4.3.4 Stormwater Wetlands

General Application Stormwater BMP

Description: A constructed wetland system used for stormwater management. Runoff volume is both stored and treated in the wetland facility.

KEY DESIGN CONSIDERATIONS

DESIGN GUIDELINES:

- Minimum contributing drainage area of 25 acres; 5 acres for a pocket wetland.
- 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-foot depth).

ADVANTAGES / BENEFITS:

- Good nutrient removal.
- Provides natural wildlife habitat.
- Relatively low maintenance costs.

DISADVANTAGES / LIMITATIONS:

- Requires large land area.
- Needs continuous baseflow for viable wetland.
- Regular sediment removal is critical.

MAINTENANCE REQUIREMENTS:

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

STORMWATER MANAGEMENT SUITABILITY

- ✓ **Water Quality**
- ✓ **Channel Protection**
- ✓ **Overbank Flood Protection**
- ✓ **Extreme Flood Protection**

Provides pretreatment for SPAP land uses? *No*

FEASIBILITY CONSIDERATIONS

M-H	**Land Requirement**
M	**Capital Cost**
	Maintenance Burden:
M	Shallow Wetland
M	ED Shallow Wetland
H	Pocket Wetland
M	Pond/Wetland

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

POLLUTANT REMOVAL

H	**Total Suspended Solids**
M	**Nutrients** - Total Phosphorus / Total Nitrogen
M	**Metals** - Cadmium, Copper, Lead, and Zinc
M	**Pathogens** - Coliform, Streptococci, E.Coli

OTHER CONSIDERATIONS

Residential Subdivision Use: *Yes*

High-Density/Ultra-Urban: *Yes*

Drainage Area: *25 acres min. (5 to 10 acres for Pocket Wetlands)*

Soils: *Hydrologic group 'A' and 'B' soils may require liner*

4.3.4.1 General 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 can be utilized effectively for 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. The variations are shown in Figure 4-19. These include the shallow wetland, the extended detention shallow wetland, pond/wetland system and pocket wetland.

Figure 4-19. Stormwater Wetland Examples

Shallow Wetland

Extended Detention Shallow Wetland

Pocket wetland

Newly Constructed Shallow Wetland

Below are descriptions of each stormwater wetland 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 shallow wetland option, plants that can tolerate both wet and dry periods need to be specified in the ED zone.

- **Pond/Wetland System** – 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.

Certain types of wetlands, such as *submerged gravel wetland systems* are not recommended for general application use to meet stormwater management goals due to limited performance data. They may be applicable in special or retrofit situations where there are severe limitations on what can be implemented. Please see a further discussion of submerged gravel wetlands in Section 4.4.3.

4.3.4.2 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 the minimum design standards for water quality, channel protection and flood protection for a given drainage area.

Water Quality Volume (WQv)
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 4.3.4.3 provides median pollutant removal efficiencies that can be used for planning and design purposes.

Channel Protection Volume (CPv)
The storage volume above the permanent pool/water surface level in a stormwater wetland is used to provide control of the channel protection volume (CPv). 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.

Overbank Flood Protection (up to Qp_{25}) and Extreme Flood Protection (Qp_{100})
A stormwater wetland can also provide storage above the permanent pool/water surface level to reduce the post-development peak flow of the 2, 10, 25 and 100-year storms to pre-development levels (detention). If a wetland facility is not used for flood protection, it should be designed as an off-line system to pass higher flows around rather than through the wetland system, and/or designed to safely pass discharges from extreme storm events.

4.3.4.3 Pollutant Removal Capabilities

All of the stormwater wetland design variants are presumed to be able to remove 75% of the total suspended solids load in typical urban post-development runoff when sized, designed, constructed and maintained in accordance with the specifications provided in this manual. Since stormwater wetlands cannot achieve the 80% TSS standard by itself, additional stormwater quality BMPs will be required in a treatment train with stormwater wetlands. Undersized or poorly designed wetland facilities can reduce TSS removal performance.

Additionally, research has shown that use of stormwater ponds or wetlands will have benefits beyond the removal of TSS, such as the removal of other pollutants (i.e. phosphorous, nitrogen, fecal coliform and heavy metals), as well, which is useful information should the pollutant removal criteria change in the future. 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 stormwater BMPs may be put in place at the given site in a series or "treatment train" approach.

- Total Suspended Solids – 75%
- Total Phosphorus – 45%
- Total Nitrogen – 30%
- Pathogens – 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.stormwatercenter.net and the International Stormwater Best Management Practices Database at www.bmpdatabase.org.

4.3.4.4 Application and Site Feasibility Criteria

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
- Suitable for High Density/Ultra Urban Areas, however, land requirements may preclude use
- Suitable for Regional Stormwater Control

Physical Feasibility - Physical Constraints at Project Site

- Drainage Area – A minimum of 25 acres and a positive water balance is needed to maintain wetland conditions; a minimum of 5 acres for pocket wetland. The Knox County Director of Engineering and Public Works (the Director) may approve a smaller drainage area with an adequate water balance and anti-clogging device.
- Space Required – Approximately 3 to 5% of the tributary drainage area
- Site Slope – Wetlands are feasible on sites where the upstream slope (above the wetland) is no more than 15%.
- Minimum Head – Enough elevation drop is required, from inlet to outlet, to allow hydraulic conveyance by gravity. Generally, the minimum head for a pocket wetland is 2 to 3 feet. For all other wetlands the minimum head is 3 to 5 feet.
- Minimum Depth to Water Table – In general, no minimum separation distance to the water table is required for stormwater wetlands. In fact, water table interception may be helpful to sustain a permanent pool. However, some source water protection requirements may dictate a separation distance if there is a sensitive underlying aquifer. In such situations, an impermeable liner, or a minimum separation between 2 to 4 feet is required for portions of the wetland that will have standing water.
- Soils – 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.

4.3.4.5 Planning and Design Standards

The following standards shall be considered **minimum** design standards for the design of a stormwater wetland facility. Stormwater wetlands that are not designed to these standards will not be approved. The Director shall have the authority to require additional design conditions if deemed necessary.

