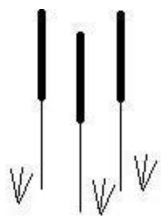
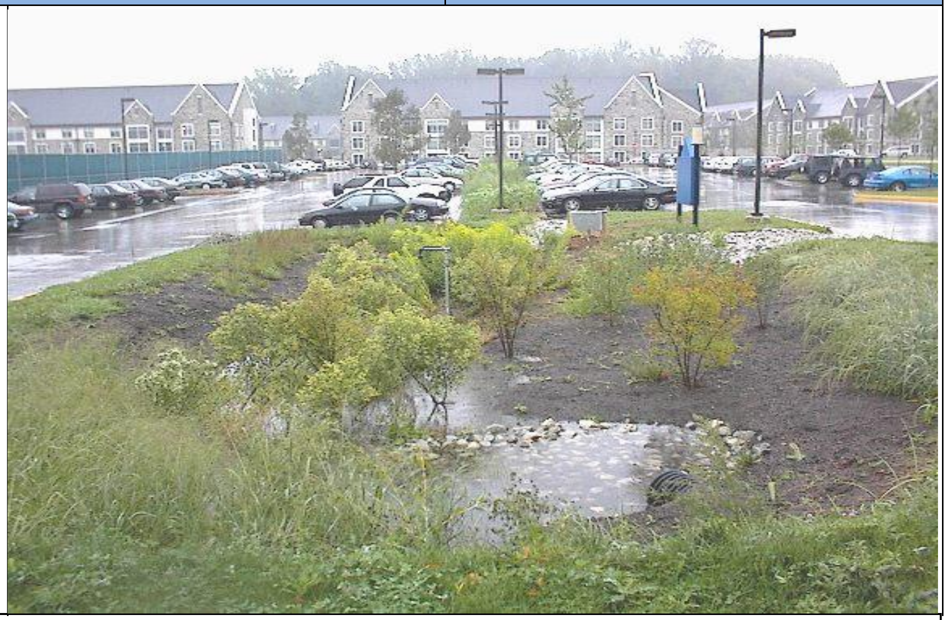
3.4 Post Construction Stormwater Control Fact Sheets (PTP)

Post Construction Stormwater Control Practices	PTP-04 Constructed Wetlands
 Symbol **SW**	

Description

Constructed wetlands are constructed basins that have a pool of water throughout the year (or at a minimum, throughout the wet season). They differ from wet ponds primarily in being shallower and having greater vegetation coverage. They are considered among the most effective stormwater practices in terms of pollutant removal and offer additional benefits in terms of aesthetics, groundwater interaction, and wildlife and vegetative habitat. As stormwater runoff flows through the wetlands, treatment is achieved through settling of particulates in the wetland system and uptake of nutrients and other constituents in the water by vegetation, soil, and biota.

Constructed wetlands are best suited to removing contaminants other than sediment from flow. If sediment loads are high, pretreatment is required. Pretreatment options include the use of sediment forebays, filter strips, and construction of a pond upstream of the wetland to remove sediment. The choice of a particular pretreatment option depends on site and hydrologic conditions.

A constructed wetland may consist of:

- Shallow marsh areas of varying depths with wetland vegetation
- Permanent micropool at the outlet
- Overlying zone in which runoff volumes are stored
- A sediment forebay at the inflow(s)
- Emergency spillway
- Maintenance access
- Safety bench
- Wetland buffer
- Indigenous wetland vegetation and landscaping

Applications

- Constructed wetlands are recommended for the following locations:
  - Small outfalls with soil conditions that will support the establishment and growth of wetland vegetation.
  - Large industrial and commercial sites with enough space and soil conditions favorable towards the establishment and growth of wetland vegetation.
  - Adjacent to greenways, parks, and recreational areas or other locations amenable towards the promotion of wetland vegetation.
  - Residential subdivisions of low to moderate density.

- Constructed wetlands are **not** recommended for the following locations:
  - Areas with high sediment loads
  - Where sufficient land is not available of the wetland
  - On sites where wetland hydrology cannot be maintained

Low and high visibility sites are conducive towards the establishment of constructed wetlands, so long as the problem of stagnant or standing water is minimized.

Constructed wetlands are typically installed at the downstream end of the treatment train. Constructed wetland size and outflow regulation requirements can be significantly reduced with the use of additional upstream BMPs. However, when a constructed wetland is constructed, it is likely to be the only management practice employed at a site, and therefore must be designed to provide adequate water quality and water quantity treatment for all regulated storms.

