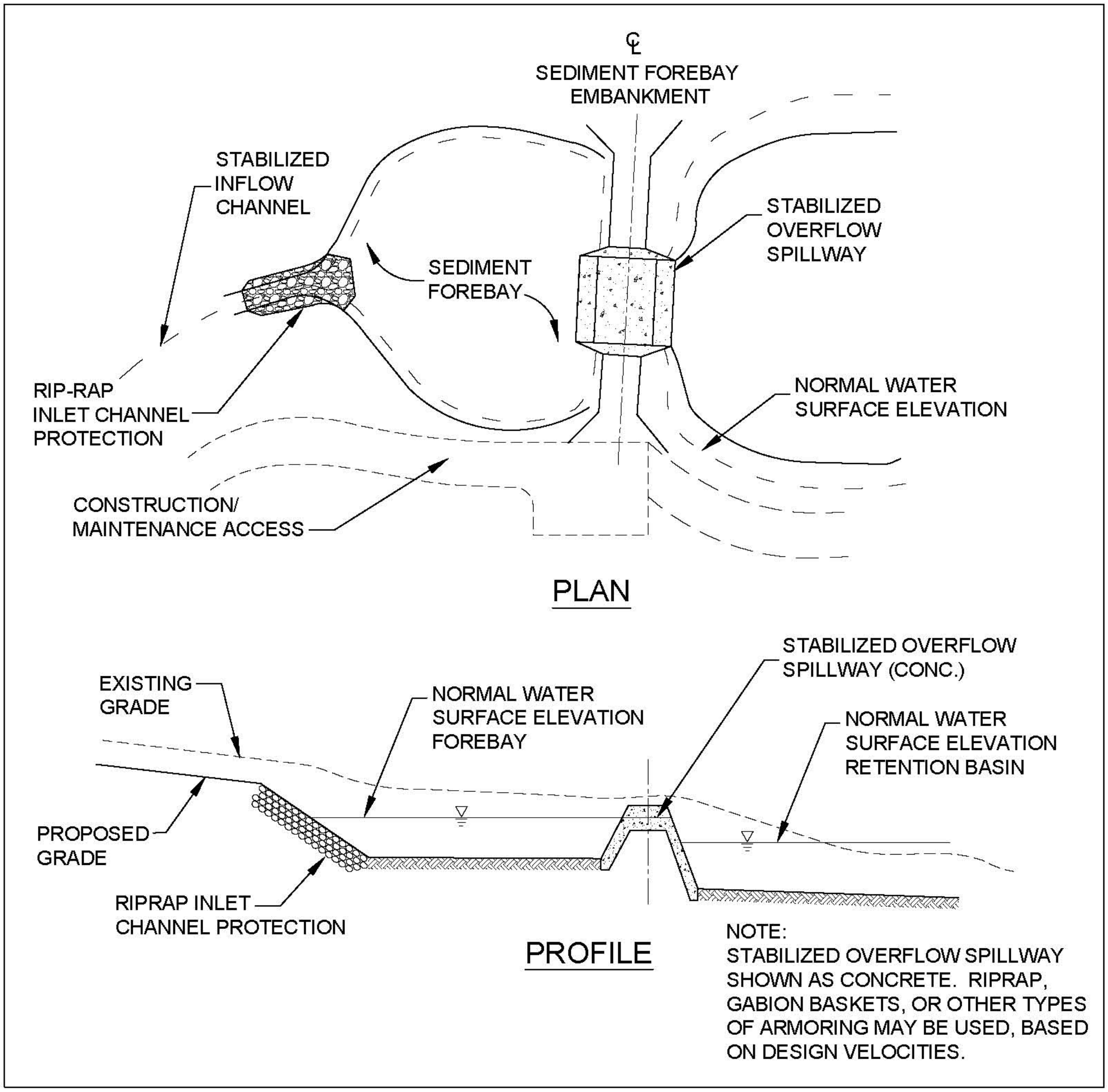


Figure 1.6. Typical Sediment Forebay Plan and Section.

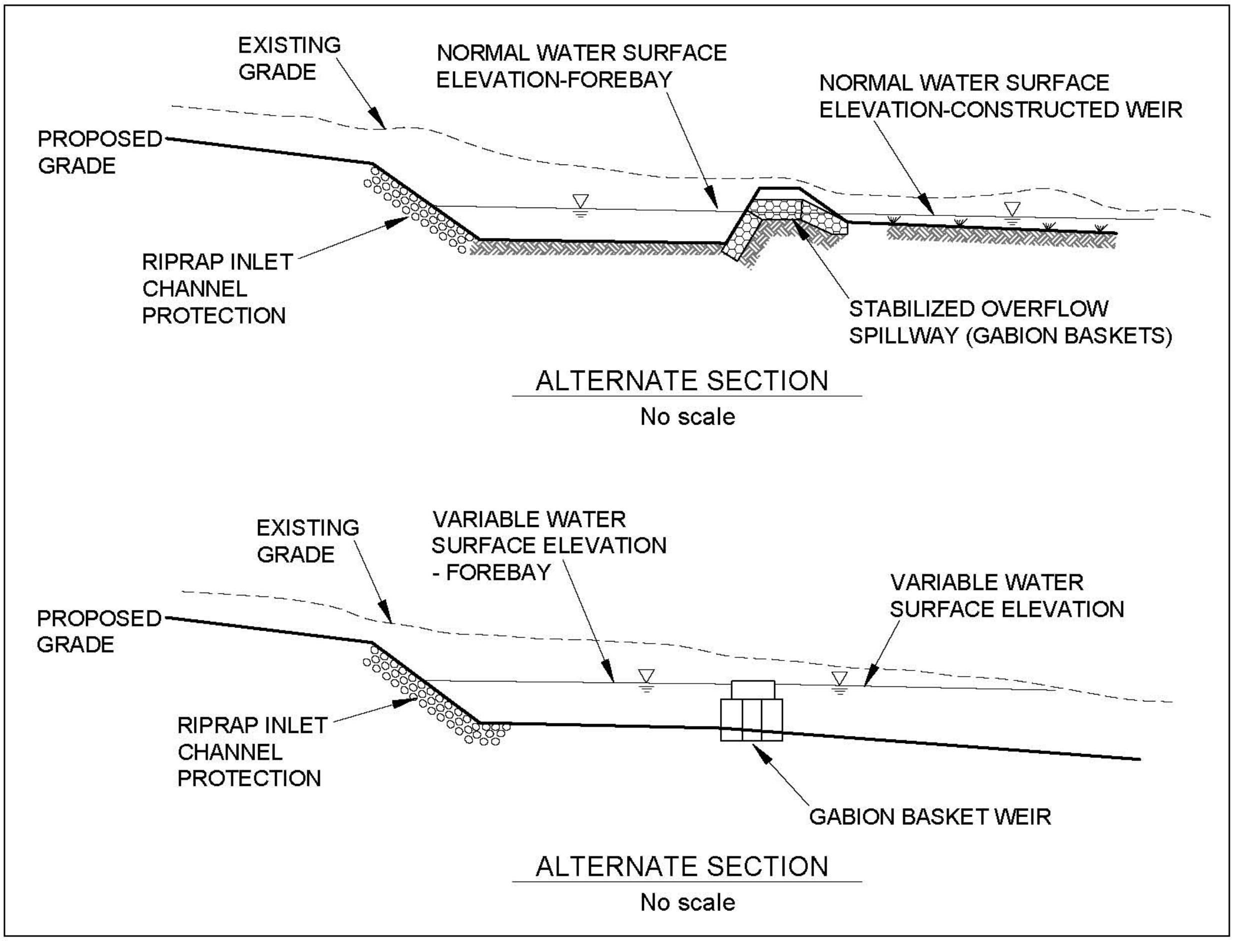


Figure 1.7. Typical Sediment Forebay Alternate Sections.

SECTION 5. SITE FEASIBILITY & DESIGN APPLICATIONS

Stormwater ponds are generally applicable to most types of new development and redevelopment, and can be used in both residential and nonresidential areas. Ponds can also be used in retrofit situations. The following criteria should be evaluated to ensure the suitability of a stormwater pond for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – YES
- Suitable for High Density/Ultra-Urban Areas – Land requirements may preclude use
- Regional Stormwater Control – YES

Physical Feasibility - Physical Constraints at Project Site

- <u>Drainage Area</u> – A minimum of 25 acres is needed for wet pond and wet ED pond to maintain a permanent pool, 10 acres minimum for micropool ED pond. A smaller drainage area may be acceptable with an adequate water balance and anti-clogging device.
- <u>Space Required</u> – Approximately 2 to 3% of the tributary drainage area
- <u>Site Slope</u> – There should not be more than 15% slope across the pond site.
- <u>Minimum Head</u> – Elevation difference needed at a site from the inflow to the outflow: 6 to 8 ft
- <u>Minimum Depth to Water Table</u> – If used on a site with an underlying water supply aquifer or when treating an area with potential for high pollutant loading, a separation distance of 2 ft is required between the bottom of the pond and the elevation of the seasonally high water table.
- <u>Soils</u> – Underlying soils of hydrologic group “C” or “D” should be adequate to maintain a permanent pool. Most group “A” soils and some group “B” soils will require a pond liner. *Evaluation of soils should be based upon an actual subsurface analysis and permeability tests*.

SECTION 6. PLANNING AND DESIGN CRITERIA

The following criteria are to be considered minimum standards for the design of a stormwater pond facility.

Location and Siting

- Stormwater ponds should have a minimum contributing drainage area of 25 acres or more for wet pond or wet ED pond to maintain a permanent pool. For a micropool ED pond, the minimum drainage area is 10 acres. A smaller drainage area can be considered when water availability can be confirmed (such as from a groundwater source or areas with a high water table). In these cases a water balance may be performed. Ensure that an appropriate anti-clogging device is provided for the pond outlet.
- A stormwater pond should be sited such that the topography allows for maximum runoff storage at minimum excavation or construction costs. Pond siting should also take into account the location and use of other site features such as buffers and undisturbed natural areas and should attempt to

aesthetically "fit" the facility into the landscape. Bedrock close to the surface may prevent excavation.

- Stormwater ponds should not be located on steep (>15%) or unstable slopes.
- Stormwater ponds cannot be located within a stream or any other navigable waters of the U.S., including wetlands, without obtaining a Section 404 permit under the Clean Water Act, and any other applicable State permit.
- Minimum setback requirements for stormwater pond facilities:
  - From a property line – 10 ft
  - From a private well – 100 ft; if well is downgradient from a land use area with potential for high pollutant loading, then the minimum setback is 250 ft
  - From a septic system tank/leach field – 50 ft
- All utilities should be located outside of the pond/basin site.

General Design

- A well-designed stormwater pond consists of:
  - Permanent pool of water,
  - Overlying zone in which runoff control volumes are stored, and
  - Shallow littoral zone (aquatic bench) along the edge of the permanent pool that acts as a biological filter.
- In addition, all stormwater pond designs need to include a sediment forebay at the inflow to the basin to allow heavier sediments to drop out of suspension before the runoff enters the permanent pool. A sediment forebay schematic can be found in Section 4 above.
- Additional pond design features include an emergency spillway, maintenance access, safety bench, pond buffer, and appropriate native landscaping.
- Figures 1.2 thru 1.5 in this specification provide plan view and profile schematics for the design of a wet pond, wet ED pond, micropool ED pond and multiple pond system.

Physical Specifications / Geometry

In general, pond designs are unique for each site and application. However, there are number of geometric ratios and limiting depths for pond design that must be observed for adequate pollutant removal, ease of maintenance, and improved safety.

- Permanent pool volume is typically sized as follows:
  - Standard wet ponds: 100% of the water quality treatment volume (1.0 WQ_v)
  - Wet ED ponds: 50% of the water quality treatment volume (0.5 WQ_v)
  - Micropool ED ponds: Approximately 0.1 inch per impervious acre
- Proper geometric design is essential to prevent hydraulic short-circuiting (unequal distribution of inflow), which results in the failure of the pond to achieve adequate levels of pollutant removal. The

minimum length-to-width ratio for the permanent pool shape is 1.5:1, and should ideally be greater than 3:1 to avoid short-circuiting. In addition, ponds should be wedge-shaped when possible so that flow enters the pond and gradually spreads out, improving the sedimentation process. Baffles, pond shaping or islands can be added within the permanent pool to increase the flow path.

- Maximum depth of the permanent pool should generally not exceed 8 ft to avoid stratification and anoxic conditions. Minimum depth for the pond bottom should be 3 to 4 ft. Deeper depths near the outlet will yield cooler bottom water discharges that may mitigate downstream thermal effects.
- Side slopes to the pond should not usually exceed 3:1 (h:v) without safety precautions or if mowing is anticipated and should terminate on a safety bench (see Figure 1.8). The safety bench requirement may be waived if slopes are 4:1 or gentler.

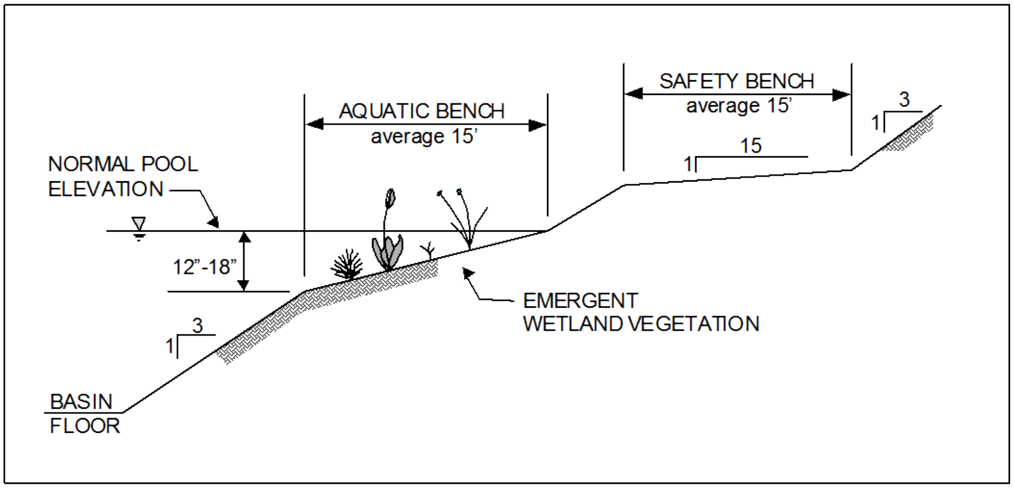


Figure 1.8. Typical Stormwater Pond Geometry Criteria.

- The perimeter of all deep pool areas (4 ft or greater in depth) should be surrounded by two benches: safety and aquatic. For larger ponds, a safety bench extends approximately 15 ft outward from the normal water edge to the toe of the pond side slope. The maximum slope of the safety bench should be 6%. An aquatic bench extends inward from the normal pool edge (15 ft on average) and has a maximum depth of 18 inches below the normal pool water surface elevation (see Figure 1.8).
- The contours and shape of the permanent pool should be irregular to provide a more natural landscaping effect.

Pretreatment / Inlets

- Each pond should have a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal in a larger permanent pool. The forebay should consist of a separate cell, formed by an acceptable barrier. A forebay is to be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. In some design configurations, the pretreatment volume may be located within the permanent pool.
- The forebay is sized to contain 0.1 inches per impervious acre of contributing drainage and should be

4 to 6 ft deep. The pretreatment storage volume is part of the total WQ_v requirement and may be subtracted from WQ_v for permanent pool sizing.

- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels are to be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the pond can be partially submerged. Exit velocities from the forebay must be nonerosive.

Outlet Structures

- Flow control from a stormwater 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 (see Figure 1.9). The riser should be located within the embankment for maintenance access, safety and aesthetics.

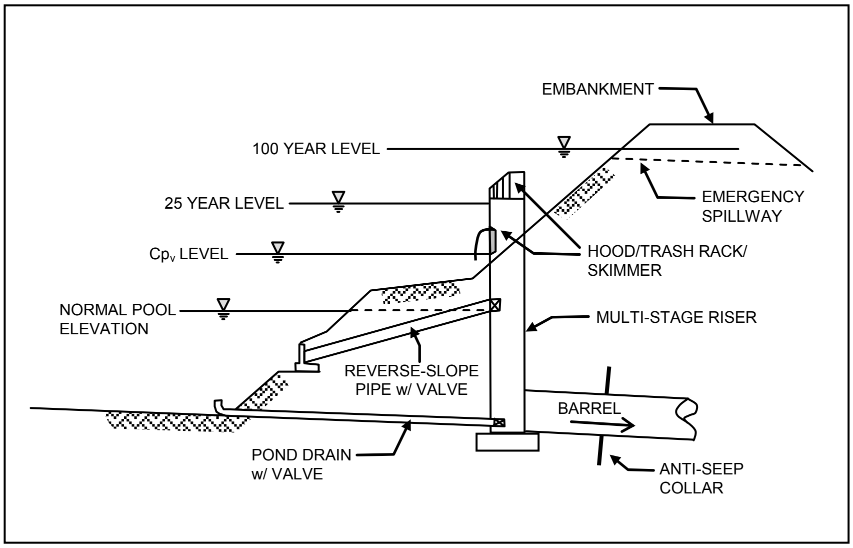


Figure 1.9. Typical Pond Outlet Structure.

- 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. The number of orifices can vary and is usually a function of the pond design.

  For example, a wet pond riser configuration is typically comprised of a channel protection outlet (usually an orifice) and overbank flood protection outlet (often a slot or weir). The channel protection orifice 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). Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet pond, it simply displaces that same volume through

the channel protection orifice. Thus an off-line wet pond providing *only* water quality treatment can use a simple overflow weir as the outlet structure.
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 ft 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.

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.

- The water quality outlet (if design is for a wet ED or micropool ED pond) and channel protection outlet should be fitted with adjustable gate valves or other mechanism that can be used to adjust detention time.
- Higher flows (overbank and extreme flood protection) flows pass through openings or slots protected by trash racks further up on the riser.
- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars should be installed on the outlet barrel to reduce the potential for pipe failure.
- Riprap, plunge pools or pads, or other energy dissipaters are to be placed at the outlet of the barrel to prevent scouring and erosion. If a pond daylights to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance.
- Each pond must have a bottom drain pipe with an adjustable valve that can completely or partially drain the pond 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 (a) will not normally be inundated and (b) can be operated in a safe manner.