A. 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. The Director may consider allowing the use of a stormwater wetland for a smaller drainage area when water availability can be confirmed (such as from a groundwater source or areas that typically have a high water table). It is important that wetlands that serve smaller drainage areas have an adequate anti-clogging device provided for the wetland outlet.
- A continuous base flow or high water table is required to support wetland vegetation. A water balance shall be performed to demonstrate that a stormwater wetland can withstand a 30-day drought at summer evaporation rates without completely drawing down (see Chapter 3 for details).
- When determining an appropriate location for a stormwater wetland, the site designer should also take into account the location and use of other site features such as natural depressions, buffers, and undisturbed natural areas. The site designer should attempt to aesthetically "fit" the wetland into the landscape.
- Stormwater wetlands shall not be located in a stream or any other navigable waters of the United States, including natural (i.e., not constructed) wetlands. Where an appeal or variance of this policy is desired, the property owner must obtain coverage under a Section 404 permit under the Clean Water Act and/or an Aquatic Resource Alteration Permit (ARAP) and provide proof of such coverage with the Stormwater Management Plan. The Director may approve the conversion of an existing degraded wetland into a stormwater wetland where appropriate for local watershed restoration efforts, and when prior approval for such a conversion is obtained from all applicable State and Federal agencies.
- If a wetland facility is not used for overbank and extreme flood protection, it shall be designed as an off-line system to bypass the higher flows rather than passing them through the wetland system.
- Each wetland or wetland system shall be placed in a water quality easement that is recorded with the deed. The water quality easement shall be defined at the outer edge of the safety bench, or a minimum of 15 feet from the normal water pool elevation (measured perpendicular from the pool elevation boundary) if a safety bench is not included in the wetland design. Minimum setback requirements for the easement shall be as follows unless otherwise specified by the Director:
  - from a property line – 10 feet;
  - From a public water system well – TDEC specified distance per designated category;
  - From a private well – 100 feet; if well is downgradient from a land use that requires a Special Pollution Abatement Permit, then the minimum setback is 250 feet;
  - From a septic system tank/leach field – 50 feet.
- All utilities should be located outside of the wetland site.

B. GENERAL DESIGN

- A stormwater wetland shall consist of the following elements, designed in accordance with the specifications provided in this section.
  - Shallow marsh areas of varying depths with wetland vegetation;
  - Permanent micropool;
  - Overlying zone in which runoff control volumes are stored if the wetland will be used for storage of the CPv, Qp_2, Qp_{10}, Qp_{25} and Qp_{100}.
  - Emergency spillway;
  - Maintenance access;
  - Safety bench;
  - Sediment forebay at each wetland inlet (unless the inlet provides less than 10% of the total inflow to the wetland);

- Wetland buffer (this is not the same as a regulatory water quality buffer – see section I-Landscaping for more information); and
- Appropriate wetland vegetation and native landscaping.
- Pond/wetland systems that also include stormwater pond facilities must meet all of the design parameters in Section 4.3.1 for pond design.

C. 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 shall be observed for adequate pollutant removal, ease of maintenance, and improved safety. Table 4-8 provides the recommended physical specifications and geometry for the various stormwater wetland design variants.

Table 4-8. Recommended Design Criteria for Stormwater Wetlands

(Source: 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 WQv 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)[1] 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	See section D below
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

1 – Depth Considerations:
Deepwater: 1.5 to 6 feet 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 shall 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 4-8. The four basic depth zones are:

  Deepwater zone
  From 1.5 to 6 feet 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 dry weather flow path shall be provided from inflow to outlet across the stormwater wetland. The path shall have a minimum length to width ratio of 2:1. Ideally, the path length to width ratio should be greater than 3:1. This path may be achieved by constructing internal dikes or berms, using marsh plantings, and/or 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 micropool having a depth no greater than 4 to 6 feet shall 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 shall not exceed 6 feet.
- The volume that is handled through extended detention shall not comprise more than 50% of the total WQv, and its maximum water surface elevation shall not extend more than 3 feet above the normal pool. Storage of CPv, Qp_2, Qp_{10}, Qp_{25} and Qp_{100} can be provided above the maximum WQv elevation within the wetland.
- The perimeter of all deep pool areas (4 feet or greater in depth) shall be surrounded by safety and aquatic benches similar to those for stormwater ponds (see subsection 4.3.1).
- The contours of the wetland shall be irregular to provide a more natural landscaping effect.