Constructed Wetland Variations

Figure PTP-03- 1 Shallow Wetland
Source, Stormwater Managers Resource Center, www.stormwatercenter.net

- **Shallow Wetland**

The shallow wetland requires a minimum drainage area of 25 acres. The design requires different areas of shallow and relatively deeper marshes with the deeper portions located at the sediment forebay at the inlet and at the micropool at the outlet. Due to the high surface area to volume ratio, a large amount of land is required to meet the necessary water quality volume.

Constructed Wetland Variations

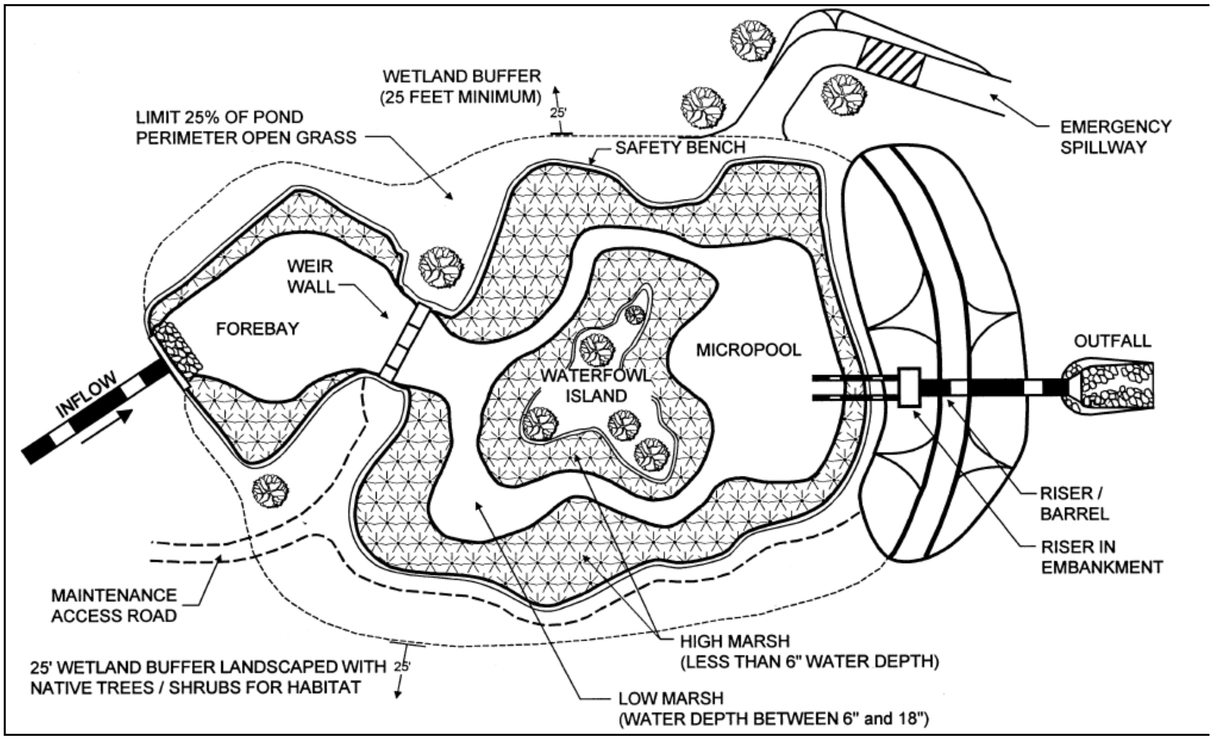


Figure PTP-03- 2 Shallow Wetland

Source, Georgia Stormwater Management Manual