See the design procedures in Chapter 7 and Appendix G for additional information and specifications on pond routing and outlet works.

Emergency Spillway

- An emergency spillway is to be included in the stormwater pond design to safely pass the extreme flood flow. The spillway prevents pond water levels from overtopping the embankment and causing structural damage. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.
- A minimum of 1 ft of freeboard must be provided, measured from the top of the water surface

elevation for the extreme flood to the lowest point of the dam embankment, not counting the emergency spillway.

Maintenance Access

- A maintenance right of way or easement must be provided to a pond from a public or private road. Maintenance access should be at least 12 ft wide, have a maximum slope of no more than 15%, and be appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access must extend to the forebay, safety bench, riser, and outlet and, to the extent feasible, be designed to allow vehicles to turn around.
- Access to the riser is to be provided by lockable manhole covers, and manhole steps within easy reach of valves and other controls.

Safety Features

- All embankments and spillways for ponds with a volume over 50 acre-ft must be obtain an Arkansas Natural Resources Commission permit, in accordance with ANRC Title VII, Rules Governing Design and Operation of Dams.
- The safety bench should be landscaped to deter access to the pool.
- The principal spillway opening should not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent access. Warning signs should be posted near the pond to prohibit swimming and fishing in the facility.

Landscaping

- Aquatic vegetation can play an important role in pollutant removal in a stormwater pond. In addition, vegetation can enhance the appearance of the pond, stabilize side slopes, serve as wildlife habitat, and can temporarily conceal unsightly trash and debris. Therefore, wetland plants should be encouraged in a pond design, along the aquatic bench (fringe wetlands), 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 (plus or minus) of the normal pool elevation.
- Woody vegetation may not be planted on the embankment or allowed to grow within 15 ft of the toe of the embankment and 25 ft from the principal spillway structure.
- A pond buffer should be provided that extends 25 ft outward from the maximum water surface elevation of the pond. The pond buffer should be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers) or that are part of the overall stormwater management concept plan. No structures should be located within the buffer, and an additional setback to permanent structures may be provided.
- 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.
- The soils of a pond buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration

and therefore may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites and backfill these with uncompacted topsoil.

- A fountain or solar-powered aerator may be used for oxygenation of water in the permanent pool.
- Compatible multi-objective use of stormwater pond locations is strongly encouraged.

Additional Site-Specific Design Criteria and Issues

- **Physiographic Factors - Local terrain design constraints**
  - Low Relief – Maximum normal pool depth is limited; providing pond drain can be problematic
  - High Relief – Embankment heights restricted
  - Karst – Requires poly or clay liner to sustain a permanent pool of water and protect aquifers; limits on ponding depth; geotechnical tests may be required
- **Soils**
  - Hydrologic group "A" soils generally require pond liner; group "B" soils may require infiltration testing

SECTION 7. DESIGN PROCEDURES

Step 1. Compute runoff control volumes from the Unified Stormwater Sizing Criteria

- Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v), Overbank Flood Protection Volume (Q_p), and the Extreme Flood Volume (Q_f).
- Details on the Stormwater Sizing Criteria are found in Chapter 2.

Step 2. Determine if the development site and conditions are appropriate for the use of a stormwater pond

- Consider the Application and Site Feasibility Criteria in Section 6 of this specification.

Step 3. Confirm local design criteria and applicability

- Consider any special site-specific design conditions/criteria from Section 6 of this specification.
- Check with City Engineer to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Determine pretreatment volume

A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. The forebay should be sized to contain 0.1 inches per impervious acre of contributing drainage and should be 4 to 6 ft deep. The forebay storage volume counts toward the total WQ_v requirement and may be subtracted from the WQ_v for subsequent calculations.

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

Wet Pond: Size permanent pool volume to 1.0 WQ_v

Wet ED Pond: Size permanent pool volume to 0.5 WQ_v. Size extended detention volume to 0.5 WQ_v.

Micropool ED Pond: Size permanent pool volume to 25 to 30% of WQ_v. Size extended detention volume to remainder of WQ_v.

Step 6. Determine pond location and preliminary geometry. Conduct pond grading and determine storage available for permanent pool (and water quality extended detention if wet ED pond or micropool ED pond)

This step involves initially grading the pond (establishing contours) and determining the elevation-storage relationship for the pond.

- Include safety and aquatic benches.
- Set WQ_v permanent pool elevation (and WQ_v-ED elevation for wet ED and micropool ED pond) based on volumes calculated earlier.

See Section 6 of this specification for more details.

Step 7. Compute extended detention orifice release rate(s) and size(s), and establish Cp_v elevation

Wet Pond: The Cp_v elevation is determined from the stage-storage relationship and the orifice is then 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). The channel protection orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 ft below the elevation of the permanent pool, is a recommended design. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wirecloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter.

Wet ED Pond and Micropool ED Pond: Based on the elevations established in Step 6 for the extended detention portion of the water quality volume, the water quality orifice is sized to release this extended detention volume in 24 hours. The water quality orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 ft below the elevation of the permanent pool, is a recommended design. Adjustable gate valves can also be used to achieve this equivalent diameter. The Cp_v elevation is then determined from the stage-storage relationship. The invert of the channel protection orifice is located at the water quality extended detention elevation, and the orifice 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).

Step 8. Calculate Q_{p25} (25-year storm) release rate and water surface elevation

Set up a stage-storage-discharge relationship for the control structure for the extended detention orifice(s) and the 25-year storm.

Step 9. Design embankment(s) and spillway(s)

Size emergency spillway, calculate 100-year water surface elevation, set top of embankment elevation, and analyze safe passage of the Extreme Flood Volume (Q_f).

At final design, provide safe passage for the 100-year event.

Step 10. Investigate potential pond hazard classification

The design and construction of stormwater management ponds are required to follow the latest version of the State of Georgia dam safety rules (see Appendix H).

Step 11. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

See Section 6 of this specification for more details.

Step 12. Prepare Vegetation and Landscaping Plan

A landscaping plan for a stormwater pond and its buffer should be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation.

See Section 6 of this specification for more details.

SECTION 8. INSPECTION AND MAINTENANCE REQUIRMENTS

Table 3.1. Typical Maintenance Activities for Ponds (Source: WMI, 1997).	
Activity	**Schedule**
• Clean and remove debris from 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)
Remove 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

SECTION 9. REFERENCES

Atlanta Regional Commission, 2001. *Georgia Stormwater Management Manual, Volume 2: Technical Handbook.* Atlanta, GA. http://www.georgiastormwater.com/GSMMVol2.pdf

Center for Watershed Protection (CWP), 1996. Design of Stormwater Filtering Systems. Prepared for Chesapeake Research Consortium.

Watershed Management Institute (WMI), 1997. Operation, Maintenance, and Management of Stormwater Management Systems. Prepared for US EPA, Office of Water.

STORMWATER WETLANDS

Description: Constructed wetland systems used for stormwater management. Runoff volume is both stored and treated in the wetland facility.

Advantages/Benefits:	Disadvantages/Limitations:
• Good nutrient removal • Provides natural wildlife habitat • Relatively low maintenance costs	• Requires large land area • Needs continuous baseflow for viable wetland • Sediment regulation is critical to sustain wetlands

Design Criteria:

- Minimum dry weather flow path of 2:1 (length:width) should be provided from inflow to outflow
- Minimum of 35% of total surface area should have a depth of 6 inches or less; 10% to 20% of surface area should be deep pool (1.5- to 6-ft depth)

Stormwater Management Capability:

- Reduction in peak rate of runoff discharge
- Water quality benefits can provide 80% TSS removal.

Land Use Considerations:

X **Residential**

X **Commercial**

X **Industrial**

Maintenance:

- Replace wetland vegetation to maintain at least 50% surface area coverage
- Remove invasive vegetation
- Monitor sediment accumulation and remove periodically

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

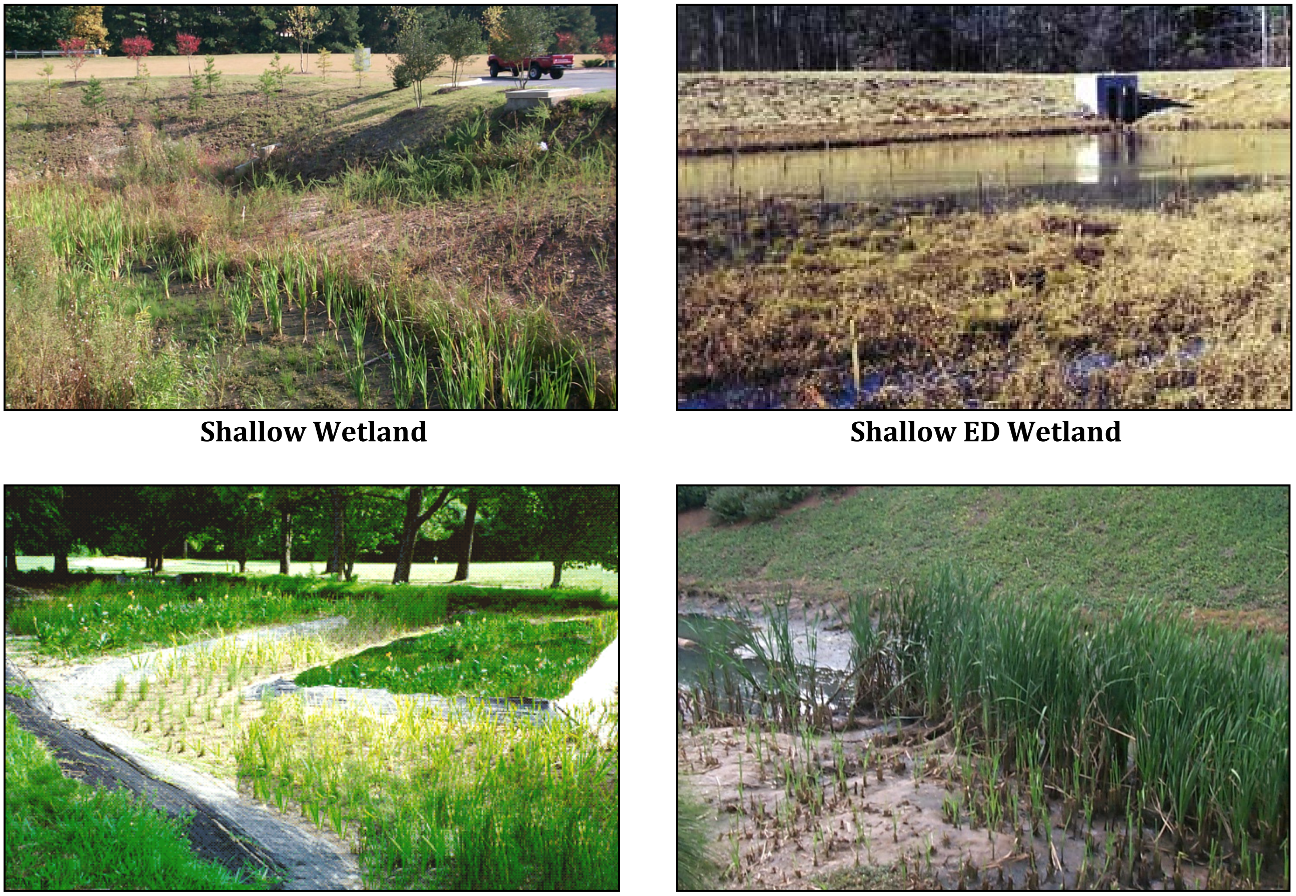
SECTION 1. DESCRIPTION

Stormwater wetlands (also referred to as *constructed wetlands*) are constructed shallow marsh systems that are designed to both treat urban stormwater and control runoff volumes. As stormwater runoff flows through the wetland facility, pollutant removal is achieved through settling and uptake by marsh vegetation.

Wetlands are among the most effective stormwater practices in terms of pollutant removal and also offer aesthetic value and wildlife habitat. Constructed stormwater wetlands differ from natural wetland systems in that they are engineered facilities designed specifically for the purpose of treating stormwater runoff and typically have less biodiversity than natural wetlands both in terms of plant and animal life. However, as with natural wetlands, stormwater wetlands require a continuous base flow or a high water table to support aquatic vegetation.

There are several design variations of the stormwater wetland, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland. These include the shallow wetland, the extended detention shallow wetland, pond/wetland system and pocket wetland. Below are descriptions of each design variant:

- **Shallow Wetland** – In the shallow wetland design, most of the water quality treatment volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland, and the micropool at the outlet. One disadvantage of this design is that, since the pool is very shallow, a relatively large amount of land is typically needed to store the water quality volume.
- **Extended Detention (ED) Shallow Wetland** – The extended detention (ED) shallow wetland design is the same as the shallow wetland; however, part of the water quality treatment volume is provided as extended detention above the surface of the marsh and released over a period of 24 hours. This design can treat a greater volume of stormwater in a smaller space than the shallow wetland design. In the extended detention wetland option, plants that can tolerate both wet and dry periods need to be specified in the ED zone.
- **Pond/Wetland Systems** – The pond/wetland system has two separate cells: a wet pond and a shallow marsh. The wet pond traps sediments and reduces runoff velocities prior to entry into the wetland, where stormwater flows receive additional treatment. Less land is required for a pond/wetland system than for the shallow wetland or the ED shallow wetland systems.
- **Pocket Wetland** – A pocket wetland is intended for smaller drainage areas of 5 to 10 acres and typically requires excavation down to the water table for a reliable water source to support the wetland system.



Shallow Wetland

Shallow ED Wetland

Newly Constructed Shallow Wetland

Pocket Wetland

Figure 2.1. Stormwater Wetland Examples.

SECTION 2. STORMWATER MANAGEMENT SUITABILITY

Similar to stormwater ponds, stormwater wetlands are designed to control both stormwater quantity and quality. Thus, a stormwater wetland can be used to address Minimum Standards 1, 2, and 3.

Minimum Standard #1

Pollutants are removed from stormwater runoff in a wetland through uptake by wetland vegetation and algae, vegetative filtering, and through gravitational settling in the slow moving marsh flow. Other pollutant removal mechanisms are also at work in a stormwater wetland, including chemical and biological decomposition, and volatilization. Section 3 of this specification provides median pollutant removal efficiencies that can be used for planning and design purposes.

Minimum Standard #2

The storage volume above the permanent pool/water surface level in a stormwater wetland is used to provide control of the channel protection volume (Cp_v). This is accomplished by releasing the 1-year, 24 hour storm runoff volume over 24 hours (extended detention). It is best to do this with minimum vertical water level fluctuation, as extreme fluctuation may stress vegetation.

Minimum Standard #3

A stormwater wetland can also provide storage above the permanent pool to reduce the post-development peak flow of the 25- and 100-year storms to pre-development levels (detention).

SECTION 3. POLLUTANT REMOVAL CAPABILITIES

All of the stormwater wetland design variants are presumed to be able to remove 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed wetland facilities can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or “treatment-train” approach.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – 40%**
- **Total Nitrogen – 30%**
- **Fecal Coliform – 70% (if no resident waterfowl population present)**
- **Heavy Metals – 50%**

For additional information and data on pollutant removal capabilities for stormwater wetlands, see the National Pollutant Removal Performance Database (2nd Edition) available at www.cwp.org and the National Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org

SECTION 4. TYPICAL SCHEMATIC DETAILS

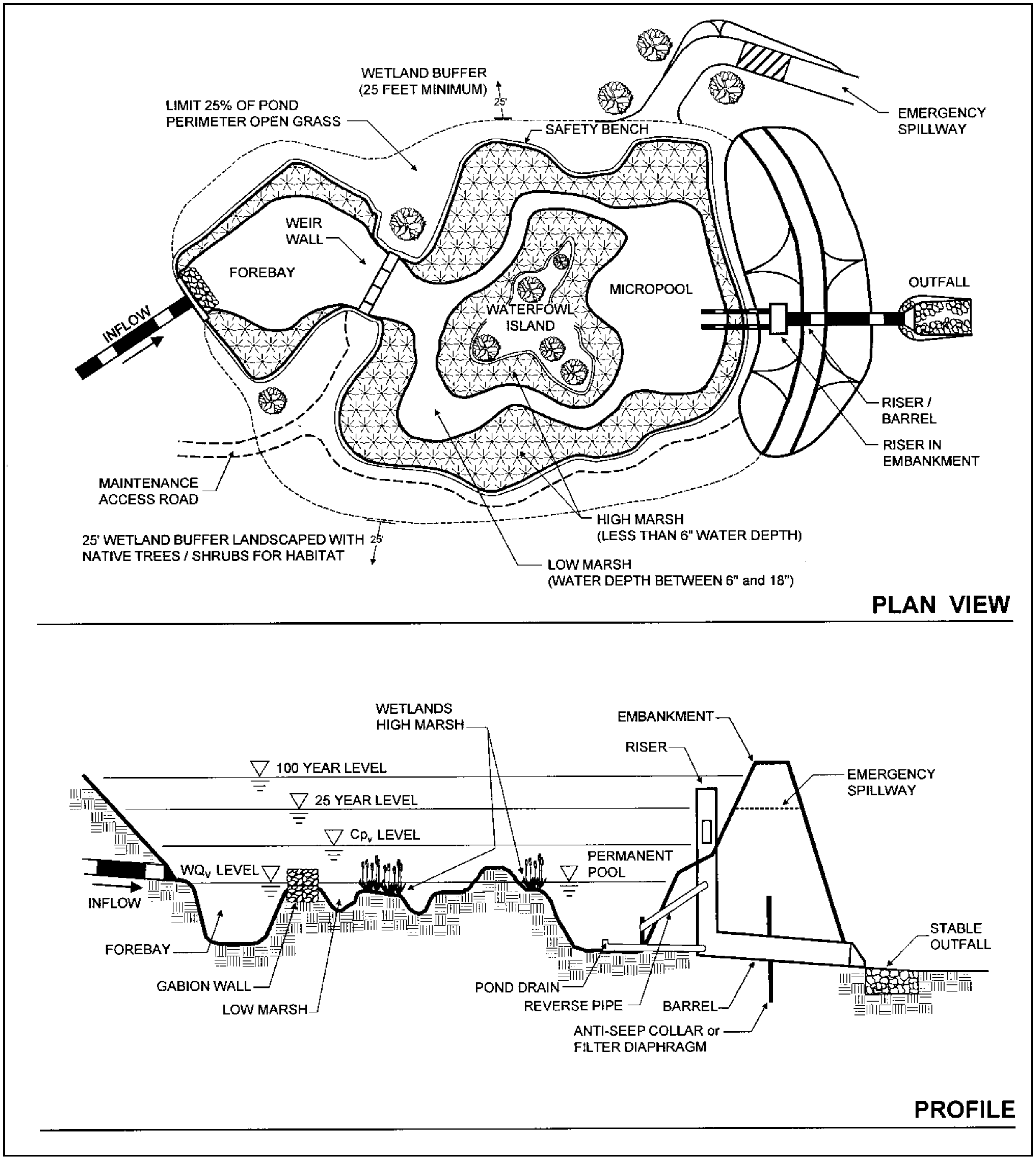


Figure 2.2. Schematic of Shallow Wetland (Source: Center for Watershed Protection).