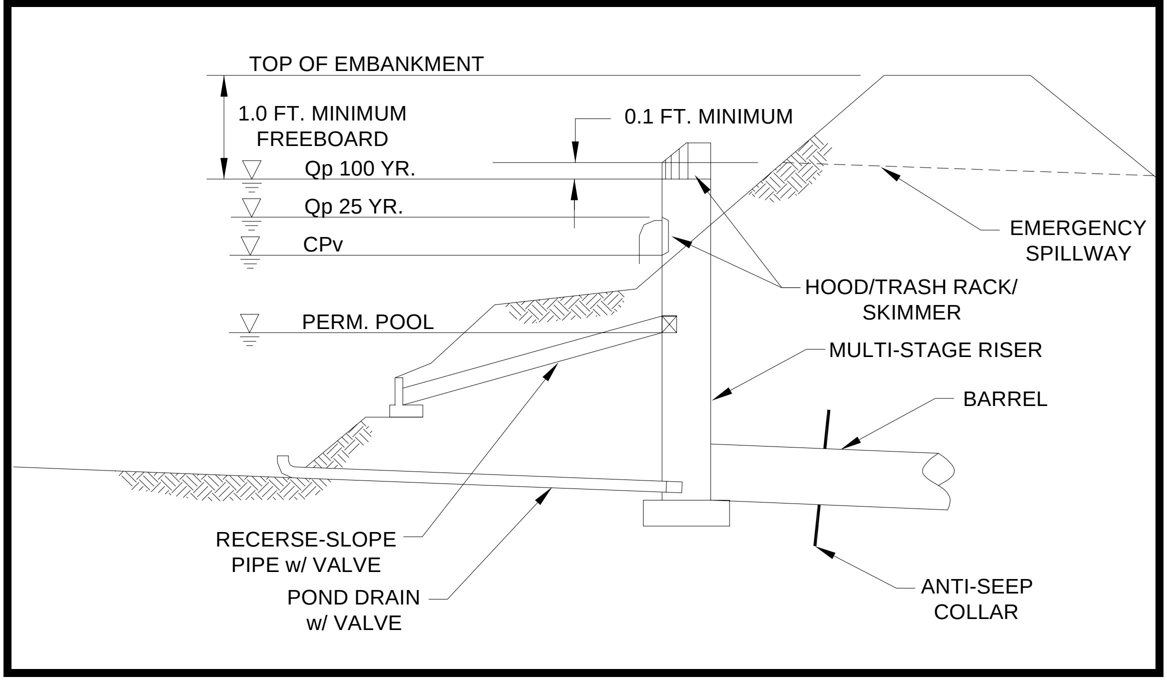
D. PRETREATMENT / INLETS

- Sediment regulation and removal is critical to sustain stormwater wetlands. A wetland facility shall have a sediment forebay or equivalent upstream pretreatment. In some cases, a pocket wetland design may not allow construction of a sediment forebay because of space limitations on small sites. In this case, a smaller "cattail" forebay is recommended to capture trash, debris and oil.
- A sediment forebay is designed to remove incoming sediment from the stormwater flow prior to dispersal into the wetland. The forebay shall consist of a separate cell, formed by an acceptable barrier. A forebay shall be provided at each inlet, unless the inlet provides less than 10% of the total design storm inflow to the wetland facility.
- The forebay shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be no more than 4 to 6 feet deep. The pretreatment storage volume is part of the total WQv design requirement and may be subtracted from the WQv 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 shall be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the pond can be partially submerged. Exit velocities from the forebay to the wetland shall be nonerosive.

E. 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 4-20).

Figure 4-20. Typical Wetland Facility Outlet Structure



- The riser shall be located within the embankment for maintenance access, safety and aesthetics. The outlet barrel shall be of reinforced concrete.

- A number of outlets at varying depths in the riser provide internal flow control for routing of WQv, CPv, Qp_2, Qp_{10}, Qp_{25} and Qp_{100}. The number of orifices can vary and is usually a function of the wetland 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. 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 an 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 foot below the elevation of the permanent pool to prevent floatables from clogging the pipe and to avoid discharging warmer water at the surface of the pond. The next outlet is sized for the release of the channel protection storage volume. The outlet (often an orifice) invert is located at the maximum elevation associated with the extended detention water quality volume and is sized to release the channel protection storage volume over a 24-hour period.

  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.

- Wetlands shall have a bottom drain pipe with an adjustable slide gate within the micropool that can completely or partially drain the wetland within 24 hours. The wetland drain shall be sized one pipe size greater than the calculated design diameter.

- Wetlands shall not be drained unless necessary for rescue or maintenance.
- Higher flows (Qp_2, Qp_{10}, Qp_{25} and Qp_{100}) pass through openings or slots protected by trash racks that are located further up on the riser.
- After entering the riser, flow is conveyed through the barrel and is discharged downstream. Anti-seep collars shall be installed on the outlet barrel to reduce the potential for pipe failure.
- Riprap, plunge pools or pads, or other energy dissipators shall be placed at the outlet of the barrel to prevent scouring and erosion. If a wetland facility discharges to a stream that has dry weather flow at any time during the year, care should be taken to minimize land disturbance along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. See Chapter 7 (Stormwater Drainage Design) and Chapter 6 (Water Quality Buffers) for more guidance on outlet designs and rules and regulations for disturbances in a water quality buffer.

See the design procedures in subsection 4.3.4.6 as well as Chapter 3 for additional information and specifications on pond routing and outlet operations.

F. EMERGENCY SPILLWAY

- An emergency spillway shall be included in the stormwater wetland design to safely pass the extreme flood (Qp_{100}) flow. The spillway prevents the wetland's water levels from overtopping the embankment and causing structural damage. The emergency spillway shall be located so that downstream structures will not be impacted by spillway discharges.
- A minimum of 1 foot of freeboard must be provided, measured from the top of the water surface elevation for the extreme flood (Qp_{100}) to the lowest point of the dam embankment, not counting the emergency spillway.

G. MAINTENANCE ACCESS

- A minimum 20' wide maintenance right of way or easement shall be provided from a driveway, public or private road. The maintenance access easement shall have a maximum slope of no more than 15% and shall have a minimum unobstructed drive path having a width of 12 feet, appropriately stabilized to withstand maintenance equipment and vehicles.
- The maintenance access shall 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 shall be provided by lockable manhole covers, and manhole steps within easy reach of slide gates and other controls.

H. SAFETY FEATURES

- All embankments and spillways shall be designed to the requirements set by TDEC's Safe Dams Act of 1973.
- Fencing of wetlands is not generally desirable, but may be required by the Director. 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. In addition, the safety bench may be landscaped to deter access to the pool.
- All outlet structures shall be designed so as not to permit access by children.

I. LANDSCAPING

- A landscaping plan shall be developed that indicates the methods used to establish and maintain wetland coverage. Minimum considerations of the 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. More information on wetland plants can be found at the following websites:

- http://wetlands.fws.gov/
- http://www.npwrc.usgs.gov/resource/plants/floraso/species.htm
- http://www.tva.gov/river/landandshore/stabilization/plantsearch.htm

- 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 infrequent 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 shall not be planted on the embankment or allowed to grow within 15 feet of the toe of the embankment and 25 feet from the principal spillway structure.
- Water quality buffers, as defined and described in Volume 2, Chapter 6 of this manual, are not required for wetlands that are constructed for the purpose of stormwater quality or quantity control. However, it should be noted that vegetated buffers can be utilized for water quality treatment and can result in a volume credit that reduces the WQv. The criteria for the vegetated buffer credit are presented in Volume 2, Chapter 5 of this manual.
- Existing trees should be preserved in the wetland area during construction, or should be replanted in another location if they are intolerant of having a saturated root zone. It is desirable to locate forest conservation areas adjacent to wetlands. To discourage resident waterfowl populations, the wetland buffer can be planted with trees, shrubs and native ground covers.
- The soils in planting areas within and surrounding a wetland 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.
- Native species of fish can be stocked in the permanent pool to aid in mosquito prevention. Knox County strongly discourages the use non-native fish species in a stormwater facility due to the possibility that the fish will enter downstream receiving waters.
- A fountain or aerator may be used for oxygenation of water in the permanent pool and to aid in mosquito breeding prevention.