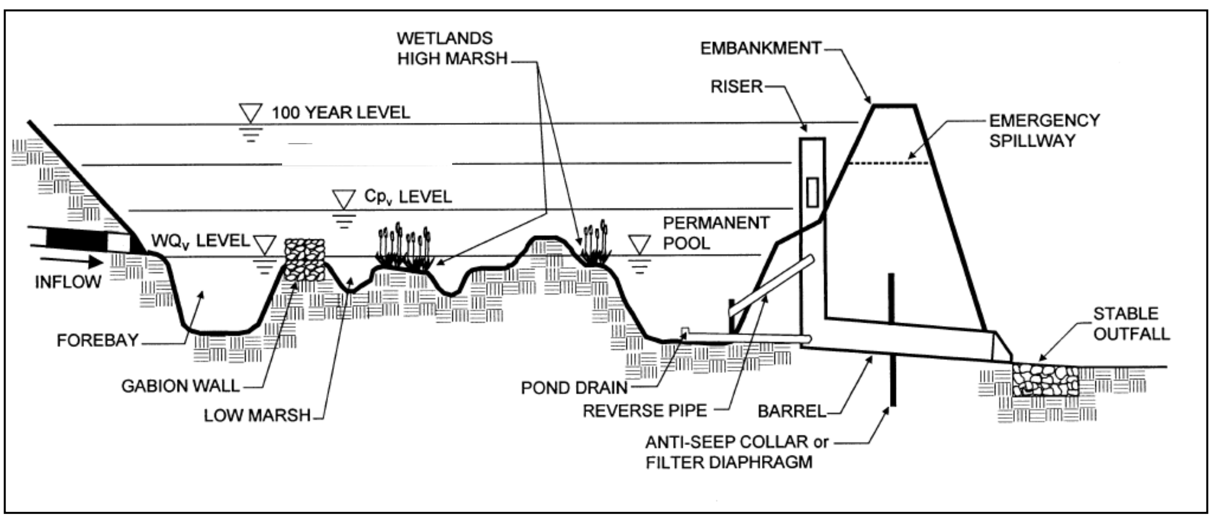


Figure PTP-03- 3 Shallow Wetland

Source, Georgia Stormwater Management Manual

Constructed Wetland Variations

Figure PTP-03- 4 Pocket Wetland
Source, Stormwater Managers Resource Center, www.stormwatercenter.net

- **Pocket Wetland**

The pocket wetland should be used for smaller drainage areas between 5 and 10 acres. The base of the wetland connects to groundwater to maintain a permanent pool, and is typically used in situations where there is not enough drainage area available to maintain a permanent pool. However, the pollutant removal efficiencies for this option are reduced due to the active connection with the water table.