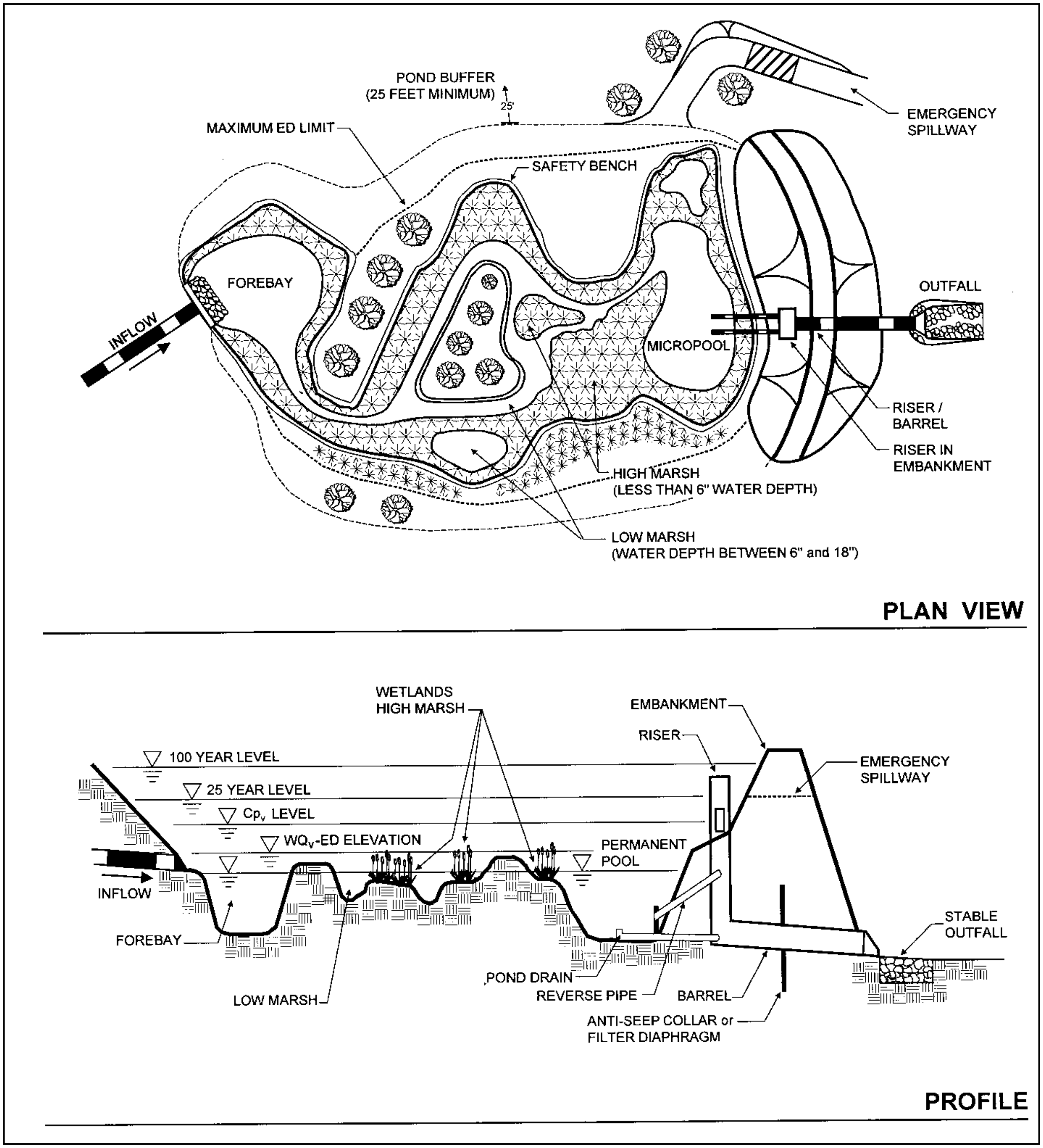


Figure 2.3. Schematic of Extended Detention Shallow Wetland (Source: Center for Watershed Protection).

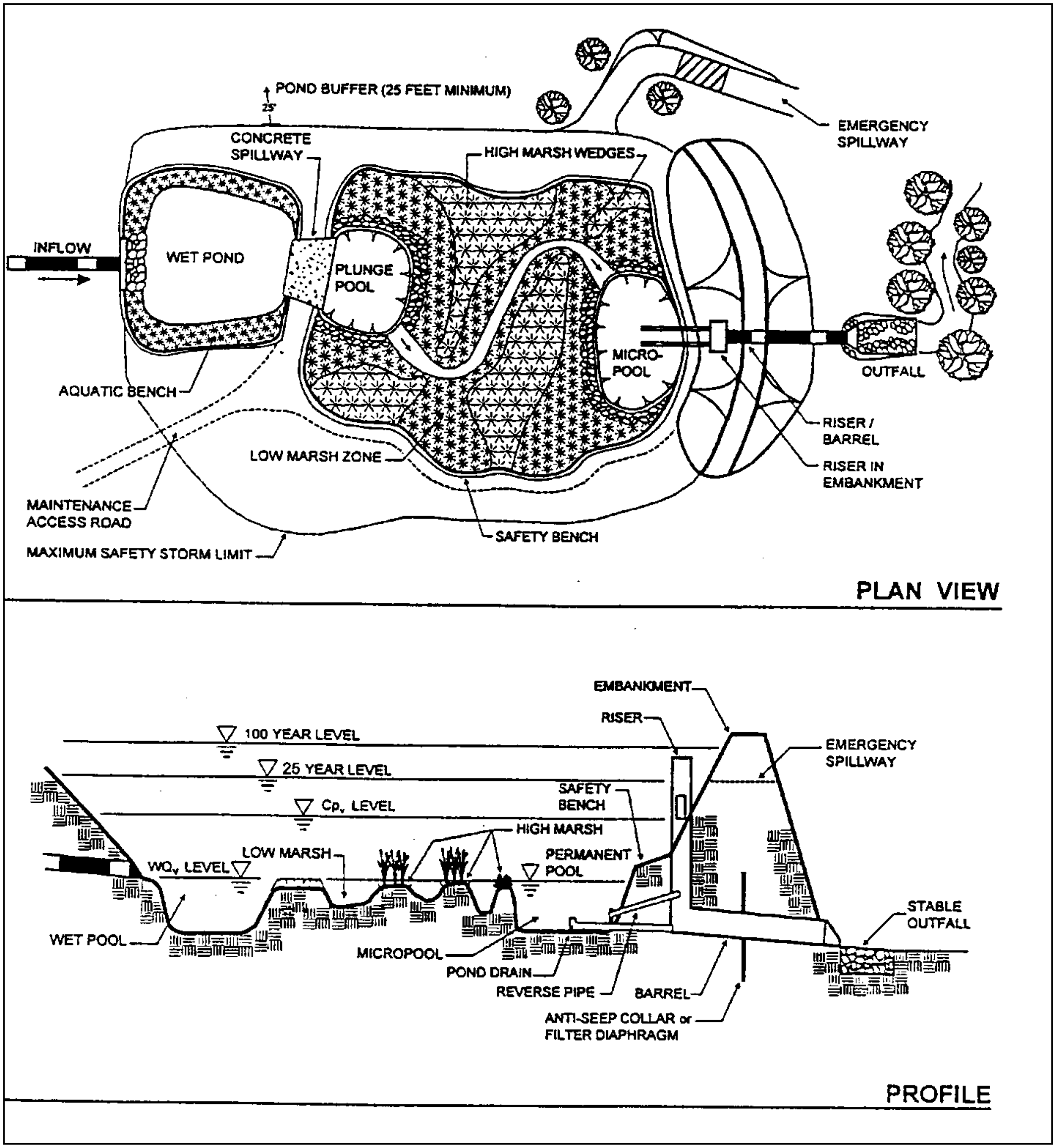


Figure 2.4. Schematic of Pond/Wetland System (Source: Center for Watershed Protection).

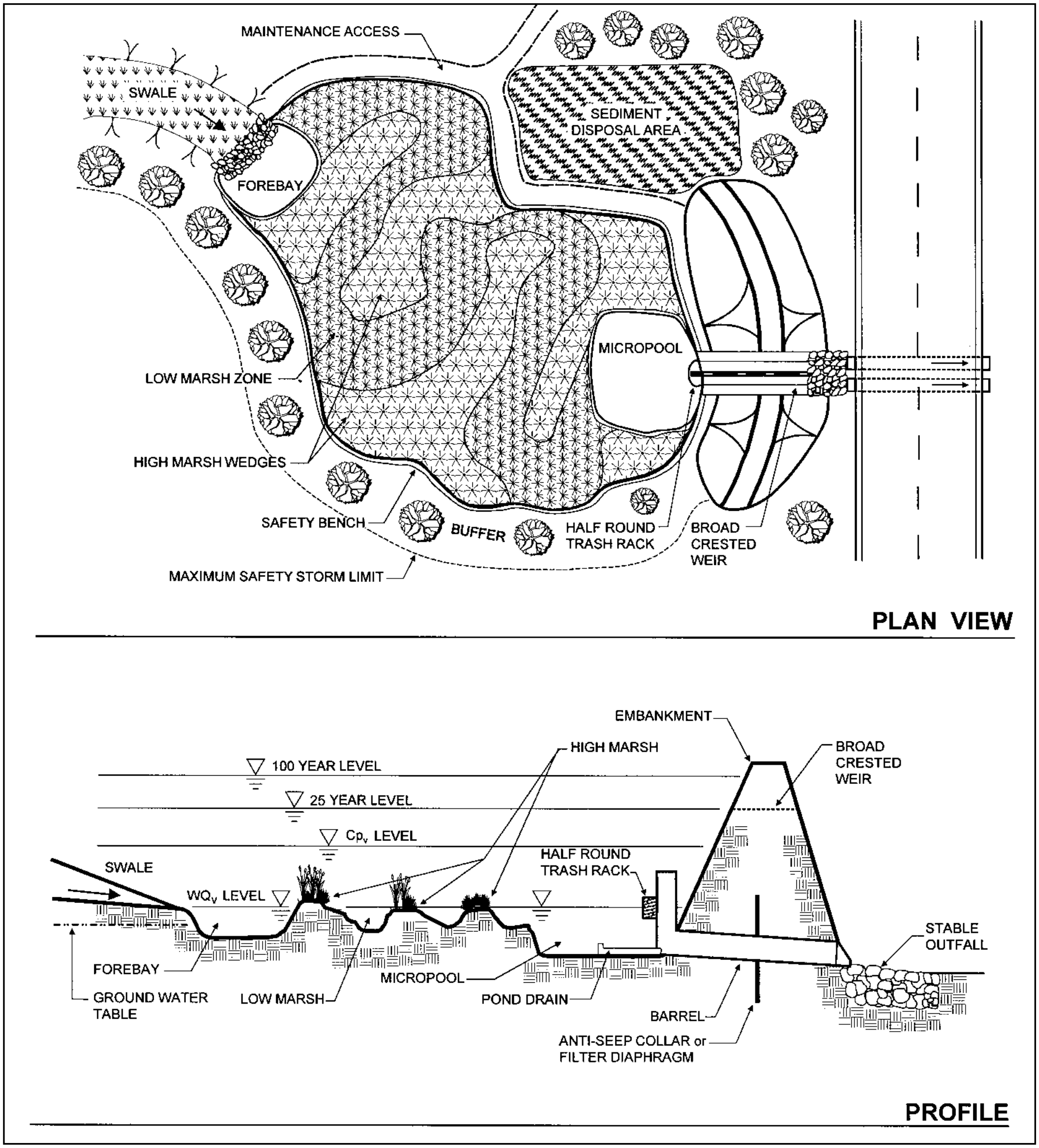


Figure 2.5. Schematic of Pocket Wetland (Source: Center for Watershed Protection).

SECTION 5. SITE FEASIBILITY & DESIGN APPLICATIONS

Stormwater wetlands are generally applicable to most types of new development and redevelopment, and can be utilized in both residential and nonresidential areas. However, due to the large land requirements, wetlands may not be practical in higher density areas. The following criteria should be evaluated to ensure the suitability of a stormwater wetland for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – YES
- Suitable for High Density/Ultra Urban Areas – Land requirements may preclude use
- Regional Stormwater Control – YES

Physical Feasibility - Physical Constraints at Project Site

- <u>Drainage Area</u> – A minimum of 25 acres and a positive water balance is needed to maintain wetland conditions; 5 acres for pocket wetland
- <u>Space Required</u> – Approximately 3 to 5% of the tributary drainage area
- <u>Site Slope</u> – There should be no more than 8% slope across the wetland site
- <u>Minimum Head</u> – Elevation difference needed at a site from the inflow to the outflow: 3 to 5 ft; 2 to 3 ft for pocket wetland
- <u>Minimum Depth to Water Table</u> – If used on a site with an underlying water supply aquifer or when treating an area with potential for high pollutant loading, a separation distance of 2 ft is recommended between the bottom of the wetland and the elevation of the seasonally high water table; pocket wetland is typically below water table.
- <u>Soils</u> – Permeable soils are not well suited for a constructed stormwater wetland without a high water table. Underlying soils of hydrologic group “C” or “D” should be adequate to maintain wetland conditions. Most group “A” soils and some group “B” soils will require a liner. Evaluation of soils should be based upon an actual subsurface analysis and permeability tests.

SECTION 6. PLANNING AND DESIGN CRITERIA

The following criteria are to be considered minimum standards for the design of a stormwater wetland facility.

Location and Siting

- Stormwater wetlands should normally have a minimum contributing drainage area of 25 acres or more. For a pocket wetland, the minimum drainage area is 5 acres.
- A continuous base flow or high water table is required to support wetland vegetation. A water balance must be performed to demonstrate that a stormwater wetland can withstand a 30-day drought at summer evaporation rates without completely drawing down.

- Wetland siting should also take into account the location and use of other site features such as natural depressions, buffers, and undisturbed natural areas, and should attempt to aesthetically "fit" the facility into the landscape. Bedrock close to the surface may prevent excavation.
- Stormwater wetlands cannot be located within navigable waters of the U.S., including wetlands, without obtaining a Section 404 permit under the Clean Water Act, and any other applicable State permit. In some isolated cases, a wetlands permit may be granted to convert an existing degraded wetland in the context of local watershed restoration efforts.
- If a wetland facility is not used for overbank flood protection, it should be designed as an off-line system to bypass higher flows rather than passing them through the wetland system.
- Minimum setback requirements for stormwater wetland facilities (when not specified by local ordinance or criteria):
  - From a property line – 10 ft
  - From a private well – 100 ft; if well is downgradient from an area with potential for high pollutant loading land use then the minimum setback is 250 ft
  - From a septic system tank/leach field – 50 ft
- All utilities should be located outside of the wetland site.

General Design

- A well-designed stormwater wetland consists of:
  - Shallow marsh areas of varying depths with wetland vegetation,
  - Permanent micropool, and
  - Overlying zone in which runoff control volumes are stored.

  Pond/wetland systems also include a stormwater pond facility (see WSC-01, Stormwater Ponds, in Appendix F for pond design information).
- In addition, all wetland designs must include a sediment forebay at the inflow to the facility to allow heavier sediments to drop out of suspension before the runoff enters the wetland marsh.
- Additional pond design features include an emergency spillway, maintenance access, safety bench, wetland buffer, and appropriate wetland vegetation and native landscaping.

Figures 2.2 through 2.5 in Section 4 of this specification provide plan view and profile schematics for the design of a shallow wetland, ED shallow wetland, pond/wetland system, and pocket wetland.

Physical Specifications / Geometry

In general, wetland designs are unique for each site and application. However, there are number of geometric ratios and limiting depths for the design of a stormwater wetland that must be observed for adequate pollutant removal, ease of maintenance, and improved safety. Table 2.1 provides the recommended physical specifications and geometry for the various stormwater wetland design variants.

Table 2.1 Recommended Design Criteria for Stormwater Wetlands
Modified from Massachusetts DEP, 1997; Schueler, 1992.

Design Criteria	Shallow Wetland	ED Shallow Wetland	Pond/ Wetland	Pocket Wetland
Length to Width Ratio (minimum)	2:1	2:1	2:1	2:1
Extended Detention (ED)	No	Yes	Optional	Optional
Allocation of WQ_v Volume (pool/marsh/ED) in %	25/75/0	25/25/50	70/30/0 (includes pond volume)	25/75/0
Allocation of Surface Area (deepwater/low marsh/high marsh/semi-wet) in %	20/35/40/5	10/35/45/10	45/25/25/5 (includes pond surface area)	10/45/40/5
Forebay	Required	Required	Required	Optional
Micropool	Required	Required	Required	Required
Outlet Configuration	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir	Reverse-slope pipe or hooded broad-crested weir	Hooded broad-crested weir

Depth:

Deepwater: 1.5 to 6 ft below normal pool elevation

Low marsh: 6 to 18 inches below normal pool elevation

High marsh: 6 inches or less below normal pool elevation

Semi-wet zone: Above normal pool elevation

- The stormwater wetland should be designed with the recommended proportion of "depth zones." Each of the four wetland design variants has depth zone allocations which are given as a percentage of the stormwater wetland surface area. Target allocations are found in Table 2.1. The four basic depth zones are:
  - **Deepwater zone**
    From 1.5 to 6 ft deep. Includes the outlet micropool and deepwater channels through the wetland facility. This zone supports little emergent wetland vegetation, but may support submerged or floating vegetation.
  - **Low marsh zone**
    From 6 to 18 inches below the normal permanent pool or water surface elevation. This zone is suitable for the growth of several emergent wetland plant species.