J. ADDITIONAL SITE-SPECIFIC DESIGN CRITERIA AND ISSUES

There are a number of additional site specific design criteria and issues (listed below) that must be considered in the design of wetlands.

Physiographic Factors - Local terrain design constraints

- Low Relief – Providing wetland drain can be problematic.
- 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. Stormwater wetlands are the preferred BMP over ponds in the karst areas.

Soils

- Hydrologic group "A" soils and some group "B" soils may require liner (not relevant for pocket wetland).

Special Watershed Considerations

- Wellhead Protection – The potential for groundwater contamination (in required wellhead protection areas) shall be reduced through pretreatment of runoff, and installation of a liner for type “A” and “B” soils; pretreat hotspots; 2 to 4 foot separation distance from water table.

4.3.4.6 Design Procedures

Step 1. Compute runoff control volumes

Calculate WQv, CPv, Qp_2, Qp_{10}, Qp_{25} and Qp_{100}, in accordance with the guidance presented in Volume 2, 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 subsections 4.3.4.4 and 4.3.4.5-A (Location and Siting).

Step 3. Confirm design criteria and applicability

Consider any special site-specific design conditions/criteria from subsection 4.3.4.5-J (Additional Site-Specific Design Criteria and Issues).

Check with Knox County, TDEC, TDOT or other agencies 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 shall be sized to contain 0.1 inches per impervious acre (363 ft^3) of contributing drainage and shall be 4 to 6 feet 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 WQv volume among marsh, micropool, and ED volumes

Use recommended criteria from Table 4-8.

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 WQv permanent pool elevation (and WQv-ED elevation for ED shallow wetland) based on volumes calculated earlier.

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

Shallow Wetland and Pocket Wetland: The CPv elevation is determined from the stage-storage relationship and the orifice is then sized to detain the channel protection storage volume for a 24-hour period, measured from centroid to centroid. The channel protection orifice 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 foot below the elevation of the permanent pool, is a recommended design. The orifice diameters less than three inches must have internal orifice protection (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 slide gates 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 be adequately protected from clogging by an acceptable external trash rack. A reverse slope pipe attached to the riser, with its inlet submerged one foot below the elevation of the permanent pool, is a recommended design. Orifice diameters less than three inches must employ internal orifice protection (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 slide gates can also be used to achieve this equivalent diameter. The CPv 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 detain the channel protection storage volume for a 24-hour period, measured from centroid to centroid.

Step 8. Calculate Qp2, Qp10, Qp25 and Qp100 release rates and water surface elevations

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)

Calculate the 100-year water surface elevation, set the top of the embankment elevation, and size the emergency spillway, ensuring safe passage of the Qp_{100}. Set the invert elevation of the emergency spillway 0.1 foot above the 100-year water surface elevation.

Step 10. Investigate potential pond/wetland hazard classification

The design and construction of stormwater management facilities are required to follow the latest version of the TDEC Rules and Regulations Application to the Safe Dams Act of 1973.

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

See subsection 4.3.4.5-D through H for more details.

Step 12. Design landscape plan

A landscape plan for a stormwater wetland and its buffer shall be prepared to indicate how aquatic and terrestrial areas will be stabilized and established with vegetation. See subsection 4.3.4.5-I (Landscaping) for more details.

4.3.4.7 Maintenance Requirements and Inspection Checklist

Note: Section 4.3.4.7 must be included in the Operations and Maintenance Plan that is recorded with the deed.

Regular inspection and maintenance is critical to the effective operation of stormwater wetlands as designed. It is the responsibility of the property owner to maintain all stormwater BMPs in accordance with the minimum design standards and other guidance provided in this manual. The Director has the authority to impose additional maintenance requirements where deemed necessary. This page provides guidance on maintenance activities that are typically required for stormwater wetlands, along with a suggested frequency for each activity. Individual wetlands may have more, or less, frequent maintenance needs, depending upon a variety of factors including the occurrence of large storm events, overly wet or dry (i.e., drought) regional hydrologic conditions, and any changes or redevelopment in the upstream land use. Each property owner shall perform the activities identified below at the frequency needed to maintain the pond in proper operating condition at all times.

Inspection Activities	Suggested Schedule
• After several storm events or an extreme storm event, inspect for: bank stability; signs of erosion; vegetation growth; drainage system function; and structural damage.	As needed
• Inspect for: invasive vegetation; trash and debris; clogging of the inlet/outlet structures and any pilot or low flow channels; excessive erosion; sediment accumulation in the basin, forebay and inlet/outlet structures; tree growth on dam or embankment; the presence of burrowing animals; standing water where there should be none; vigor and density of the grass turf on the basin side slopes and floor; differential settlement; cracking; leakage; and slope stability.	Semi-annually
• Inspect the inlet/outlet structures, pipes, sediment forebays, and upstream, downstream, and pilot channels to ensure they are free of debris and are operational. • Check for signs of unhealthy or overpopulation of plants and/or fish (if utilized). • Note signs of pollution, such as oil sheens, discolored water, or unpleasant odors. • Check sediment marker(s) for sediment accumulation in the facility and forebay. • Check for proper operation of control gates, valves or other mechanical devices. • Note changes to the wetland or contributing drainage area as such changes may affect wetland performance.	Annually
Maintenance Activities	**Suggested Schedule**
• Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants after the second growing season.	One-time
• Clean and remove debris from inlet and outlet structures. Mow side slopes (embankment) and maintenance access. Periodic mowing is only required along maintenance rights-of-way and the embankment. The wetland buffer surrounding the wetland can be managed as a meadow (mowing every other year) or forest.	Frequently (3 to 4 times per year)
• Supplement wetland plants if a significant portion have not established (at least 50% of the surface area). Remove unhealthy, invasive or nuisance plant species and replant with appropriate species if necessary. Harvest plant species if vegetation becomes too thick causing flow backup and flooding, or an overabundance of undesirable wildlife.	Annually (if needed)
• Repair damage to pond, outlet structures, embankments, control gates, valves, or other mechanical devices; repair undercut or eroded areas. Remove litter, debris, pollutants as appropriate.	As needed
• Remove sediment from the forebay. Sediments excavated from stormwater wetlands that receive treated runoff from land uses that require a Special Pollution Abatement Permit (SPAP) are not considered toxic or hazardous material and can be safely disposed of by either land application or landfilling.	As needed (typically every 5 to 7 years)
• Monitor sediment accumulations, and remove sediment when the volume in the wetland, forebay, or micropool has become reduced significantly or the wetland area is not providing a healthy habitat for vegetation and fish (if used). Discharges of turbid or untreated stormwater from the wetland may be considered an illegal discharge, as per the Knox County Stormwater Management Ordinance. Care should be exercised during wetland drawdowns to prevent downstream discharge of sediments, anoxic water, or high flows with erosive velocities. Knox County should be notified before draining a stormwater wetland.	As needed (typically every 20 to 50 years)