Constructed Wetland Variations

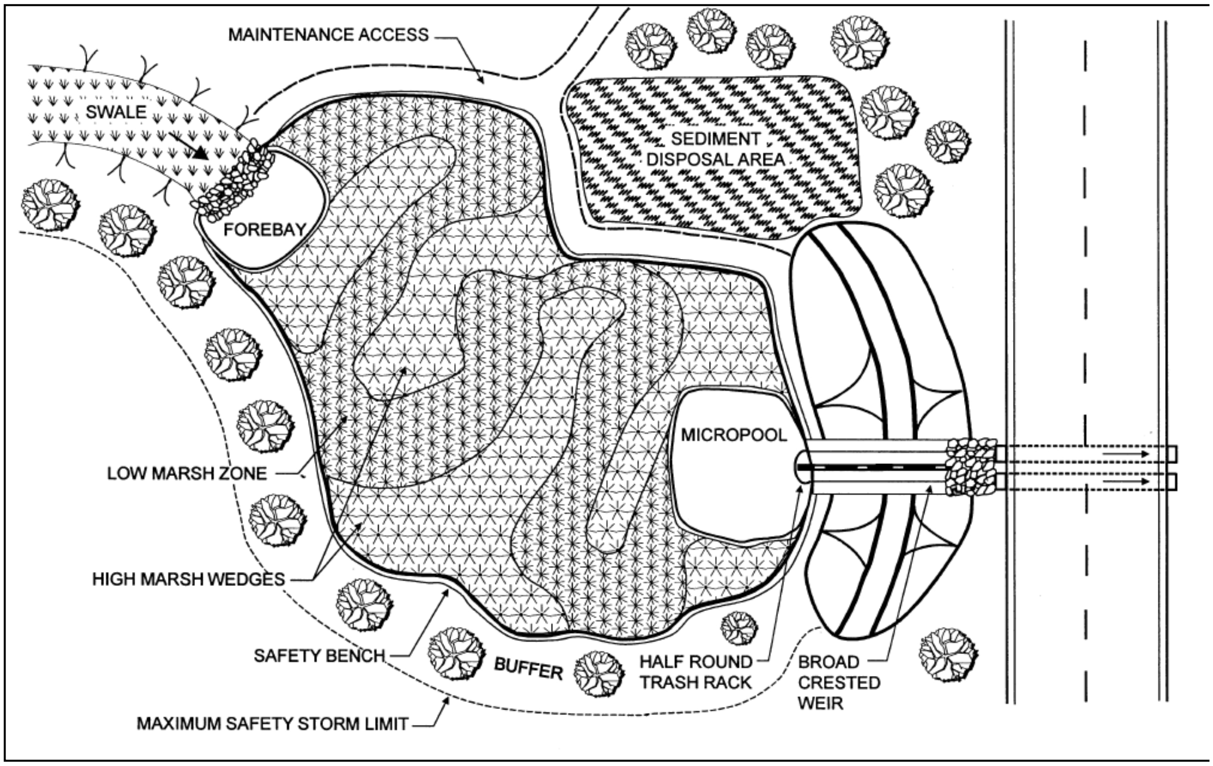


Figure PTP-03- 5 Pocket Wetland
Source, Georgia Stormwater Management Manual

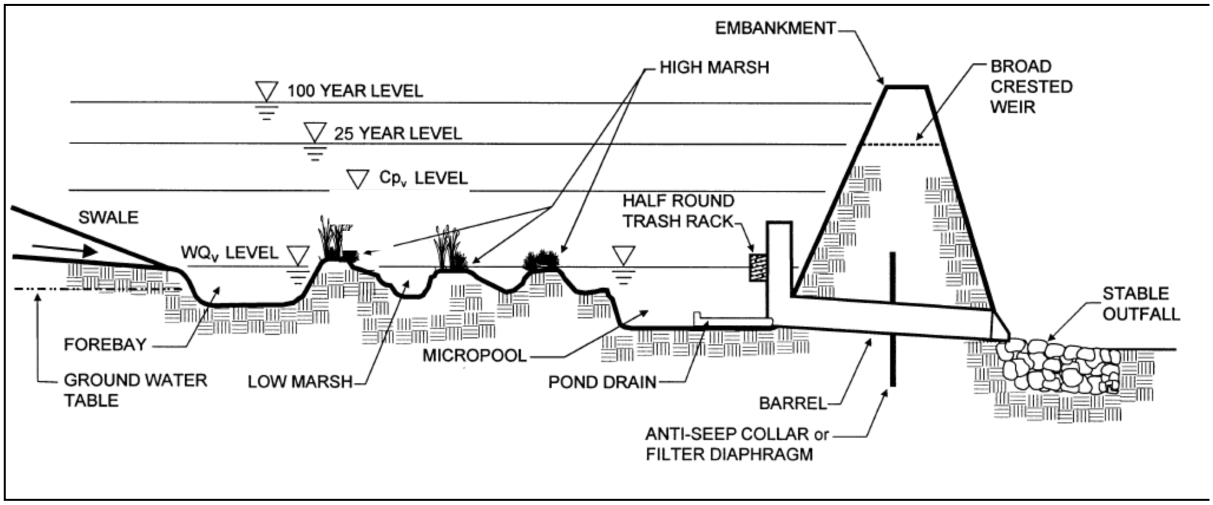


Figure PTP-03- 6 Pocket Wetland
Source, Georgia Stormwater Management Manual

Constructed Wetland Variations

Figure PTP-03- 7 Extended Detention Shallow Wetland
Source, Stormwater Managers Resource Center, www.stormwatercenter.net

- **Extended Detention (ED) Shallow Wetland**

The extended detention shallow wetland requires a minimum drainage area of 25 acres. The design incorporates additional water quality treatment detention above the surface of the shallow wetland design. The additional storage is typically designed to dewater in a period of 24 hours so that vegetation is not damaged. This design can accommodate sites with limited space by treating in smaller footprint than the shallow wetland. Water quality treatment may be reduced as residence time and contact time with vegetation is also likely to diminish. Landscaping in the extended detention area should incorporate plants tolerant of wet and drought conditions.