- **High marsh zone**
  From 6 inches below the pool to the normal pool elevation. This zone will support a greater density and diversity of wetland species than the low marsh zone. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone.
- **Semi-wet zone**
  Those areas above the permanent pool that are inundated during larger storm events. This zone supports a number of species that can survive flooding.

- A minimum dry weather flow path of 2:1 (length to width) is required from inflow to outlet across the stormwater wetland and should ideally be greater than 3:1. This path may be achieved by constructing internal dikes or berms, using marsh plantings, and by using multiple cells. Finger dikes are commonly used in surface flow systems to create serpentine configurations and prevent short-circuiting. Microtopography (contours along the bottom of a wetland or marsh that provide a variety of conditions for different species needs and increases the surface area to volume ratio) is encouraged to enhance wetland diversity.
- A 4- to 6-ft deep micropool must be included in the design at the outlet to prevent the outlet from clogging and resuspension of sediments, and to mitigate thermal effects.
- Maximum depth of any permanent pool areas should generally not exceed 6 ft.
- The volume of the extended detention must not comprise more than 50% of the total WQ_v, and its maximum water surface elevation must not extend more than 3 ft above the normal pool. Q_p and/or Cp_v storage can be provided above the maximum WQ_v elevation within the wetland.
- The perimeter of all deep pool areas (4 ft or greater in depth) should be surrounded by safety and aquatic benches similar to those for stormwater ponds.
- The contours of the wetland should be irregular to provide a more natural landscaping effect.

Pretreatment / Inlets

- Sediment regulation is critical to sustain stormwater wetlands. A wetland facility should have a sediment forebay or equivalent upstream pretreatment. A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal into the wetland. The forebay should consist of a separate cell, formed by an acceptable barrier. A forebay is to be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the wetland facility.
- The forebay is sized to contain 0.1 inches per impervious acre of contributing drainage and should be 4 to 6 ft deep. The pretreatment storage volume is part of the total WQ_v requirement and may be subtracted from WQ_v for wetland storage sizing.
- A fixed vertical sediment depth marker shall be installed in the forebay to measure sediment deposition over time. The bottom of the forebay may be hardened (e.g., using concrete, paver blocks, etc.) to make sediment removal easier.
- Inflow channels are to be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the pond can be partially submerged. Exit velocities from the forebay must be nonerosive.

Outlet Structures

- Flow control from a stormwater wetland 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 micropool with a watertight connection. The outlet barrel is a horizontal pipe attached to the riser that conveys flow under the embankment (see Figure 3.2.2-2) The riser should be located within the embankment for maintenance access, safety and aesthetics.
- 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. The number of orifices can vary and is usually a function of the pond design.
  - For shallow and pocket wetlands, the riser configuration is typically comprised of a channel protection outlet (usually an orifice) and overbank flood protection outlet (often a slot or weir). The channel protection orifice 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). Since the water quality volume is fully contained in the permanent pool, no orifice sizing is necessary for this volume. As runoff from a water quality event enters the wet pond, it simply displaces that same volume through the channel protection orifice. Thus an off-line shallow or pocket wetland providing ***only*** water quality treatment can use a simple overflow weir as the outlet structure.
  - In the case of a extended detention (ED) shallow wetland, 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 ft 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.

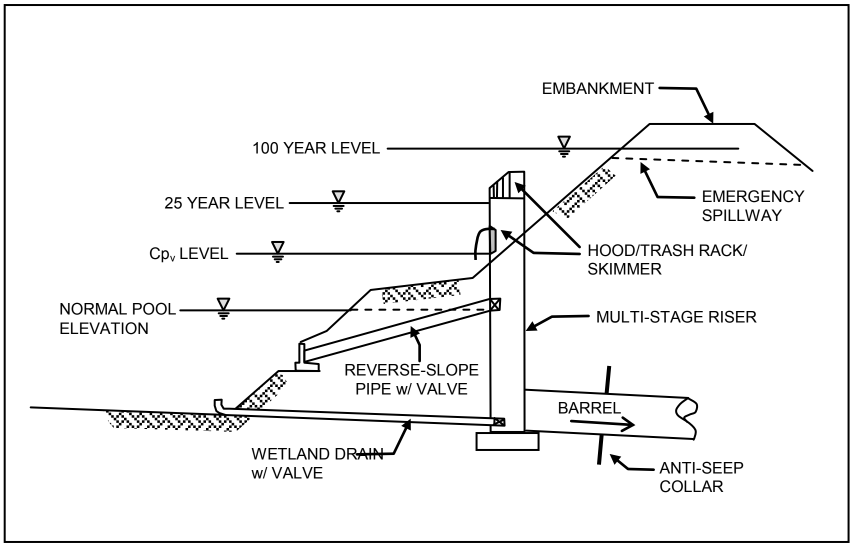


Figure 2.6. Typical Wetland Facility Outlet Structure.

- The water quality outlet (if design is for an ED shallow wetland) and channel protection outlet should be fitted with adjustable gate valves or other mechanism that can be used to adjust detention time.
- Higher flows (overbank and extreme flood protection) flows pass through openings or slots protected by trash racks further up on the riser.
- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars should be installed on the outlet barrel to reduce the potential for pipe failure.
    - Riprap, plunge pools or pads, or other energy dissipators are to be placed at the outlet of the barrel to prevent scouring and erosion. If a wetland facility daylights to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. See Section 4.5 (Energy Dissipation Design) for more guidance.
    - The wetland facility must have a bottom drain pipe located in the micropool with an adjustable valve that can completely or partially dewater the wetland within 24 hours. (This requirement may be waived for coastal areas, where positive drainage is difficult to achieve due to very low relief)
    - The wetland 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 (a) will not normally be inundated and (b) can be operated in a safe manner.

See the design procedures in Chapter 7 and Appendix G for additional information and specifications on pond routing and outlet works.

Emergency Spillway

- An emergency spillway is to be included in the stormwater wetland design to safely pass flows that exceed the design storm flows. The spillway prevents the wetland's water levels from overtopping the embankment and causing structural damage. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.

- A minimum of 1 ft of freeboard must be provided, measured from the top of the water surface elevation for the extreme flood to the lowest point of the dam embankment, not counting the emergency spillway.

Maintenance Access

- A maintenance right of way or easement must be provided to the wetland facility from a public or private road. Maintenance access should be at least 12 ft wide, have a maximum slope of no more than 15%, and be appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access must extend to the forebay, safety bench, riser, and outlet and, to the extent feasible, be designed to allow vehicles to turn around.
- Access to the riser is to be provided by lockable manhole covers, and manhole steps within easy reach of valves and other controls.

Safety Features

- All embankments and spillways must be designed to State of Georgia guidelines for dam safety (see Appendix H).
- Fencing of wetlands is not generally desirable, but may be required by the local review authority. A preferred method is to manage the contours of deep pool areas through the inclusion of a safety bench (see above) to eliminate dropoffs and reduce the potential for accidental drowning.
- The principal spillway opening should not permit access by small children, and endwalls above pipe outfalls greater than 48 inches in diameter should be fenced to prevent a hazard.

Landscaping

- A landscaping plan should be provided that indicates the methods used to establish and maintain wetland coverage. Minimum elements of a plan include: delineation of landscaping zones, selection of corresponding plant species, planting plan, sequence for preparing wetland bed (including soil amendments, if needed) and sources of plant material.
- Landscaping zones include low marsh, high marsh, and semi-wet zones. The low marsh zone ranges from 6 to 18 inches below the normal pool. This zone is suitable for the growth of several emergent plant species. The high marsh zone ranges from 6 inches below the pool up to the normal pool. This zone will support greater density and diversity of emergent wetland plant species. The high marsh zone should have a higher surface area to volume ratio than the low marsh zone. The semi-wet zone refers to those areas above the permanent pool that are inundated on an irregular basis and can be expected to support wetland plants.
- The landscaping plan should provide elements that promote greater wildlife and waterfowl use within the wetland and buffers.
- Woody vegetation may not be planted on the embankment or allowed to grow within 15 ft of the toe of the embankment and 25 ft from the principal spillway structure.

- A wetland buffer shall extend 25 ft outward from the maximum water surface elevation, with an additional 15-ft setback to structures. The wetland buffer should be contiguous with other buffer areas that are required by existing regulations (e.g., stream buffers) or that are part of the overall stormwater management concept plan. No structures should be located within the buffer, and an additional setback to permanent structures may be provided.
- 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.
- The soils of a wetland buffer are often severely compacted during the construction process to ensure stability. The density of these compacted soils is so great that it effectively prevents root penetration and therefore may lead to premature mortality or loss of vigor. Consequently, it is advisable to excavate large and deep holes around the proposed planting sites and backfill these with uncompacted topsoil.

Additional Site-Specific Design Criteria and Issues

- Physiographic Factors - Local terrain design constraints
  - Low Relief – Providing wetland drain can be problematic
  - High Relief – Embankment heights restricted
  - Karst – Requires poly or clay liner to sustain a permanent pool of water and protect aquifers; limits on ponding depth; geotechnical tests may be required
- Soils
  - Hydrologic group “A” soils and some group “B” soils may require liner (not relevant for pocket wetland)

SECTION 7. DESIGN PROCEDURES

Step 1. Compute runoff control volumes from the Unified Stormwater Sizing Criteria

Calculate the Water Quality Volume (WQv), Channel Protection Volume (Cpv), Overbank Flood Protection Volume (Qp), and the Extreme Flood Volume (Qf).

Details on the Stormwater Sizing Criteria are found in Chapter 2.

Step 2. Determine if the development site and conditions are appropriate for the use of a stormwater wetland

Consider the Application and Site Feasibility Criteria in Section 6 of this specification (Location and Siting).

Step 3. Confirm local design criteria and applicability

Consider any special site-specific design conditions/criteria from Section 6 of this specification (Additional Site-Specific Design Criteria and Issues).

Check with the City Engineer to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Determine pretreatment volume

A sediment forebay is provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the pond. The forebay should be sized to contain 0.1 inches per impervious acre of contributing drainage and should be 4 to 6 ft deep. The forebay storage volume counts toward the total WQv requirement and may be subtracted from the WQv for subsequent calculations.

Step 5. Allocate the WQ_v volume among marsh, micropool, and ED volumes

Use recommended criteria from Table 2.1 of this specification

Step 6. Determine wetland location and preliminary geometry, including distribution of wetland depth zones

This step involves initially laying out the wetland design and determining the distribution of wetland surface area among the various depth zones (high marsh, low marsh, and deepwater). Set WQ_v permanent pool elevation (and WQ_v-ED elevation for ED shallow wetland) based on volumes calculated earlier.

See Section 6 of this specification (Physical Specification / Geometry) for more details.

Step 7. Compute extended detention orifice release rate(s) and size(s), and establish Cp_v elevation

Shallow Wetland and Pocket Wetland: The Cp_v elevation is determined from the stage-storage relationship and the orifice is then 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). The channel protection orifice should have a minimum diameter of 3 inches and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 ft below the elevation of the permanent pool is a recommended design. The orifice diameter may be reduced to 1 inch if internal orifice protection is used (i.e., an over-perforated vertical stand pipe with ½-inch orifices or slots that are protected by wirecloth and a stone filtering jacket). Adjustable gate valves can also be used to achieve this equivalent diameter.

ED Shallow Wetland: Based on the elevations established in Step 6 for the extended detention portion of the water quality volume, the water quality orifice is sized to release this extended detention volume in 24 hours. The water quality orifice should have a minimum diameter of 3 inches, and should be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged 1 ft below the elevation of the permanent pool, is a recommended design. Adjustable gate valves can also be used to achieve this equivalent diameter. The Cp_v elevation is then determined from the stage-storage relationship. The invert of the channel protection orifice is located at the water quality extended detention elevation, and the orifice 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).

Step 8. Calculate Q_{p25} (25-year storm) release rate and water surface elevation

Set up a stage-storage-discharge relationship for the control structure for the extended detention orifice(s) and the 25-year storm.

Step 9. Design embankment(s) and spillway(s)

Size emergency spillway, calculate 100-year water surface elevation, set top of embankment elevation, and analyze safe passage of the Extreme Flood Volume (Q_f).

At final design, provide safe passage for the 100-year event. Attenuation may not be required.

Step 10. Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

See Section 6 of this specification for more details.

Step 11. Prepare Vegetation and Landscaping Plan

A landscaping plan for the wetland facility and its buffer should be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation.

See Section 6 of this specification (Landscaping) for more details.

SECTION 8. INSPECTION AND MAINTENANCE REQUIREMENTS

Table 2.2. Typical Maintenance Activities for Wetlands (Adapted from WMI, 1997 and CWP, 1998).

Activity	Schedule
• Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants after the second growing season.	One-Time Activity
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Frequently (3 to 4 times/year)
• Monitor wetland vegetation and perform replacement planting as necessary.	Semi-annual Inspection (first 3 years)
• Examine stability of the original depth zones and microtopographical features. • Inspect for invasive vegetation, and remove where possible. • Inspect for damage to the embankment and inlet/outlet structures. Repair as necessary. • 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.	Annual Inspection
• Repair undercut or eroded areas.	As Needed
• Harvest wetland plants that have been “choked out” by sediment build-up.	Annually
• 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, plants are “choked” with sediment, or the wetland becomes eutrophic.	10 to 20 years or after 25% of the wetland volume has been lost

Additional Maintenance Considerations and Requirements

- Maintenance requirements for constructed wetlands are particularly high while vegetation is being established. Monitoring during these first years is crucial to the future success of the wetland as a stormwater structural control. Wetland facilities should be inspected after major storms (greater than 2 inches of rainfall) during the first year of establishment to assess bank stability, erosion damage, flow channelization, and sediment accumulation within the wetland. For the first 3 years, inspections should be conducted at least twice a year.
- A sediment marker should be located in the forebay to determine when sediment removal is required.
- Accumulated sediments will gradually decrease wetland storage and performance. The effects of sediment deposition can be mitigated by the removal of the sediments.
- Sediments excavated from stormwater wetlands that do not receive runoff from designated hotspots are not considered toxic or hazardous material and can be safely disposed of by either land application or landfilling. Sediment testing may be required prior to sediment disposal when a hotspot land use is present. Sediment removed from stormwater wetlands should be disposed of according to an approved erosion and sediment control plan.

- Periodic mowing of the wetland buffer is only required along maintenance rights-of-way and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest.
- Regular inspection and maintenance is critical to the effective operation of stormwater wetlands as designed.

SECTION 9. REFERENCES

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Watershed Management Institute (WMI), 1997. Operation, Maintenance, and Management of Stormwater Management Systems. Prepared for US EPA, Office of Water.

SAND FILTERS

Description: Multi-chamber structure designed to treat stormwater runoff through filtration, using a sediment forebay, a sand bed as its primary filter media and, typically, an underdrain collection system.

Advantages/Benefits:	Disadvantages/Limitations:
• Applicable to small drainage areas • Good for highly impervious areas • Good retrofit capability	• High maintenance burden • Not recommended for areas with high sediment content in stormwater or clay/silt runoff areas • Relatively costly • Possible odor problems

Design Criteria:

- Typically requires 2 to 6 ft of head
- Maximum contributing drainage area of 10 acres for surface sand filter; 2 acres for perimeter sand filter
- Sand filter media with underdrain system

Stormwater Management Capability:

- Water quality benefits can provide 80% TSS removal.

Land Use Considerations:

	Residential
X	**Commercial**
X	**Industrial**

Maintenance:

- Inspect for clogging – rake first inch of sand
- Remove sediment from forebay/chamber
- Replace sand filter media as needed

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

SECTION 1: DESCRIPTION

Sand filters (also referred to as *filtration basins*) are structural stormwater controls that capture and temporarily store stormwater runoff and pass it through a filter bed of sand. Most sand filter systems consist of two-chamber structures. The first chamber is a sediment forebay or sedimentation chamber, which removes floatables and heavy sediments. The second is the filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. The filtered runoff is typically collected and returned to the conveyance system, though it can also be partially or fully exfiltrated into the surrounding soil in areas with porous soils.

Because they have few site constraints beside head requirements, sand filters can be used on development sites where the use of other structural controls may be precluded. However, sand filter systems can be relatively expensive to construct and install.

There are two primary sand filter system designs, the *surface sand filter* and the *perimeter sand filter*. Below are descriptions of these filter systems:

- **Surface Sand Filter** – The surface sand filter is a ground-level open air structure that consists of a pretreatment sediment forebay and a filter bed chamber. This system can treat drainage areas up to 10 acres in size and is typically located off-line. Surface sand filters can be designed as an excavation with earthen embankments or as a concrete or block structure.
- **Perimeter Sand Filter** – The perimeter sand filter is an enclosed filter system typically constructed just below grade in a vault along the edge of an impervious area such as a parking lot. The system consists of a sedimentation chamber and a sand bed filter. Runoff flows into the structure through a series of inlet grates located along the top of the control.

A third design variant, the *underground sand filter*, is intended primarily for extremely space limited and high density areas and is thus considered a limited application structural control. See subsection 4.6.10 for more details.

Surface Sand Filter

Perimeter Sand Filter

Figure 3.1. Sand Filter Examples.

SECTION 2: STORMWATER MANAGEMENT SUITABILITY

Sand filter systems are designed primarily as off-line systems for stormwater quality (i.e., the removal of stormwater pollutants) and will typically need to be used in conjunction with another structural control to provide downstream channel protection, overbank flood protection, and extreme flood protection, if required. However, under certain circumstances, filters can provide limited runoff quantity control, particularly for smaller storm events.