Knox County encourages the use of the inspection checklist that is presented on the next page to guide the property owner in the inspection and maintenance of stormwater wetlands. The Director can require the use of this checklist or other form(s) of maintenance documentation when and where deemed necessary in order to ensure the long-term proper operation of the wetland. Questions regarding stormwater facility inspection and maintenance should be referred to the Knox County Department of Engineering and Public Works, Stormwater Management Division.

INSPECTION CHECKLIST AND MAINTENANCE GUIDANCE (continued)
STORMWATER WETLAND INSPECTION CHECKLIST

Location: ______________________________ Owner Change since last inspection? Y N
Owner Name, Address, Phone: ______________________________
Date: __________ Time: ____________ Site conditions:______________________________

Inspection Items	Satisfactory (S) or Unsatisfactory (U)	Comments/Corrective Action
Embankment and Emergency Spillway		
Healthy vegetation?		
Erosion on embankment?		
Animal burrows in embankment?		
Cracking, sliding, bulging of dam?		
Blocked or malfunctioning drains?		
Leaks or seeps on embankment?		
Obstructions of spillway(s)?		
Erosion in/around emergency spillway?		
Other (describe)?		
Inlet/Outlet Structures and Channels		
Clear of debris and functional?		
Trash rack clear of debris and functional?		
Sediment accumulation?		
Condition of concrete/masonry?		
Pipes in good condition?		
Slide gate operation?		
Drain valve operation?		
Outfall channels function, not eroding?		
Other (describe)?		
Sediment Forebays		
Evidence of sediment accumulation?		
Permanent Pool Areas (if applicable)		
Undesirable vegetation growth?		
Visible pollution?		
Shoreline erosion?		
Erosion at outfalls into wetland?		
Headwalls and endwalls in good condition?		
Encroachment by other activities?		
Evidence of sediment accumulation?		
Wetland Vegetation Areas		
Vegetation adequate?		
Undesirable vegetation growth?		
Excessive sedimentation?		
Hazards		
Have there been complaints from residents?		
Public hazards noted?		

If any of the above inspection items are **UNSATISFACTORY**, list corrective actions and the corresponding completion dates below:

Corrective Action Needed	Due Date

Inspector Signature:______________________________ Inspector Name (printed)______________________________

4.3.4.8 Example Schematics

Figure 4-21. Schematic of Shallow Wetland

(Source: Adapted from Atlanta Regional Council, 2000)

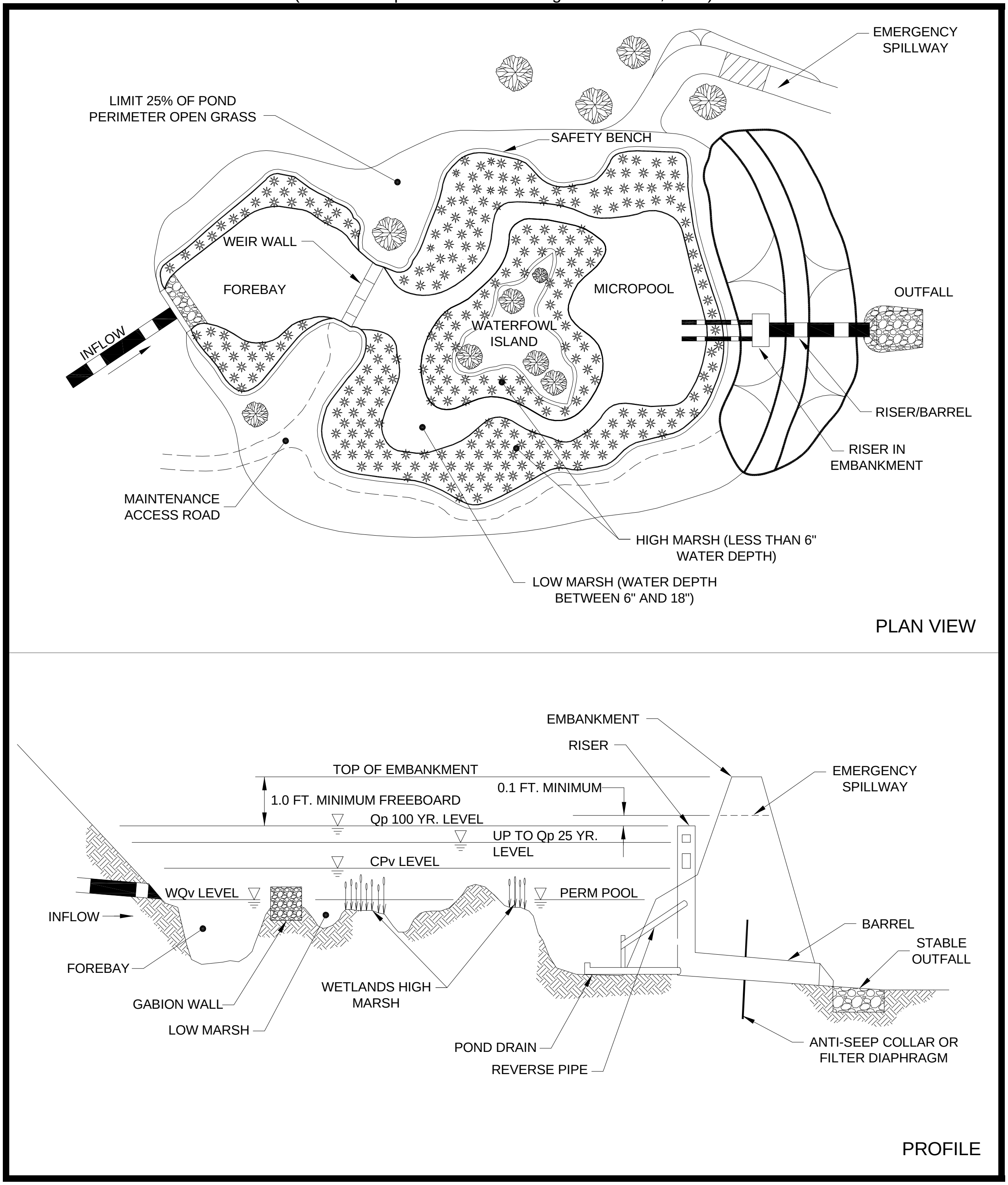


Figure 4-22. Schematic of Extended Detention Shallow Wetland

(Source: Adapted from Atlanta Regional Council, 2000)

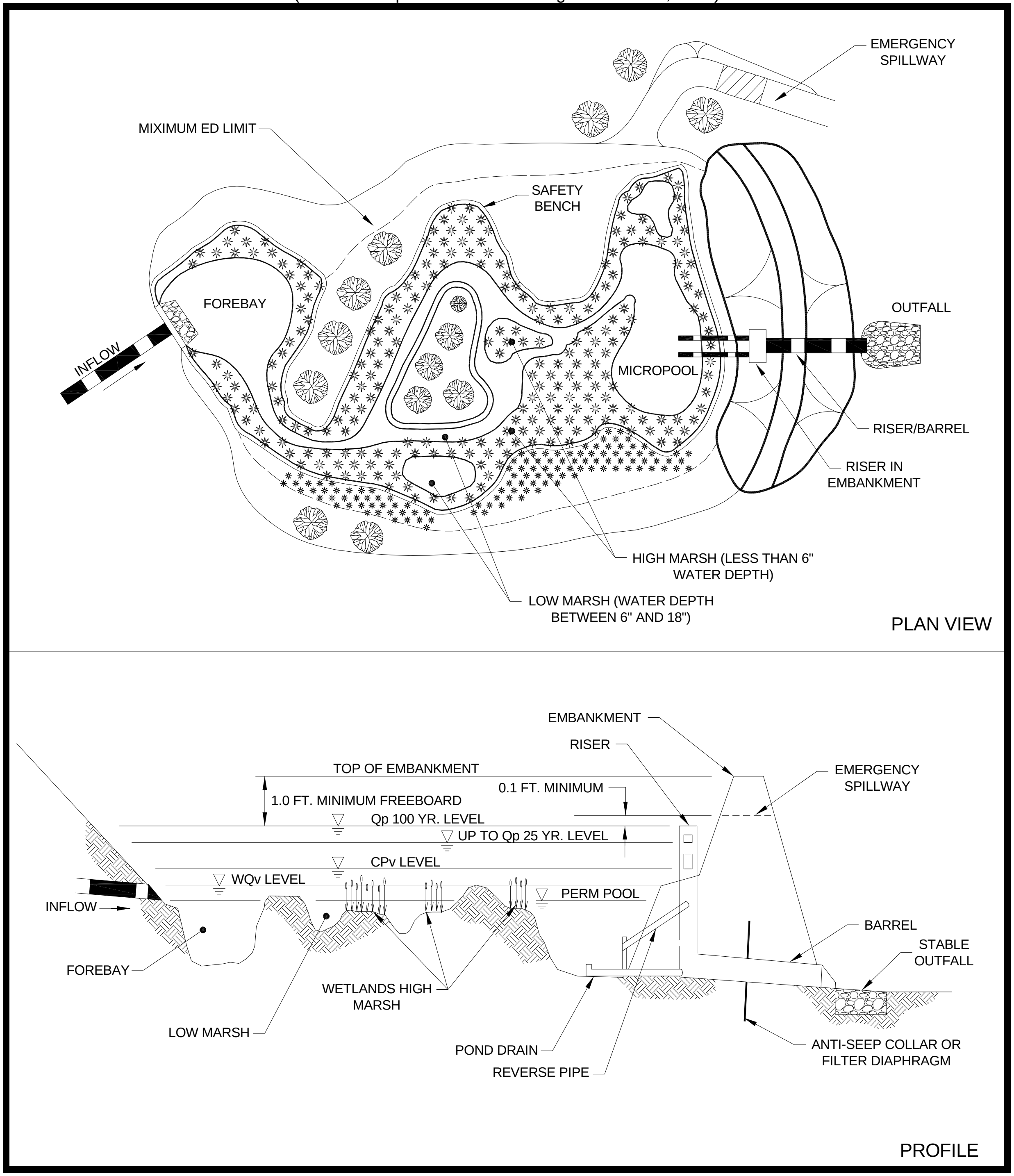


Figure 4-23. Schematic of Pond/Wetland System

(Source: Adapted from Atlanta Regional Council, 2000)