Minimum Standard #1

In sand filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration and adsorption. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants. Surface sand filters with a grass cover have additional opportunities for bacterial decomposition as well as vegetation uptake of pollutants, particularly nutrients. Section 4.6.4.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

Minimum Standard #2

For smaller sites, a sand filter may be designed to capture the entire channel protection volume Cp_v in either an off- or on-line configuration. Given that a sand filter system is typically designed to completely drain over 40 hours, the requirement of extended detention of the 1-year, 24-hour storm runoff volume will be met. For larger sites –or– where only the WQ_v is diverted to the sand filter facility, another structural control must be used to provide Cp_v extended detention.

Minimum Standard #3

Another structural control must be used in conjunction with a sand filter system to reduce the post-development peak flow of the 25-year storm (Qp) to pre-development levels (detention). Sand filter facilities must provide flow diversion and/or be designed to safely pass extreme storm flows (100-year storm event) and protect the filter bed and facility.

SECTION 3: POLLUTANT REMOVAL CAPABILITIES

Both the surface and perimeter sand filters are presumed to be able to remove 80% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the recommended specifications. Undersized or poorly designed sand filters can reduce TSS removal performance.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or "treatment train" approach.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – 50%**
- **Total Nitrogen – 25%**

- **Fecal Coliform – 40%**
- **Heavy Metals – 50%**

For additional information and data on pollutant removal capabilities for sand filters, see the National Pollutant Removal Performance Database (3rd Edition) available at www.cwp.org and the National Stormwater Best Management Practices (BMP) Database at www.bmpdatabase.org

SECTION 4: TYPICAL SCHEMATIC DETAILS

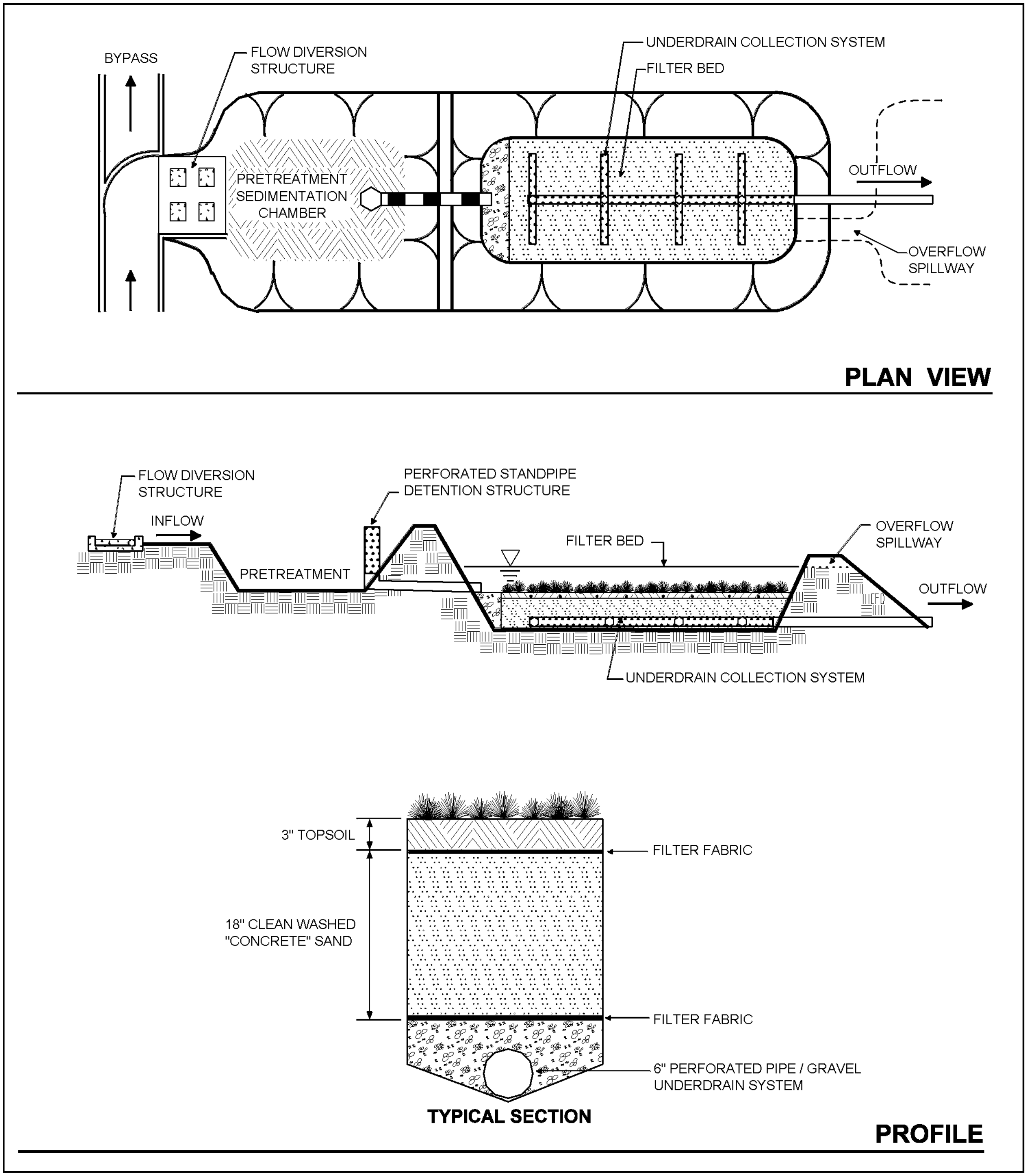

Figure 3.2. Schematic of Surface Sand Filter (Source: Center for Watershed Protection).

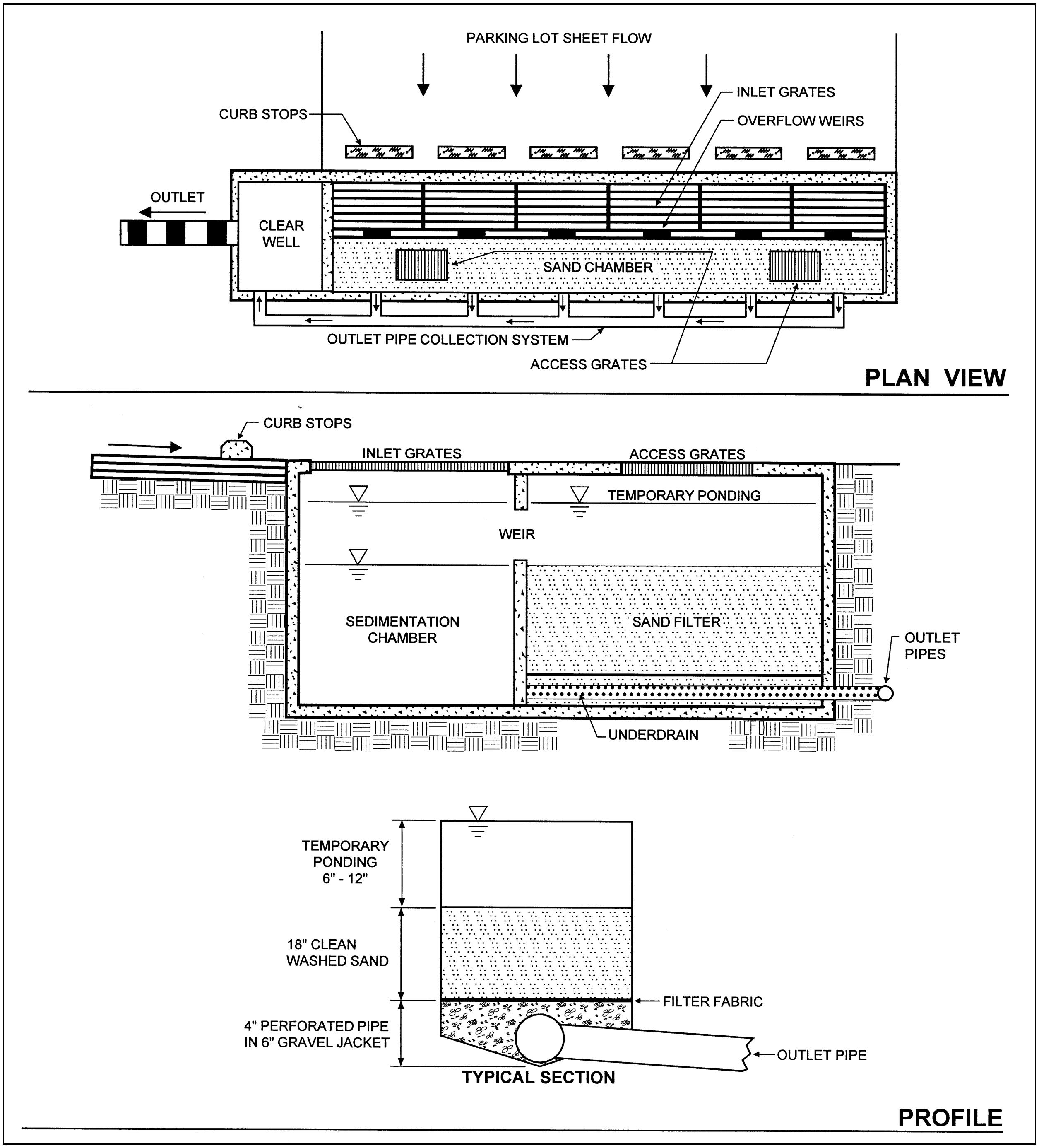

Figure 3.3. Schematic of Perimeter Sand Filter. (Source: Center for Watershed Protection).

SECTION 5: SITE FEASIBILITY & DESIGN APPLICATIONS

Sand filter systems are well suited for highly impervious areas where land available for structural controls is limited. Sand filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as: parking lots, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards. Sand filters may also be feasible and appropriate in some multi-family or higher density residential developments.

To avoid rapid clogging and failure of the filter media, the use of sand filters should be avoided in areas with less than 50% impervious cover, or high sediment yield sites with clay/silt soils.

The following basic criteria should be evaluated to ensure the suitability of a sand filter facility for meeting stormwater management objectives on a site or development.

General Feasibility

- Suitable for Residential Subdivision Usage – NO
- Suitable for High Density/Ultra Urban Areas – YES
- Regional Stormwater Control – NO

Physical Feasibility - Physical Constraints at Project Site

- <u>Drainage Area</u> – 10 acres maximum for surface sand filter; 2 acres maximum for perimeter sand filter
- <u>Space Required</u> – Function of available head at site
- <u>Site Slope</u> – No more than 6% slope across filter location
- <u>Minimum Head</u> – Elevation difference needed at a site from the inflow to the outflow: 5 ft for surface sand filters; 2 to 3 ft for perimeter sand filters
- <u>Minimum Depth to Water Table</u> – For a surface sand filter with exfiltration (earthen structure), 2 ft are required between the bottom of the sand filter and the elevation of the seasonally high water table
- <u>Soils</u> – No restrictions; Group "A" soils generally required to allow exfiltration (for surface sand filter earthen structure)

Other Constraints / Considerations

- <u>Aquifer Protection</u> – Do not allow exfiltration of filtered runoff into groundwater from areas with potential for high pollutant loading.

SECTION 6: PLANNING AND DESIGN CRITERIA

The following criteria are to be considered minimum standards for the design of a sand filter facility.

Location and Siting

- Surface sand filters should have a contributing drainage area of 10 acres or less. The maximum drainage area for a perimeter sand filter is 2 acres.
- Sand filter systems are generally applied to land uses with a high percentage of impervious surfaces. Sites with less than 50% imperviousness or high clay/silt sediment loads must not use a sand filter without adequate pretreatment due to potential clogging and failure of the filter bed. Any disturbed areas within the sand filter facility drainage area should be identified and stabilized. Filtration controls should only be constructed after the construction site is stabilized.
- Surface sand filters are generally used in an off-line configuration where the water quality volume (WQ_v) is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Stormwater flows greater than the WQ_v are diverted to other controls or downstream using a diversion structure or flow splitter.
- Perimeter sand filters are typically sited along the edge, or perimeter, of an impervious area such as a parking lot.
- Sand filter systems are designed for intermittent flow and must be allowed to drain and reaerate between rainfall events. They should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

General Design

- *Surface Sand Filter*
  - A surface sand filter facility consists of a two-chamber open-air structure, which is located at ground-level. The first chamber is the sediment forebay (a.k.a sedimentation chamber) while the second chamber houses the sand filter bed. Flow enters the sedimentation chamber where settling of larger sediment particles occurs. Runoff is then discharged from the sedimentation chamber through a perforated standpipe into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system. Figure 3.2 provides plan view and profile schematics of a surface sand filter.

- *Perimeter Sand Filter*
  - A perimeter sand filter facility is a vault structure located just below grade level. Runoff enters the device through inlet grates along the top of the structure into the sedimentation chamber. Runoff is discharged from the sedimentation chamber through a weir into the filtration chamber. After passing though the filter bed, runoff is collected by a perforated pipe and gravel underdrain system. Figure 3.3 provides plan view and profile schematics of a perimeter sand filter.

Physical Specificiations / Geometry

- *Surface Sand Filter*
  - The entire treatment system (including the sedimentation chamber) must temporarily hold at least 75% of the WQ_v prior to filtration. Figure 3.4 illustrates the distribution of the treatment volume (0.75 WQ_v) among the various components of the surface sand filter, including:
    - V_s – volume within the sedimentation basin

- V_f – volume within the voids in the filter bed
- $V_{f\text{-temp}}$ – temporary volume stored above the filter bed
- A_s – the surface area of the sedimentation basin
- Af – surface area of the filter media
- hs – height of water in the sedimentation basin
- hf – average height of water above the filter media
- df – depth of filter media

- The sedimentation chamber must be sized to at least 25% of the computed WQ_v and have a length-to-width ratio of at least 2:1. Inlet and outlet structures should be located at opposite ends of the chamber.
- The filter area is sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand should be used. The filter bed is typically designed to completely drain in 40 hours or less.

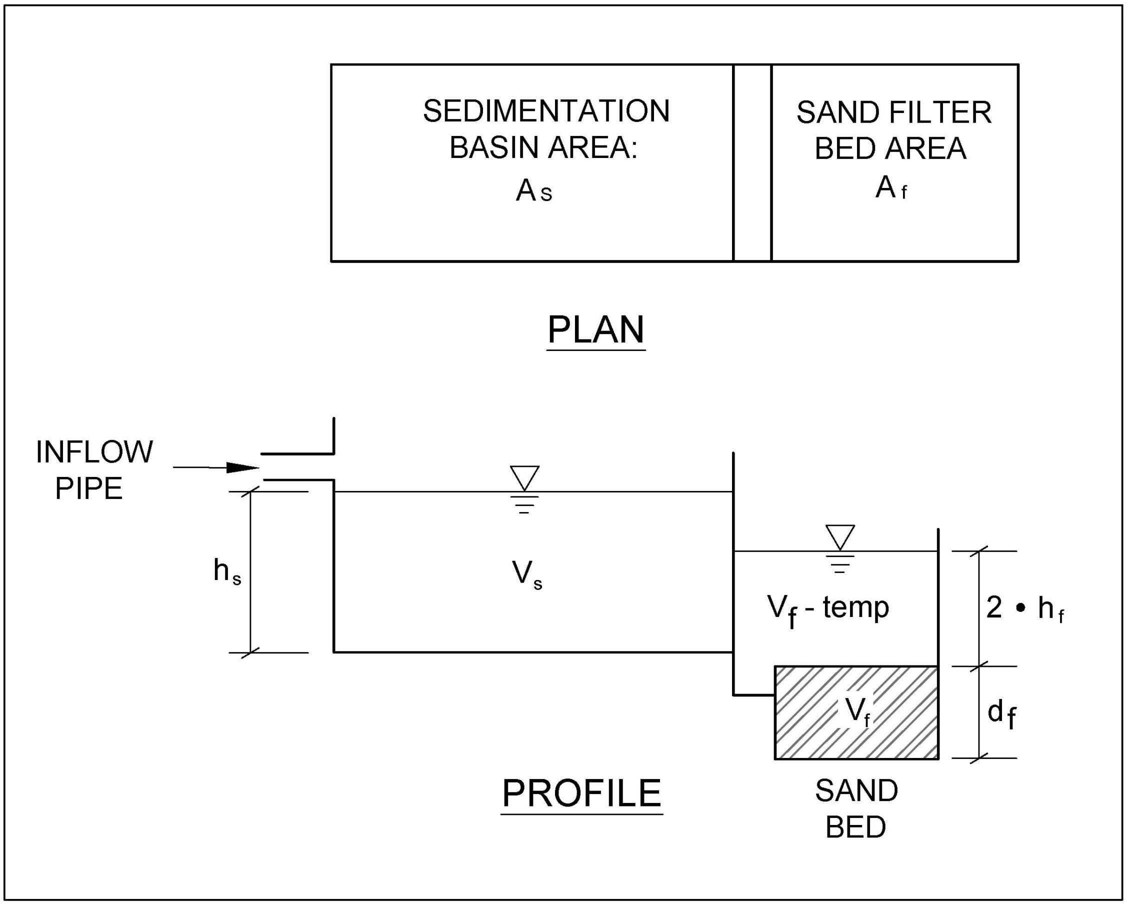

Figure 3.4. Surface Sand Filter Volumes (Source: Clayton and Schueler, 1996).

- The filter media consists of an 18-inch layer of clean washed medium sand (meeting ASTM C-33 concrete sand) on top of the underdrain system. Three inches of topsoil are placed over the sand bed. Permeable filter fabric is placed both above and below the sand bed to prevent clogging of the sand filter and the underdrain system. Figure 3.6 illustrates a typical media cross section.
  - The filter bed is equipped with a 6-inch perforated PVC pipe (AASHTO M 252) underdrain in a gravel layer. The underdrain must have a minimum grade of 1/8-inch per foot (1% slope). Holes should be 3/8-inch diameter and spaced approximately 6 inches on center. Gravel should be clean washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40%. Aggregate contaminated with soil shall not be used.
  - The structure of the surface sand filter may be constructed of impermeable media such as concrete, or through the use of excavations and earthen embankments. When constructed with earthen walls/embankments, filter fabric should be used to line the bottom and side slopes of the structures before installation of the underdrain system and filter media.