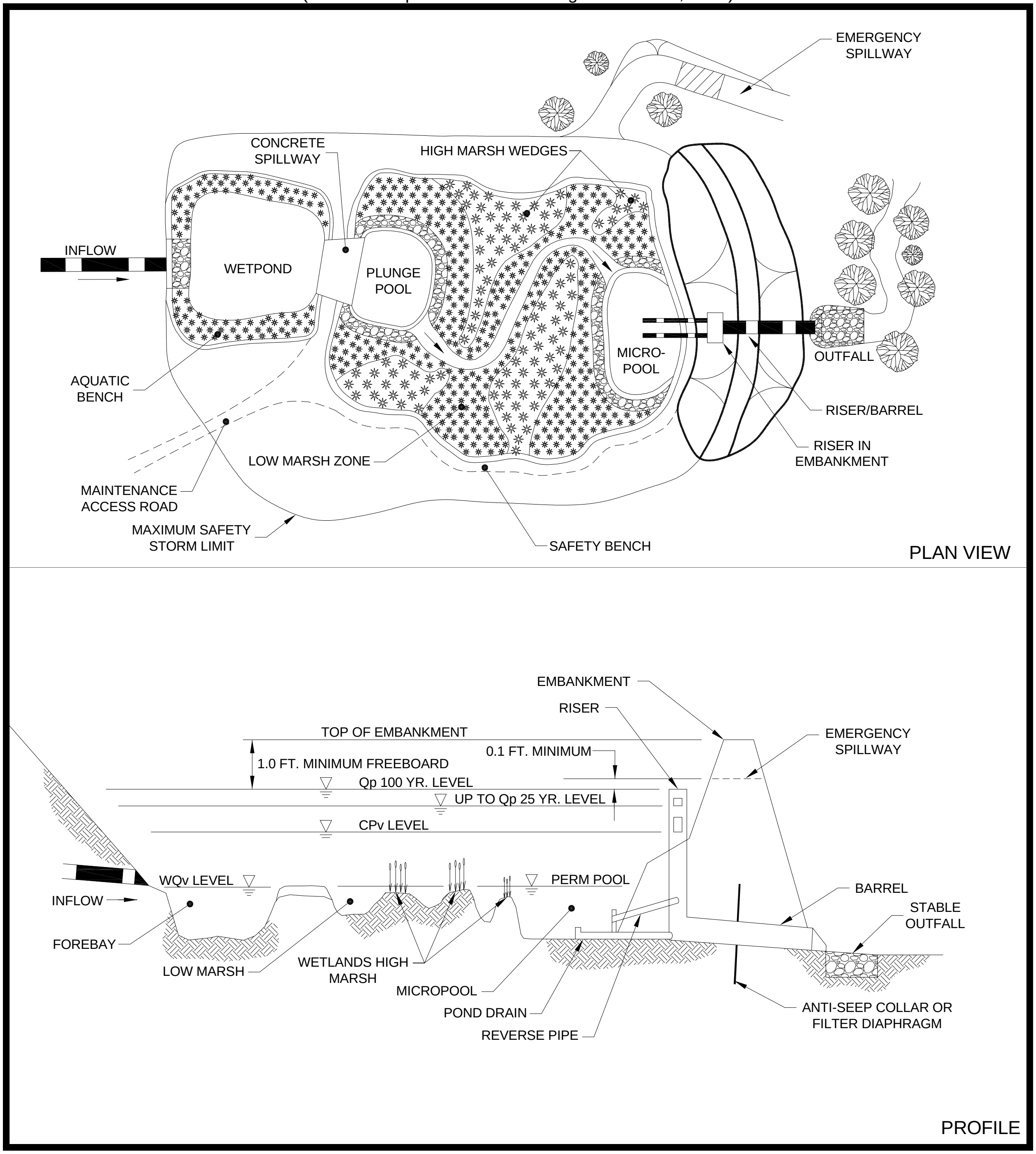
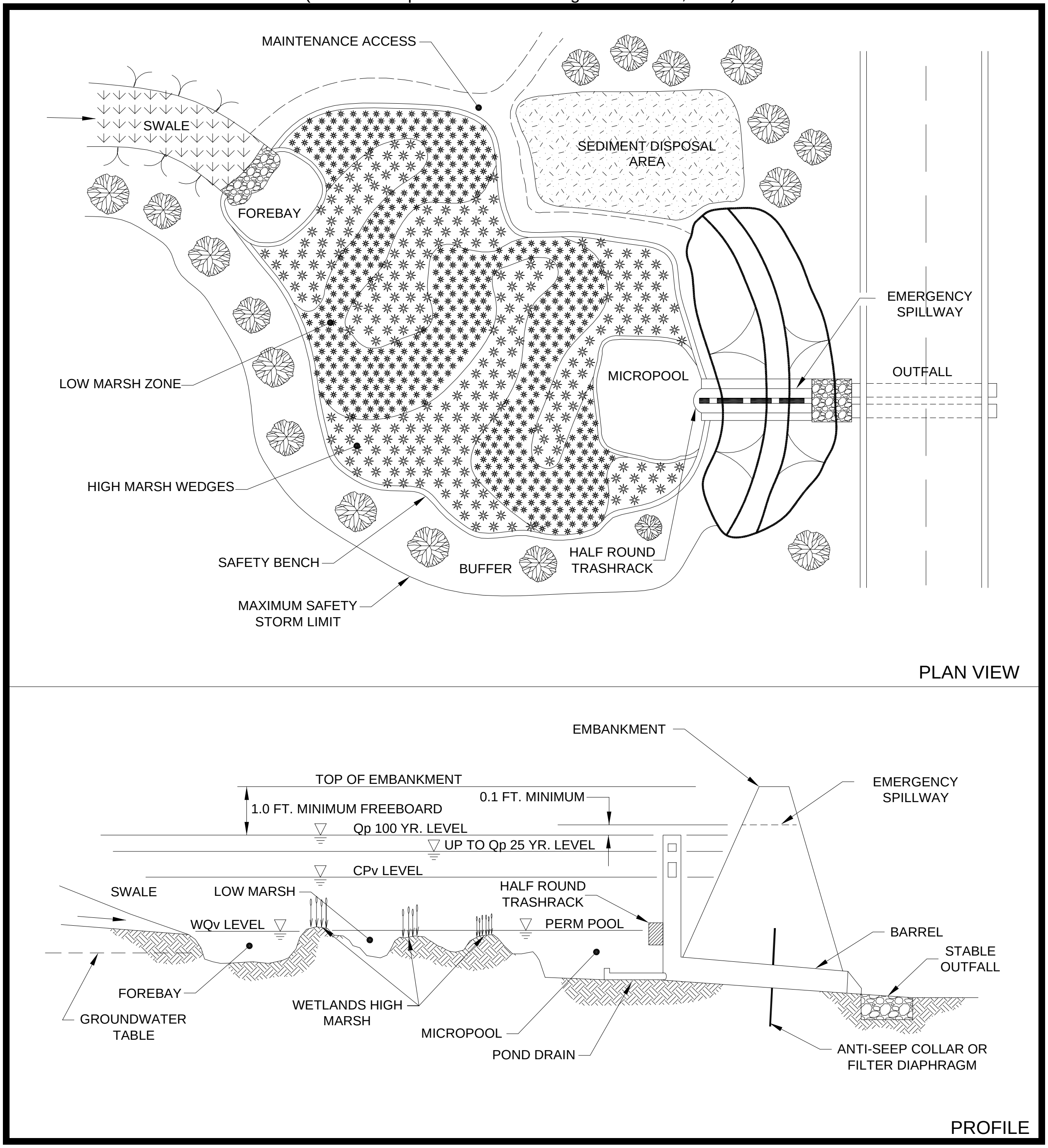


Figure 4-24. Schematic of Pocket Wetland
(Source: Adapted from Atlanta Regional Council, 2000)



4.3.4.9 Design Forms

Knox County recommends the use of the following design procedure forms when designing a stormwater wetland. Proper use and completion of the form may allow a faster review of the Stormwater Management Plan by Knox County Engineering.