- *Perimeter Sand Filter*
  - The entire treatment system (including the sedimentation chamber) must temporarily hold at least 75% of the WQ_v prior to filtration. Figure 3.5 illustrates the distribution of the treatment volume (0.75 WQ_v) among the various components of the perimeter sand filter, including:
    - V_w – wet pool volume within the sedimentation basin
    - V_f – volume within the voids in the filter bed
    - V_{temp} – temporary volume stored above the filter bed
    - A_s – the surface area of the sedimentation basin
    - A_f – surface area of the filter media
    - h_f – average height of water above the filter media (1/2 h_{temp})
    - d_f – depth of filter media
  - The sedimentation chamber must be sized to at least 50% of the computed WQ_v.
  - The filter area is sized based on the principles of Darcy's Law. A coefficient of permeability (k) of 3.5 ft/day for sand should be used. The filter bed is typically designed to completely drain in 40 hours or less.
    - The filter media should consist of a 12- to 18-inch layer of clean washed medium sand (meeting ASTM C-33 concrete sand) on top of the underdrain system. Figure 3.6 illustrates a typical media cross section.
    - The perimeter sand filter is equipped with a 4 inch perforated PVC pipe (AASHTO M 252) underdrain in a gravel layer. The underdrain must have a minimum grade of 1/8 inch per foot (1% slope). Holes should be 3/8-inch diameter and spaced approximately 6 inches on center. A permeable filter fabric should be placed between the gravel layer and the filter media. Gravel should be clean washed aggregate with a maximum diameter of 3.5 inches and a minimum diameter of 1.5 inches with a void space of about 40%. Aggregate contaminated with soil shall not be used.

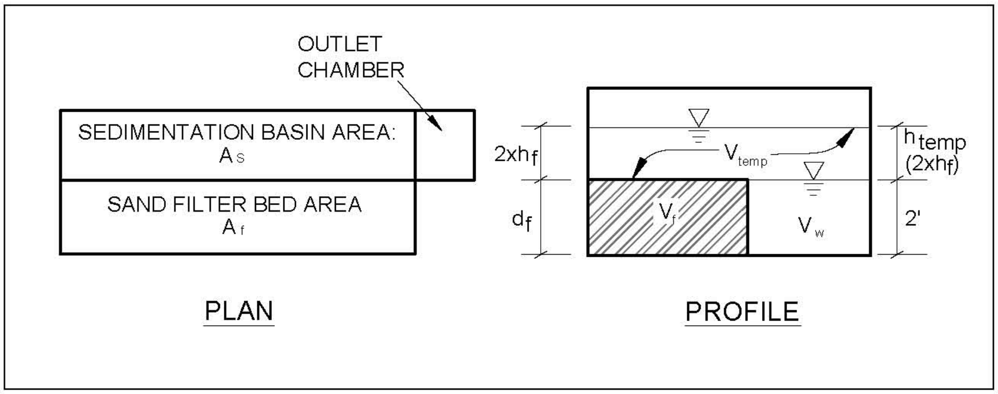

Figure 3.5. Perimeter Sand Filter Volumes (Source: Clayton and Schueler, 1996).

Pretreatment / Inlets

- Pretreatment of runoff in a sand filter system is provided by the sedimentation chamber.
- Inlets to surface sand filters are to be provided with energy dissipators. Exit velocities from the sedimentation chamber must be nonerosive.
- Figure 3.7 shows a typical inlet pipe from the sedimentation basin to the filter media basin for the surface sand filter.

Outlet Structures

- Outlet pipe is to be provided from the underdrain system to the facility discharge. Due to the slow rate of filtration, outlet protection is generally unnecessary (except for emergency overflows and spillways).

Emergency Spillway

- An emergency or bypass spillway must be included in the surface sand filter to safely pass flows that exceed the design storm flows. The spillway prevents filter water levels from overtopping the embankment and causing structural damage. The emergency spillway should be located so that downstream buildings and structures will not be impacted by spillway discharges.

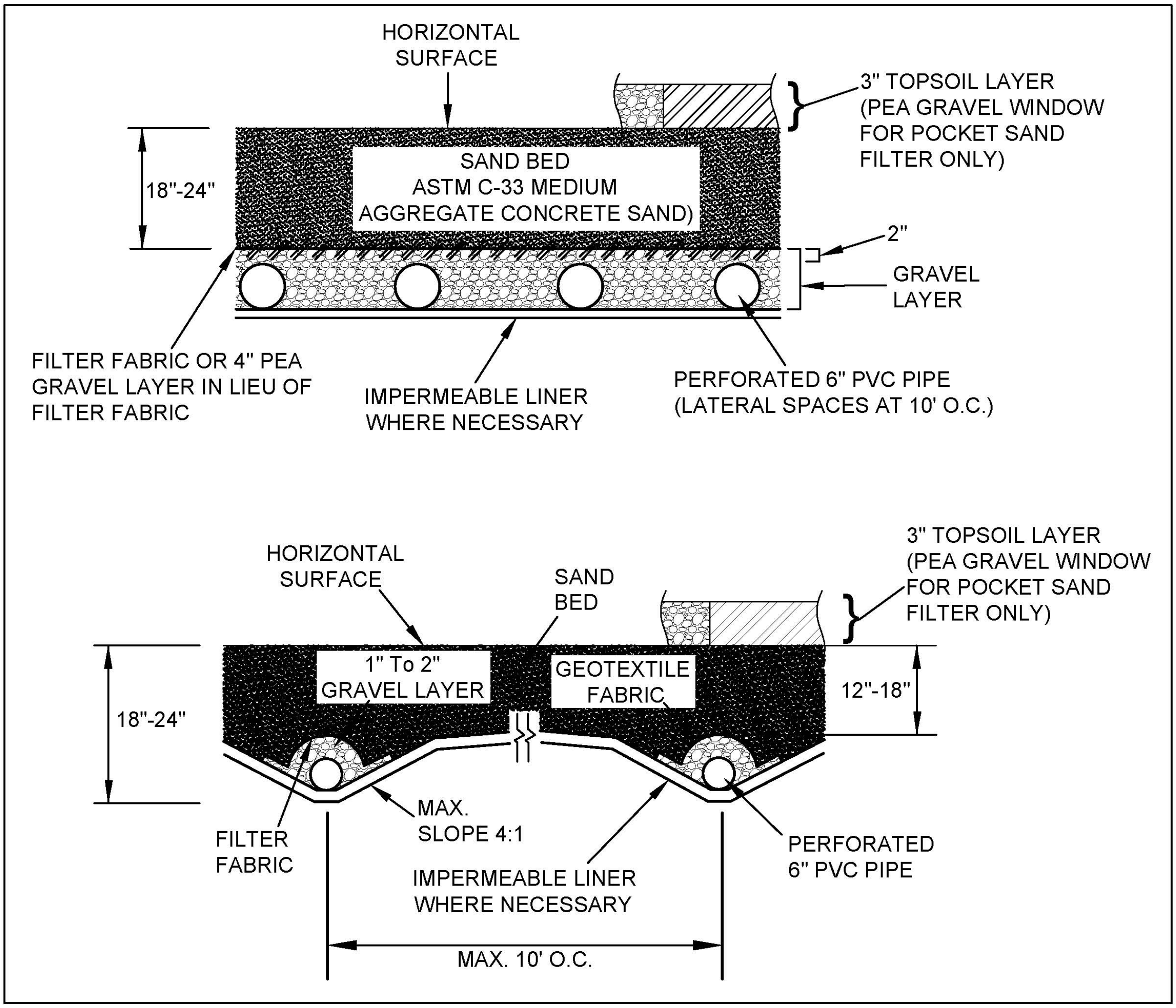

Figure 3.6.Typical Sand Filter Media Cross Sections (Source: Clayton and Schueler, 1996).

Maintenance Access

- Adequate access must be provided for all sand filter systems for inspection and maintenance, including the appropriate equipment and vehicles. Access grates to the filter bed need to be included in a perimeter sand filter design. Facility designs must enable maintenance personnel to easily replace upper layers of the filter media.

Safety Features

- Surface sand filter facilities can be fenced to prevent access. Inlet and access grates to perimeter sand filters may be locked.

Landscaping

- Surface filters can be designed with a grass cover to aid in pollutant removal and prevent clogging. The grass should be capable of withstanding frequent periods of inundation and drought.

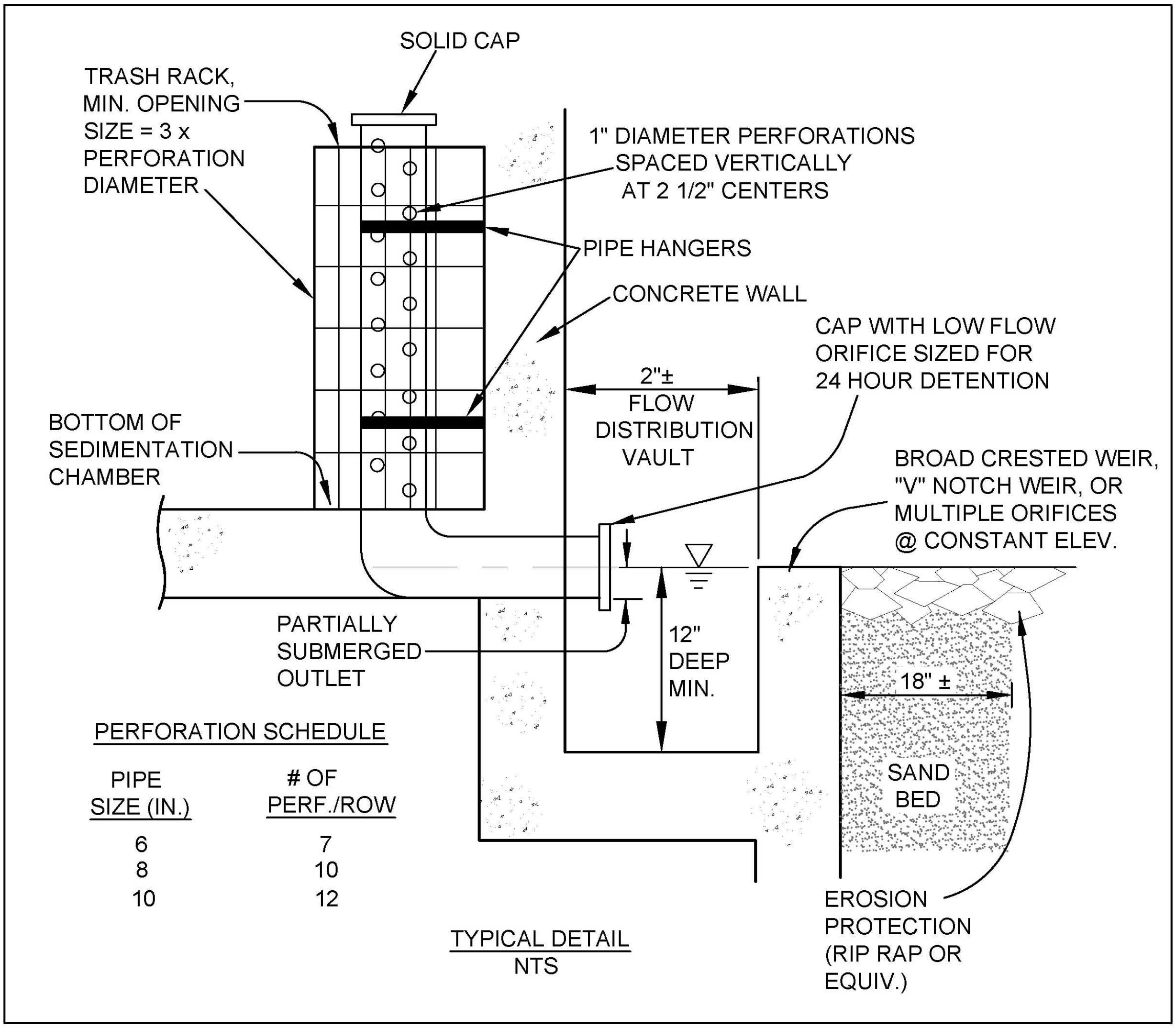

Figure 3.7. Surface Sand Filter Perforated Stand-Pipe (Source: Clayton and Schueler, 1996).

Additional Site-Specific Design Criteria and Issues

- Physiographic Factors - Local terrain design constraints
  - Low Relief – Use of surface sand filter may be limited by low head
  - High Relief – Filter bed surface must be level
  - Karst – Use polyliner or impermeable membrane to seal bottom of earthen surface sand filter or use watertight structure

- Soils
  - No restrictions
- Special Downstream Watershed Considerations
  - Aquifer Protection – Use polyliner or impermeable membrane to seal bottom of earthen surface sand filter or use watertight structure; no exfiltration of filter runoff into groundwater

SECTION 7: DESIGN PROCEDURES

Step 1. Compute runoff control volumes from the Unified Stormwater Sizing Criteria

Calculate the Water Quality Volume (WQ_v), Channel Protection Volume (Cp_v), Overbank Flood Protection Volume (Q_p), and the Extreme Flood Volume (Q_f).

Details on the Stormwater Sizing Criteria are found in Chapter 2.

Step 2. Determine if the development site and conditions are appropriate for the use of a surface or perimeter sand filter.

Consider the Application and Site Feasibility Criteria in Section 6 of this specification (Location and Siting).

Step 3. Confirm local design criteria and applicability

Consider any special site-specific design conditions/criteria from Section 6 of this specification (Additional Site-Specific Design Criteria and Issues).

Check with City Engineer to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.

Step 4. Compute WQ_v peak discharge (Q_{wq})

The peak rate of discharge for water quality design storm is needed for sizing of off-line diversion structures (see Chapter 3).

1. Using WQ_v, compute CN
2. Compute time of concentration using TR-55 method
3. Determine appropriate unit peak discharge from time of concentration
4. Compute Q_{wq} from unit peak discharge, drainage area, and WQ_v.

Step 5. Size flow diversion structure, if needed

A flow regulator (or flow splitter diversion structure) should be supplied to divert the WQ_v to the sand filter facility.

Size low flow orifice, weir, or other device to pass Q_{wq}.

Step 6. Size filtration basin chamber

The filter area is sized using the following equation (based on 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
(typically 18 inches, no more than 24 inches)
k = coefficient of permeability of filter media (ft/day)
(use 3.5 ft/day for sand)
h_f = average height of water above filter bed (ft)
(1/2 h_{max}, which varies based on site but h_{max} is typically $\leq$ 6 ft)
t_f = design filter bed drain time (days)
(1.67 days or 40 hours is recommended maximum)

Set preliminary dimensions of filtration basin chamber.

See subsection 4.6.4.5-C (Physical Specifications/Geometry) for filter media specifications.

Step 7. Size sedimentation chamber

Surface sand filter: The sedimentation chamber should be sized to at least 25% of the computed WQ_v and have a length-to-width ratio of 2:1. The Camp-Hazen equation is used to compute the required surface area:

$$A_s = -(Q_o/w) * Ln(1-E)$$

Where:
A_s = sedimentation basin surface area (ft^2)
Q_o = rate of outflow = the WQ_v over a 24-hour period
w = particle settling velocity (ft/sec)
E = trap efficiency

Assuming:

- 90% sediment trap efficiency (0.9)
- particle settling velocity (ft/sec) = 0.0033 ft/sec for imperviousness < 75%
- particle settling velocity (ft/sec) = 0.0004 ft/sec for imperviousness $\geq$ 75%
- average of 24 hour holding period

Then:
A_s = (0.066) (WQ_v) ft^2 for I < 75%
A_s = (0.0081) (WQ_v) ft^2 for I $\geq$ 75%

Set preliminary dimensions of sedimentation chamber.

Perimeter sand filter: The sedimentation chamber should be sized to at least 50% of the computed WQ_v. Use same approach as for surface sand filter.

Step 8. Compute V_{min}

$V_{min} = 0.75 * WQ_v$

Step 9. Compute storage volumes within entire facility and sedimentation chamber orifice size

Surface sand filter:

$$\mathbf{V_{min} = 0.75\ WQ_v = V_s + V_f + V_{f\text{-}temp}}$$

1. Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
   Where: n = porosity = 0.4 for most applications
2. Compute $V_{f\text{-}temp}$ = temporary storage volume above the filter bed = $2 * h_f * A_f$
3. Compute V_s = volume within sediment chamber = $V_{min} - V_f - V_{f\text{-}temp}$
4. Compute h_s = height in sedimentation chamber = V_s/A_s
5. Ensure h_s and h_f fit available head and other dimensions still fit – change as necessary in design iterations until all site dimensions fit.
6. Size orifice from sediment chamber to filter chamber to release V_s within 24-hours at average release rate with 0.5 h_s as average head.
7. Design outlet structure with perforations allowing for a safety factor of 10 (see example)
8. Size distribution chamber to spread flow over filtration media – level spreader weir or orifices.

Perimeter sand filter:

1. Compute V_f = water volume within filter bed/gravel/pipe = $A_f * d_f * n$
2. Where: n = porosity = 0.4 for most applications
3. Compute V_w = wet pool storage volume A_s * 2 ft minimum
4. Compute V_{temp} = temporary storage volume = $V_{min} – (V_f + V_w)$
5. Compute h_{temp} = temporary storage height = $V_{temp} / (A_f + A_s)$
6. Ensure $h_{temp} \geq 2 * h_f$, otherwise decrease h_f and re-compute. Ensure dimensions fit available head and area – change as necessary in design iterations until all site dimensions fit.
7. Size distribution slots from sediment chamber to filter chamber.

Step 10. Design inlets, pretreatment facilities, underdrain system, and outlet structures

See Section 6 of this specification for more details.

Step 11. Compute overflow weir sizes

***Surface sand filter*:**

1. Size overflow weir at elevation h_s in sedimentation chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm (see example).
   Plan inlet protection for overflow from sedimentation chamber and size overflow weir at elevation h_f in filtration chamber (above perforated stand pipe) to handle surcharge of flow through filter system from 25-year storm (see example).