Design Procedure Form: Stormwater Wetlands

PRELIMINARY HYDROLOGIC CALCULATIONS

1a. Compute Runoff Coefficient, Rv — Rv = ________
Compute WQv — WQv = ________ acre-ft

1b. Estimate CPv — CPv = ________ acre-ft

1c. Estimate storage volumes
Compute storage volume required for 2-year storm — 2-year storage = ________ acre-ft
Compute storage volume required for 10-year storm — 10-year storage = ________ acre-ft
Compute storage volume required for 25-year storm — 25-year storage = ________ acre-ft
Compute storage volume requried for 100-year storm — 100-year storage = ________ acre-ft

STORMWATER WETLAND DESIGN

2. Is the use of a stormwater wetland appropriate? — ***See subsections 4.3.4.4 and 4.3.4.5 - A***

3. Confirm design criteria and applicability. — ***See subsection 4.3.4.5 - J***

4. Pretreatment Volume (Forebay)
V_{pre} =(I)(.1")(1'/12") — Vol_{pre} = ________ acre-ft

5. Allocation of pool, Marsh, and ED Volumes

Shallow Wetland
Vol_{pool}= 0.2(WQv-Vol_{pre}) — Vol_{pool}= ________ acre-ft
Vol_{marsh}= 0.7(WQv-Vol_{pre}) — Vol_{marsh}= ________ acre-ft

Shallow ED Wetland
Vol_{pool}= 0.1(WQv-Vol_{pre}) — Vol_{pool}= ________ acre-ft
Vol_{marsh}= 0.3(WQv-Vol_{pre}) — Vol_{marsh}= ________ acre-ft
Vol_{ED}= 0.5(WQv-Vol_{pre}) — Vol_{ED}= ________ acre-ft

Pocket Wetland
Vol_{pool}= 0.1(WQv-Vol_{pre}) — Vol_{pool}= ________ acre-ft
Vol_{marsh}= 0.8(WQv-Vol_{pre}) — Vol_{marsh}= ________ acre-ft

6. Allocation of Surface Area

Pool/Deepwater Wetland Zone (1.5-6 feet deep) — $Area_{water}$= ________ acres, %= ________
Low Marsh Wetland Zone (6-18 inches deep) — $Area_{low}$= ________ acres, %= ________
High Marsh Wetland Zone (0-6 inches deep) — $Area_{high}$= ________ acres, %= ________
Semi-Wet Wetland Zone (above pool depth) — $Area_{semi}$= ________ acres, %= ________
100.00%

Conduct grading and determine storage available for marsh zones (and ED if applicable), and compute orifice size.

Prepare an elevation-storage table and curve using the average area method for computing volumes.

Elevation MSL	Area ft^2	Ave. Area ft^2	Depth ft	Volume ft^3	Cumulative Volume ft^3	Cumulative Volume acre-ft	Volume above Permanent Pool acre-ft

Design Procedure Form: Stormwater Wetlands (continued)

7. WQv Orifice Computations
   Average ED release rate (if applicable) — release rate= ____________ cfs
   Average head, h = (ED elev. - Permanent pool elev.) / 2 — head= ____________ ft
   Area of orifice from orifice equation — Area= ____________ ft^2
   $Q=CA(2gh)^{0.5}$ C varies with orifice condition — diameter ____________ inches

   Establish CPv top elevation using stage-storage curve — CPv WSEL= ____________ ft-NGVD
   Estimate orifice size — CPv orifice diameter = ____________ inches
   Perform hydrograph routing to check detention time — centroid-centroid det. = ____________ hours
   Iterate to final orifice size — Final CPv orifice diameter = ____________ inches

8. Calculate Qp_2, Qp_{10}, Qp_{25} and Qp_{100} release rates and WSELs — Set up a stage-storage-discharge relationship

Elevation	Storage	Low Flow	Riser			Barrel		Emergency	Total
		WQv-ED	CPv-ED	High Storage		Inlet	Pipe	Spillway	Outflow
				Orif.	Weir				
MSL	acre-ft	H(ft) Q(cfs)	H(ft) Q(cfs)	H Q	H Q	H(ft) Q(cfs)	H(ft) Q(cfs)	H(ft) Q(cfs)	Q (cfs)

Qp_2=pre-dev. Peak discharge - (WQv-ED release + CPv-ED release) — Qp_2= ____________ cfs
Qp_{10}=pre-dev. Peak discharge - (WQv-ED release + CPv-ED release) — Qp_{10}= ____________ cfs
Qp_{25} = pre-dev. Peak discharge - (WQ_v-ED release + CPv-ED release) — Qp_{25}= ____________ cfs

Maximum head = — H= ____________ ft
Use weir equation for slot length ($Q=CLH^{3/2}$) — L= ____________ ft

Check inlet condition — **Use culvert design guidance in Chapter 7**
Check outlet condition

9. Size emergency spillway using the Qp_{100} and set top of embankment elevation and emergency spillway elevation based on $WSEL_{100}$
   $Q_{ES}=Qp_{100}$ ____________ cfs
   $WSEL_{100}$= ____________ ft
   El_{embank} ____________ ft
   El_{ES}= ____________ ft

10. Investigate potential pond hazard classification — **See TN Safe Dams Act of 1973**

11. Design inlets, sediment forebays, outlet structures, maintenance access, and safety features — **See subsection 4.3.4.5 - D through H**

12. Design vegetation according to guidance in Chapter 6

13. Verify peak flow control, water quality drawdown time and channel protection detention time

4.3.4.10 References

AMEC. *Metropolitan Nashville and Davidson County Stormwater Management Manual Volume 4 Best Management Practices.* 2006.

Atlanta Regional Council (ARC). *Georgia Stormwater Management Manual Volume 2 Technical Handbook.* 2000*.*

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4.3.4.11 Suggested Reading

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California Storm Water Quality Task Force. *California Storm Water Best Management Practice Handbooks.* 1993.

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