Perimeter sand filter:

1. Size overflow weir at end of sedimentation chamber to handle excess inflow, set at WQ_v elevation.

SECTION 8: INSPECTION AND MAINTENANCE REQUIRMENTS

Table 3.1. Typical Maintenance Activities for Sand Filters (Source: WMI, 1997; Pitt, 1997.)

Activity	Schedule
• Ensure that contributing area, facility, inlets and outlets are clear of debris. • Ensure that the contributing area is stabilized and mowed, with clippings removed. • Remove trash and debris. • Check to ensure that the filter surface is not clogging (also check after moderate and major storms). • Ensure that activities in the drainage area minimize oil/grease and sediment entry to the system. • If permanent water level is present (perimeter sand filter), ensure that the chamber does not leak, and normal pool level is retained.	Monthly
• Check to see that the filter bed is clean of sediment, and the sediment chamber is not more than 50% full or 6 inches, whichever is less, of sediment. Remove sediment as necessary. • Make sure that there is no evidence of deterioration, spalling or cracking of concrete. • Inspect grates (perimeter sand filter). • Inspect inlets, outlets and overflow spillway to ensure good condition and no evidence of erosion. • Repair or replace any damaged structural parts. • Stabilize any eroded areas. • Ensure that flow is not bypassing the facility. • Ensure that no noticeable odors are detected outside the facility.	Annually
• If filter bed is clogged or partially clogged, manual manipulation of the surface layer of sand may be required. Remove the top few inches of sand, roto-till or otherwise cultivate the surface, and replace media with sand meeting the design specifications. • Replace any filter fabric that has become clogged.	As needed

Additional Maintenance Considerations and Requirements

- A record should be kept of the dewatering time for a sand filter to determine if maintenance is necessary.
- When the filtering capacity of the sand filter facility diminishes substantially (i.e., when water ponds on the surface of the filter bed for more than 48 hours), then the top layers of the filter media (topsoil and 2 to 3 inches of sand) will need to be removed and replaced. This will typically need to be done every 3 to 5 years for low sediment applications, more often for areas of high sediment yield or high oil and grease.
- Removed sediment and media may usually be disposed of in a landfill.

SECTION 9: REFERENCES

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Weather Flow Collection and Treatment Systems for Newly Urbanized Areas. US EPA. Office of Research and Development.

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ORGANIC FILTER

Description: Design variant of the surface sand filter using organic materials in the filter media.

Advantages/Benefits:	Disadvantages/Limitations:
• Can be used in high density/ultra urban areas • High pollutant removal capability	• High maintenance requirements • Severe clogging potential if exposed soil surfaces exist upstream

Design Considerations:

- Intended for areas with potential for high pollutant loading or space limited applications requiring enhanced pollutant removal capability
- Removal of dissolved pollutants is greater than sand filter due to cation exchange capacity
- Minimum head requirement of 5 to 8 ft

Stormwater Management Capability:

- Water quality benefits can provide 80% TSS removal.

Land Use Considerations:

	Residential
X	**Commercial**
X	**Industrial**

Maintenance:

- Sediment and debris must be removed periodically
- Check media for clogging
- Replace media as needed

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

SECTION 1: DESCRIPTION

The organic filter is a design variant of the surface sand filter, which uses organic materials such as leaf compost or a peat/sand mixture as the filter media. The organic material enhances pollutant removal by providing adsorption of contaminants such as soluble metals, hydrocarbons, and other organic chemicals.

As with the surface sand filter, an organic filter consists of a pretreatment chamber, and one or more filter cells. Each filter bed contains a layer of leaf compost or the peat/sand mixture, followed by filter fabric and a gravel/perforated pipe underdrain system. The filter bed and subsoils can be separated by an impermeable polyliner or concrete structure to prevent movement into groundwater.

Organic filters are typically used in high-density applications, or for areas requiring an enhanced pollutant removal ability. Maintenance is typically higher than the surface sand filter facility due to the potential for clogging. In addition, organic filter systems have a higher head requirement than sand filters.

SECTION 2: POLLUTANT REMOVAL CAPABILITIES

Peat/sand filter systems provide good removal of bacteria and organic waste metals.
The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – 60%**
- **Total Nitrogen – 40%**
- **Fecal Coliform – 50%**
- **Heavy Metals – 75%**

SECTION 3: DESIGN CRITERIA AND SPECIFICATIONS

- Organic filters are typically used on relatively small sites (up to 10 acres), to minimize potential clogging.
- The minimum head requirement (elevation difference needed at a site from the inflow to the outflow) for an organic filter is 5 to 8 ft.
- Organic filters can utilize a variety of organic materials as the filtering media. Two typical media bed configurations are the peat/sand filter and compost filter (see Figure 4.1). The peat filter includes an 18-inch 50/50 peat/sand mix over a 6-inch sand layer and can be optionally covered by 3 inches of topsoil and vegetation. The compost filter has an 18-inch compost layer. Both variants utilize a gravel underdrain system.
- The type of peat used in a peat/sand filter is critically important. Fibric peat in which undecomposed fibrous organic material is readily identifiable is the preferred type. Hemic peat containing more decomposed material may also be used. Sapric peat made up of largely decomposed matter should *not* be used in an organic filter.

- Typically, organic filters are designed as "off-line" systems, meaning that the water volume (WQ_v) is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Stormwater flows greater than the WQ_v are diverted to other controls or downstream using a diversion structure or flow splitter.
- Consult the design criteria for the surface sand filter (see WSC-03, Sand Filters, in Appendix F) for the organic filter sizing and design steps.

SECTION 4: TYPICAL SCHEMATIC DETAILS

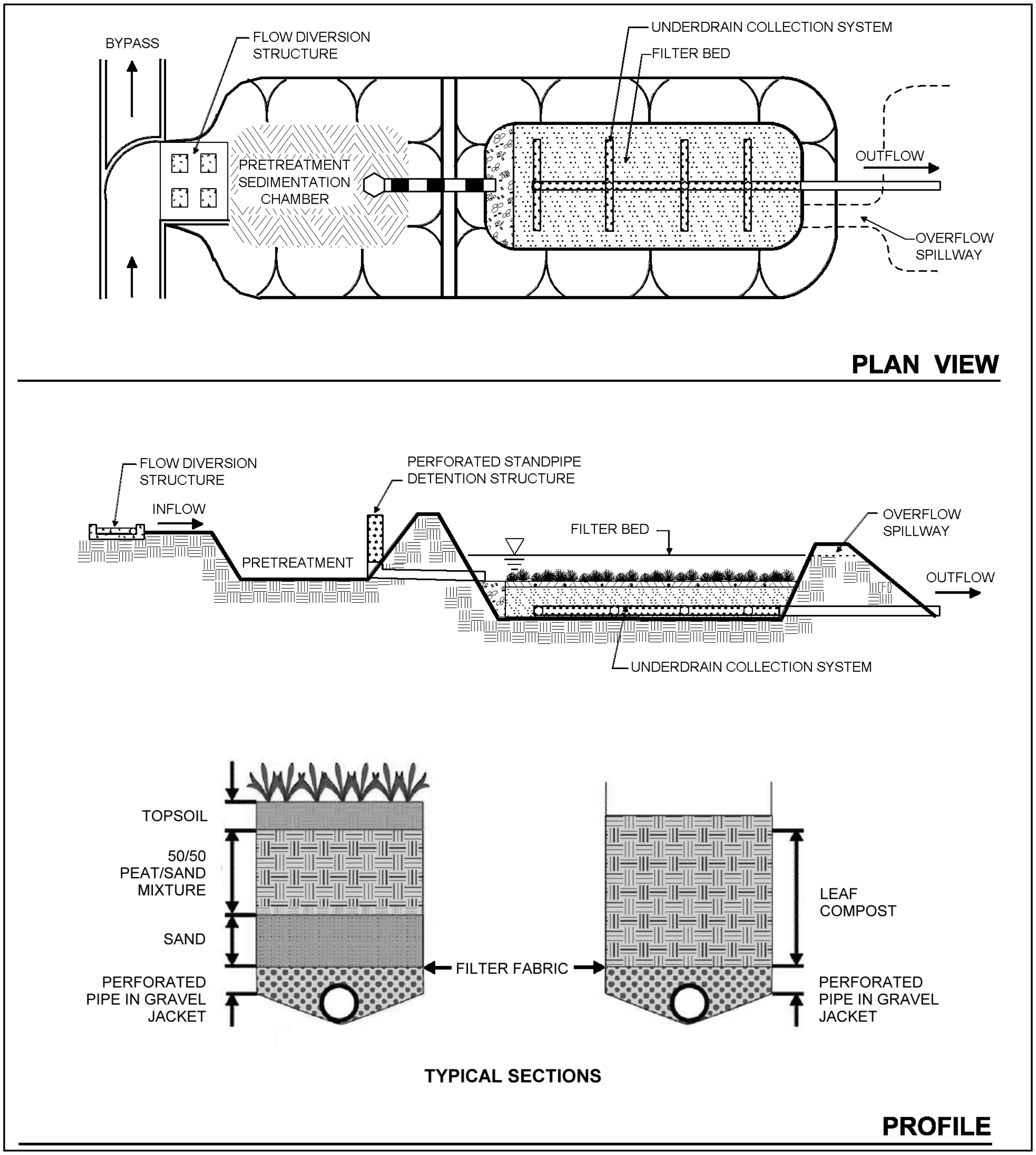

Figure 4.1. Schematic of Organic Filter (Source: Center for Watershed Protection).

SECTION 5: INSPECTION AND MAINTENANCE REQUIREMENTS

The inspection and maintenance requirements for organic filters are similar to those for surface sand filter facilities (see WSC-03, Sand Filter, in Appendix F)

SECTION 6: REFERENCES

Atlanta Regional Commission. 2001. *Georgia Stormwater Management Manual, Volume 2: Technical Handbook.* Atlanta, GA. http://www.georgiastormwater.com/GSMMVol2.pdf

Center for Watershed Protection (CWP), 1996. Design of Stormwater Filtering Systems. Prepared for Chesapeake Research Consortium.

UNDERGROUND SAND FILTER

Description: Design variant of the surface sand filter using organic materials in the filter media.

Advantages/Benefits:	Disadvantages/Limitations:
• Can be used in high density/ultra urban areas • High pollutant removal capability	• High maintenance requirements

Design Considerations:
• Intended for areas with potential for high pollutant loading or space limited applications requiring enhanced pollutant removal capability • High removal rates for sediment, BOD, and fecal coliform bacteria • Precast concrete shells are available, which decrease construction costs

Stormwater Management Capability:

- Water quality benefits can provide 80% TSS removal.

Land Use Considerations:

	Residential
X	Commercial
X	Industrial

Maintenance:

- Monitor water level in sand filter chamber
- Sedimentation chamber should be cleaned out when the sediment depth reaches 12 inches
- Remove accumulated oil and floatables in the sedimentation chamber

H

Maintenance Burden

L = Low M = Moderate H = High

SECTION 1: DESCRIPTION

The underground sand filter is a design variant of the sand filter located in an underground vault designed for high-density land use or ultra-urban applications where there is not enough space for a surface sand filter or other structural stormwater controls.

The underground sand filter is a three-chamber system. The initial chamber is a sedimentation (pretreatment) chamber that temporarily stores runoff and utilizes a wet pool to capture sediment. The sedimentation chamber is connected to the sand filter chamber by a submerged wall that protects the filter bed from oil and trash. The filter bed is 18 to 24 inches deep and may have a protective screen of gravel or permeable geotextile to limit clogging. The sand filter chamber also includes an underdrain system with inspection and clean out wells. Perforated drain pipes under the sand filter bed extend into a third chamber that collects filtered runoff. Flows beyond the filter capacity are diverted through an overflow weir.

Due to its location below the surface, underground sand filters have a high maintenance burden and should only be used where adequate inspection and maintenance can be ensured.

SECTION 2: GUIDELINES FOR USING PROPRIETARY SYSTEMS

Underground sand filter pollutant removal rates are similar to those for surface and perimeter sand filters (see WSC-03, Sand Filters, in Appendix F).

SECTION 3: DESIGN CRITERIA AND SPECIFICATIONS

- Underground sand filters are typically used on highly impervious sites of 1 acre or less. The maximum drainage area that should be treated by an underground sand filter is 5 acres.
- Underground sand filters are typically constructed on-line, but can be constructed off-line. For off-line construction, the overflow between the second and third chambers is not included.
- The underground vault should be tested for water tightness prior to placement of filter layers.
- Adequate maintenance access must be provided to the sedimentation and filter bed chambers.
- Compute the minimum wet pool volume required in the sedimentation chamber as:

  $\mathbf{V_w = A_s * 3}$ **ft minimum**
- Consult the design criteria for the perimeter sand filter (see Section 4.6.4) for the rest of the underground filter sizing and design steps.

SECTION 4: TYPCIAL SCHEMATIC DETAILS

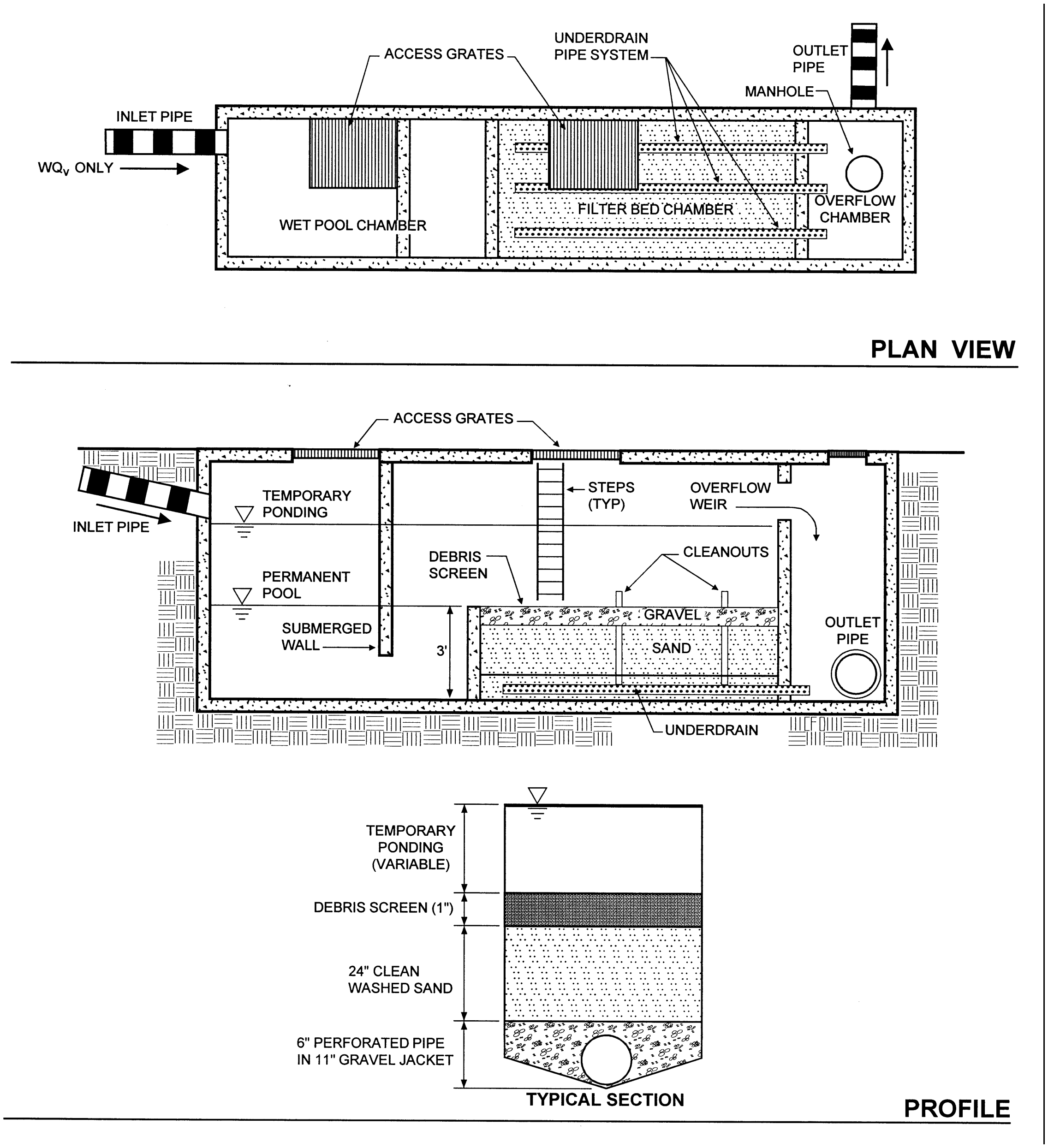

Figure 4.1. Schematic of Underground Sand Filter (Source: Center for Watershed Protection).

SECTION 5: INSPECTION AND MAINTENANCE REQUIREMENTS

Table 5.1 .Typical Maintenance Activities for Underground Sand Filters (Source: CWP, 1996).

Activity	Schedule
• Monitor water level in sand filter chamber.	Quarterly and following large storm events
• Sedimentation chamber should be cleaned out when the sediment depth reaches 12 inches.	As needed
• Remove accumulated oil and floatables in sedimentation chamber.	As needed, (typically every 6 months)

Additional inspection and maintenance requirements for organic filters are similar to those for surface sand filter facilities (see WSC-03, Sand Filters, in Appendix F)

SECTION 6: REFERENCES

Atlanta Regional Commission. 2001. *Georgia Stormwater Management Manual, Volume 2: Technical Handbook.* Atlanta, GA. http://www.georgiastormwater.com/GSMMVol2.pdf

Center for Watershed Protection (CWP), 1996. Design of Stormwater Filtering Systems. Prepared for Chesapeake Research Consortium.

SUBMERGED GRAVEL WETLANDS

Description: One or more cells filled with crushed rock designed to support wetland plants. Stormwater flows subsurface through the root zone of the constructed wetland where pollutant removal takes place.

Advantages/Benefits:	Disadvantages/Limitations:
• Can be used in high density/ultra urban areas	• High maintenance requirements • Limited performance data exists

Design Considerations:

- Generally requires low land consumption, and can fit within an area that is typically devoted to landscaping
- Can be located in low-permeability soils with a high water table
- Periodic sediment removal required to prevent clogging of gravel base

Stormwater Management Capability:

- Water quality benefits can provide 80% TSS removal.

Land Use Considerations:

	Residential
X	**Commercial**
X	**Industrial**

Maintenance:

- Ensure that inlets and outles to each submerged gravel wetland cell are free from debris and not clogged
- Check for sediment buildup in gravel bed
- Replace with clean gravel and replant vegetation as needed.

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

SECTION 1: DESCRIPTION

The submerged gravel wetland system consists of one or more treatment cells that are filled with crushed rock or gravel and is designed to allow stormwater to flow subsurface through the root zone of the constructed wetland. The outlet from each cell is set at an elevation to keep the rock or gravel submerged. Wetland plants are rooted in the media, where they can directly take up pollutants. In addition, algae and microbes thrive on the surface area of the rocks. In particular, the anaerobic conditions on the bottom of the filter can foster the denitrification process. Although widely used for wastewater treatment in recent years, only a handful of submerged gravel wetland systems have been designed to treat stormwater. Mimicking the pollutant removal ability of nature, this structural control relies on the pollutant-stripping ability of plants and soils to remove pollutants from runoff.

SECTION 2: POLLUTANT REMOVAL CAPABILITIES

The pollution removal efficiency of the submerged gravel wetland is similar to a typical wetland. Recent data show a TSS removal rate in excess of the 80% goal. This reflects the settling environment of the gravel media. These systems also exhibit removals of about 60% TP, 20% TN, and 50% Zn. The growth of algae and microbes among the gravel media has been determined to be the primary removal mechanism of the submerged gravel wetland.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment.

- **Total Suspended Solids – 80%**
- **Total Phosphorus – 50%**
- **Total Nitrogen – 20%**
- **Fecal Coliform – 70%**
- **Heavy Metals – 50%**

SECTION 3: DESIGN CRITERIA AND SPECIFICATIONS

- Submerged gravel wetlands should be designed as off-line systems designed to handle only water quality volume.
- Submerged gravel wetland systems need sufficient drainage area to maintain vegetation.
- The local slope should be relatively flat (<2%). While there is no minimum slope requirement, there does need to be enough elevation drop from the inlet to the outlet to ensure that hydraulic conveyance by gravity is feasible (generally about 3 to 5 ft).
- All submerged gravel wetland designs should include a sediment forebay or other equivalent pretreatment measures to prevent sediment or debris from entering and clogging the gravel bed.
- Unless they receive runoff from areas with potential for high pollutant loading, submerged gravel wetland systems can be allowed to intersect the groundwater table.
- See WSC-02, Stormwater Wetlands in Appendix F for additional planning and design guidance.

SECTION 4: TYPICAL SCHEMATIC DETAILS

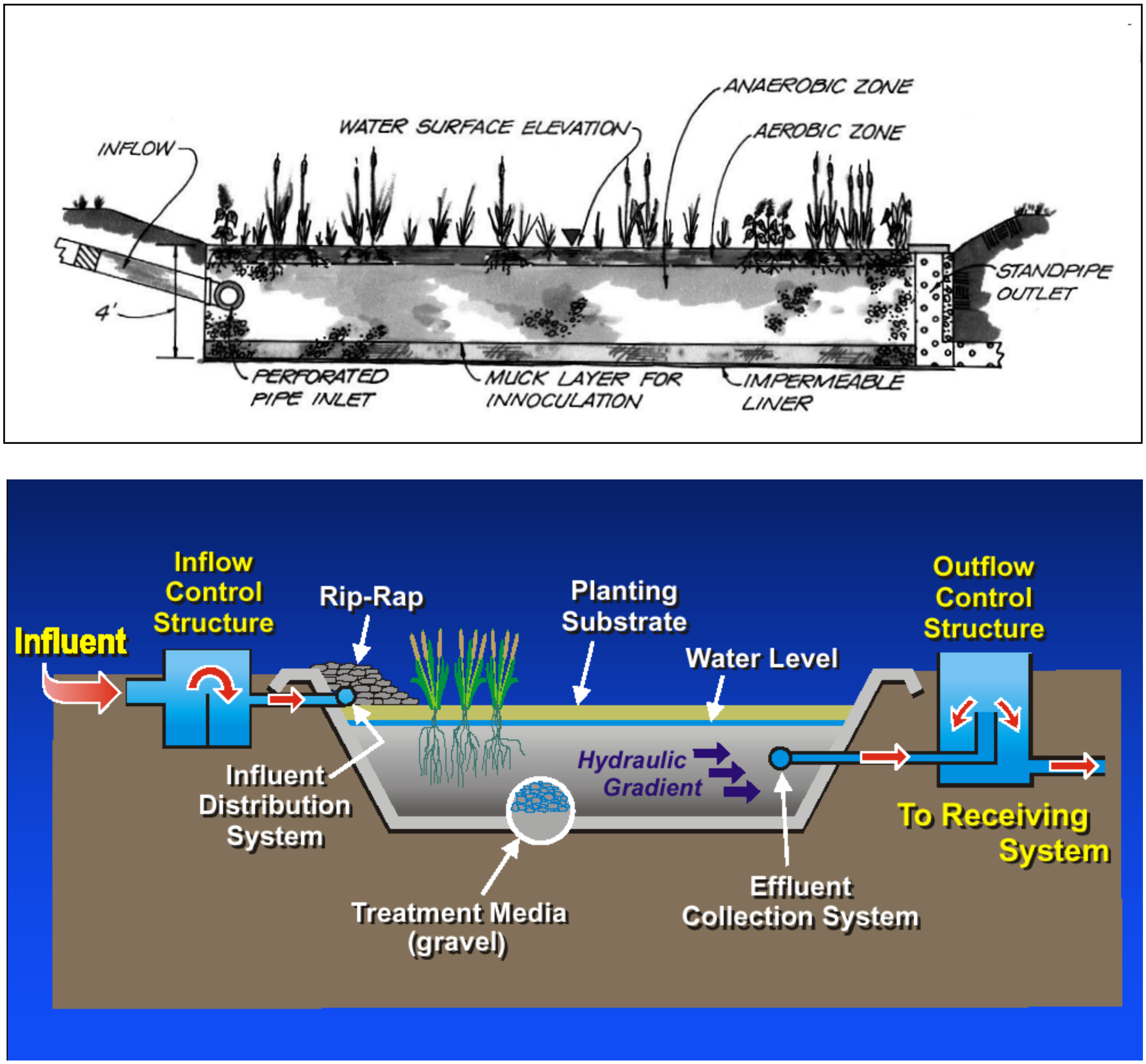

Figure 6.1. Schematic of Submerged Gravel Wetland System
(Source: Center for Watershed Protection; Roux Associates, Inc.).

SECTION 5: INSPECTION AND MAINTENANCE REQUIREMENTS

The inspection and maintenance requirements for organic filters are similar to those for surface sand filter facilities (see WSC-03, Sand Filter, in Appendix F)

SECTION 6: REFERENCES

Atlanta Regional Commission. 2001. *Georgia Stormwater Management Manual, Volume 2: Technical Handbook.* Atlanta, GA. http://www.georgiastormwater.com/GSMMVol2.pdf

Center for Watershed Protection (CWP), 1996. Design of Stormwater Filtering Systems. Prepared for Chesapeake Research Consortium.

GRAVITY (OIL-GRIT) SEPARATOR

Description: Hydrodynamic separation device designed to remove settleable solids, oil and grease, debris and floatables from stormwater runoff through gravitational settling and trapping of pollutants.

Advantages/Benefits:	Disadvantages/Limitations:
• Can be used in high density/ultra urban areas	• Cannot alone achieve the 80% TSS removal target • Limited performance data
Design Considerations:	
• Intended for the removal of settleable solids (grit and sediment) and floatable matter, including oil and grease • Dissolved pollutants are not effectively removed • Frequent maintenance required • Performance dependant on design and frequency of inspection and cleanout of unit	

Stormwater Management Capability:

- Water quality benefits can provide 80% TSS removal.

Land Use Considerations:

	Residential
X	**Commercial**
X	**Industrial**

Maintenance:

- Inspect the gravity separator unit regularly
- Clean out sediment, oil and grease, floatable as needed

H

Maintenance Burden

L = Low M = Moderate H = High

SECTION 1: DESCRIPTION

Gravity separators (also known as oil-grit separators) are hydrodynamic separation devices that are designed to remove grit and heavy sediments, oil and grease, debris and floatable matter from stormwater runoff through gravitational settling and trapping. Gravity separator units contain a permanent pool of water and typically consist of an inlet chamber, separation/storage chamber, a bypass chamber, and an access port for maintenance purposes. Runoff enters the inlet chamber where heavy sediments and solids drop out. The flow moves into the main gravity separation chamber, where further settling of suspended solids takes place. Oil and grease are skimmed and stored in a waste oil storage compartment for future removal. After moving into the outlet chamber, the clarified runoff is then discharged.

The performance of these systems is based primarily on the relatively low solubility of petroleum products in water and the difference between the specific gravity of water and the specific gravities of petroleum compounds. Gravity separators are not designed to separate other products such as solvents, detergents, or dissolved pollutants. The typical gravity separator unit may be enhanced with a pretreatment swirl concentrator chamber, oil draw-off devices that continuously remove the accumulated light liquids, and flow control valves regulating the flow rate into the unit.

Gravity separators are best used in commercial, industrial and transportation land uses and are intended primarily as a pretreatment measure for high-density or ultra urban sites, or for use in hydrocarbon hotspots, such as gas stations and areas with high vehicular traffic. However, gravity separators cannot be used for the removal of dissolved or emulsified oils and pollutants such as coolants, soluble lubricants, glycols and alcohols.

Since resuspension of accumulated sediments is possible during heavy storm events, gravity separator units are typically installed off-line. Gravity separators are available as prefabricated proprietary systems from a number of different commercial vendors.

SECTION 2: POLLUTANT REMOVAL CAPABILITIES

Testing of gravity separators has shown that they can remove between 40 and 50% of the TSS loading when used in an off-line configuration (Curran, 1996 and Henry, 1999). Gravity separators also provide removal of debris, hydrocarbons, trash and other floatables. They provide only minimal removal of nutrients and organic matter.

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling and professional judgment.

- **Total Suspended Solids – 40%**
- **Total Phosphorus – 5%**
- **Total Nitrogen – 5%**
- **Fecal Coliform – insufficient data**
- **Heavy Metals – insufficient data**

Actual field testing data and pollutant removal rates from an independent source should be obtained before using a proprietary gravity separator system.

SECTION 3: DESIGN CRITERIA AND SPECIFICATIONS

- The use of gravity (oil-grit) separators should be limited to the following applications:
- Pretreatment for other structural stormwater controls
- High-density, ultra urban or other space-limited development sites
- Hotspot areas where the control of grit, floatables, and/or oil and grease are required
- Gravity separators are typically used for areas less than 5 acres. It is recommended that the contributing area to any individual gravity separator be limited to 1 acre or less of impervious cover.
- Gravity separator systems can be installed in almost any soil or terrain. Since these devices are underground, appearance is not an issue and public safety risks are low.
- Gravity separators are rate-based devices. This contrasts with most other stormwater structural controls, which are sized based on capturing and treating a specific volume.
- Gravity separator units are typically designed to bypass runoff flows in excess of the design flow rate. Some designs have built-in high flow bypass mechanisms. Other designs require a diversion structure or flow splitter ahead of the device in the drainage system. An adequate outfall must be provided.
- The separation chamber should provide for three separate storage volumes:
- A volume for separated oil storage at the top of the chamber
- A volume for settleable solids accumulation at the bottom of the chamber
- A volume required to give adequate flow-through detention time for separation of oil and sediment from the stormwater flow
- The total wet storage of the gravity separator unit should be at least 400 cu ft per contributing impervious acre.
- The minimum depth of the permanent pools should be 4 ft.
- Horizontal velocity through the separation chamber should be 1 to 3 ft/min or less. No velocities in the device should exceed the entrance velocity.
- A trash rack should be included in the design to capture floating debris, preferably near the inlet chamber to prevent debris from becoming oil impregnated.
- Ideally, a gravity separator design will provide an oil draw-off mechanism to a separate chamber or storage area.
- Adequate maintenance access to each chamber must be provided for inspection and cleanout of a gravity separator unit.
- Gravity separator units should be watertight to prevent possible groundwater contamination.
- The design criteria and specifications of a proprietary gravity separator unit should be obtained from the manufacturer.

SECTION 4: TYPCIAL SCHEMATIC DETAILS

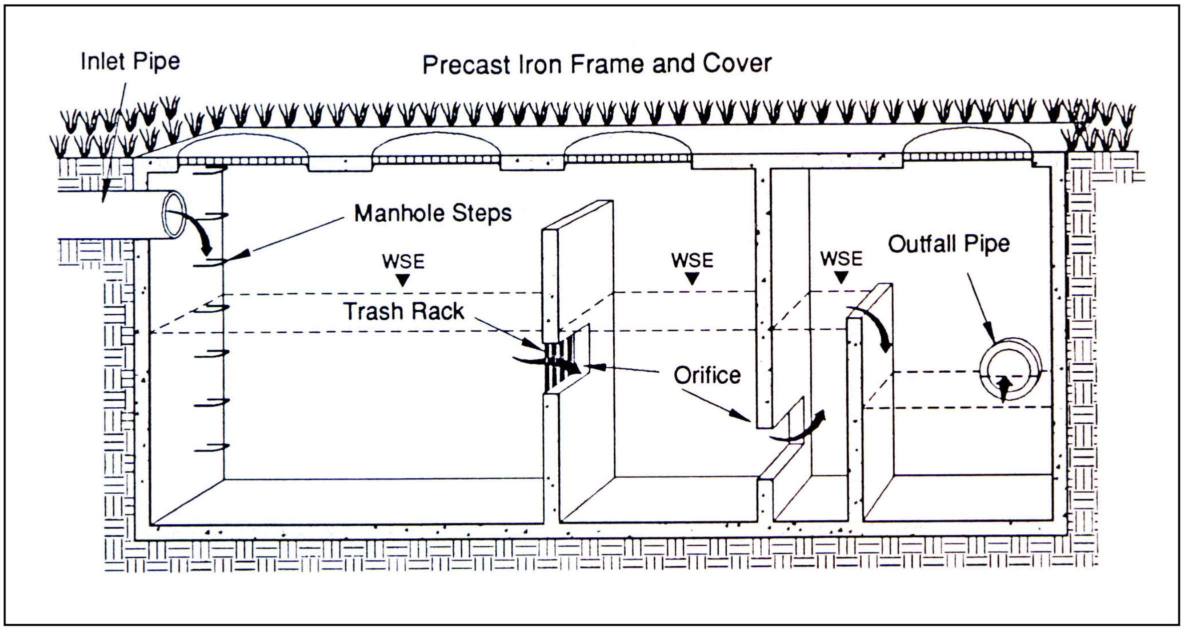

Figure 7.1. Schematic of an Example Gravity (Oil-Grit) Separator (Source: NVRC, 1992[1]).

SECTION 5: INSPECTION AND MAINTENANCE REQUIREMENTS

Table 7.1 Typical Maintenance Activities for Gravity Separators	
Activity	**Schedule**
• Inspect the gravity separator unit.	Regularly (quarterly)
• Clean out sediment, oil and grease, and floatables, using catch basin cleaning equipment (vacuum pumps). Manual removal of pollutants may be necessary.	As Needed

Additional Maintenance Considerations and Requirements

- Additional maintenance requirements for a proprietary system should be obtained from the manufacturer.
- Failure to provide adequate inspection and maintenance can result in the resuspension of accumulated solids. Frequency of inspection and maintenance is dependent on land use, climatological conditions, and the design of gravity separator.
- Proper disposal of oil, solids and floatables removed from the gravity separator must be ensured.

SECTION 6: REFERENCES

Atlanta Regional Commission. 2001. *Georgia Stormwater Management Manual, Volume 2: Technical Handbook.* Atlanta, GA. http://www.georgiastormwater.com/GSMMVol2.pdf

Center for Watershed Protection (CWP), 1996. Design of Stormwater Filtering Systems. Prepared for Chesapeake Research Consortium.

Northern Virginia Regional Commission (NVRC), 1992. The Northern Virginia BMP Handbook. Annandale, VA.

PROPRIETARY STRUCTURAL CONTROLS

Description: Manufactured structural control systems available from commercial vendors designed to treat stormwater runoff and/or provide water quantity control.

Advantages/Benefits:	Disadvantages/Limitations:
• Can be used in high density/ultra urban areas • Can provides pretreatment prior to discharging to other water quality controls	Depending on the system there may be: • Limited performance data • Application constraints • High maintenance requirements • Higher costs than other structural control alternatives
Design Considerations:	
• Independent performance data must be available to prove a demonstrated capability of meeting stormwater management goals • System or device must be appropriate for use in Fayetteville • Installation and operations/maintenance requirements must be understood by all parties approving and using the system or device in question	

Stormwater Management Capability:

- Water quality benefits can provide 80% TSS removal.

Land Use Considerations:

- X **Residential**
- X **Commercial**
- X **Industrial**

Maintenance:

- Depends on the proprietary system
- Sediment and debris must be removed periodically
- Check inlets and outlets for clogging

M

Maintenance Burden
L = Low M = Moderate H = High

SECTION 1: DESCRIPTION

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

- Hydrodynamic systems such as gravity and vortex separators
- Filtration systems
- Catch basin media inserts
- 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. Below are general guidelines that should be followed before considering the use of a proprietary commercial system.

SECTION 2: GUIDELINES FOR USING PROPRIETARY SYSTEMS

In order for use as a limited application control, a proprietary system must have a demonstrated capability of meeting the stormwater 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)
2. Proven record of longevity in the field
3. Proven ability to function in Fayetteville conditions (e.g., climate, rainfall patterns, soil types, etc.)

For a propriety system to meet (1) above for water quality goals, 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

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.

SECTION 3: REFERENCES

Atlanta Regional Commission. 2001. *Georgia Stormwater Management Manual, Volume 2: Technical Handbook.* Atlanta, GA. http://www.georgiastormwater.com/GSMMVol2.pdf