Constructed Wetland Variations

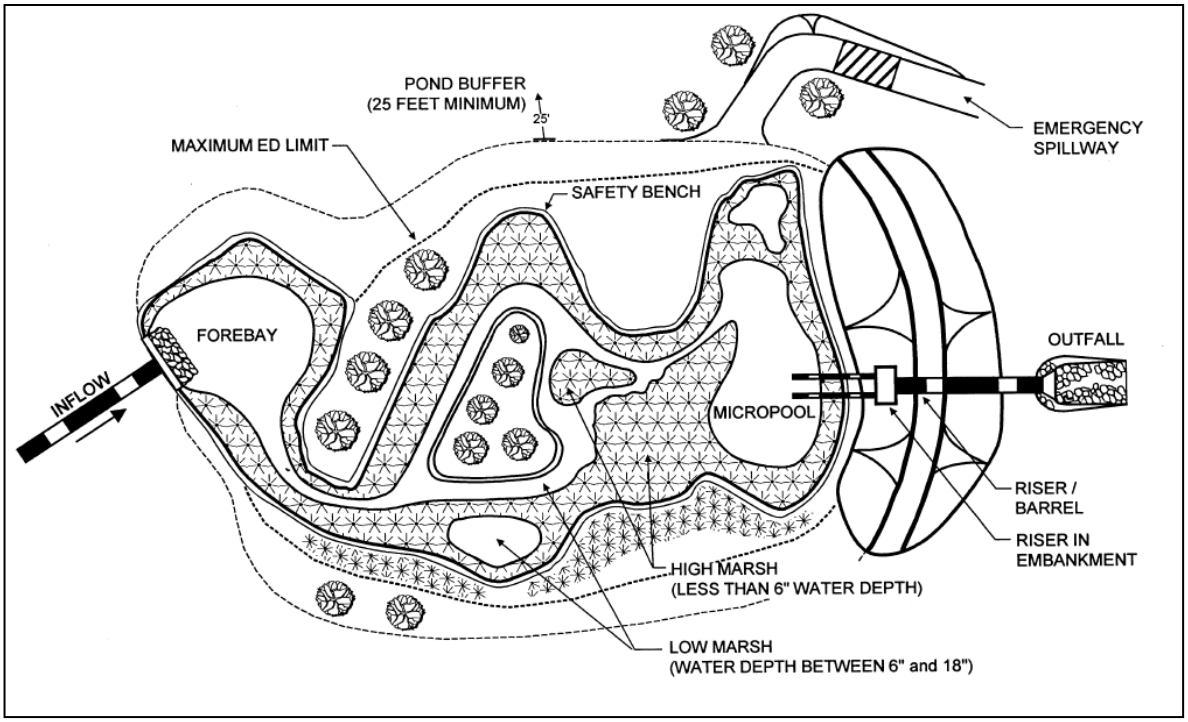


Figure PTP-03- 8 Extended Detention Shallow Wetland
Source, Georgia Stormwater Management Manual

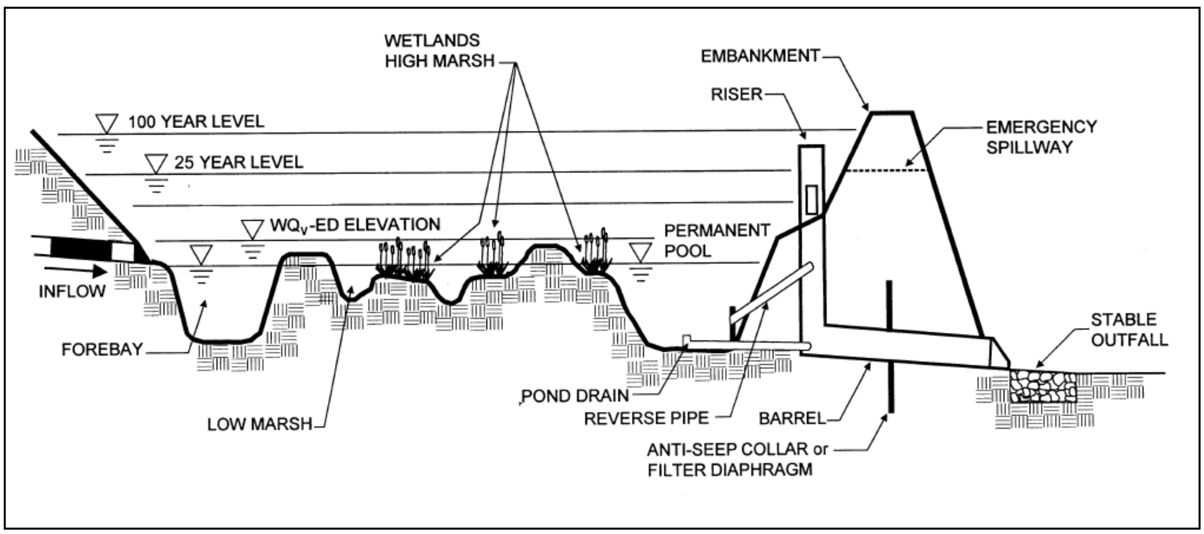


Figure PTP-03- 9 Extended Detention Shallow Wetland
Source, Georgia Stormwater Management Manual

Constructed Wetland Variations

Figure PTP-03- 10 Pond/Wetland System
This aerial photo shows a long, narrow pond design connected to the shallow wetland.
Source, Center for Watershed Protection, www.stormwatercenter.net

- **Pond/Wetland System**

The pond/wetland system requires a minimum drainage area of 25 acres. The design incorporated a wet pond and shallow marsh in order to achieve water quality and quantity goals. Stormwater flows first through the wet pond and then into the shallow wetland. The pond diffuses flows and allows entrained sediment particles to drop out before entering the wetland cell. Similarly to the ED shallow wetland, pond/wetland systems reduce the amount of surface area required compared to a shallow wetland. This is accomplished by the larger storage capacity and increased depth of the pond.

Constructed Wetland Variations

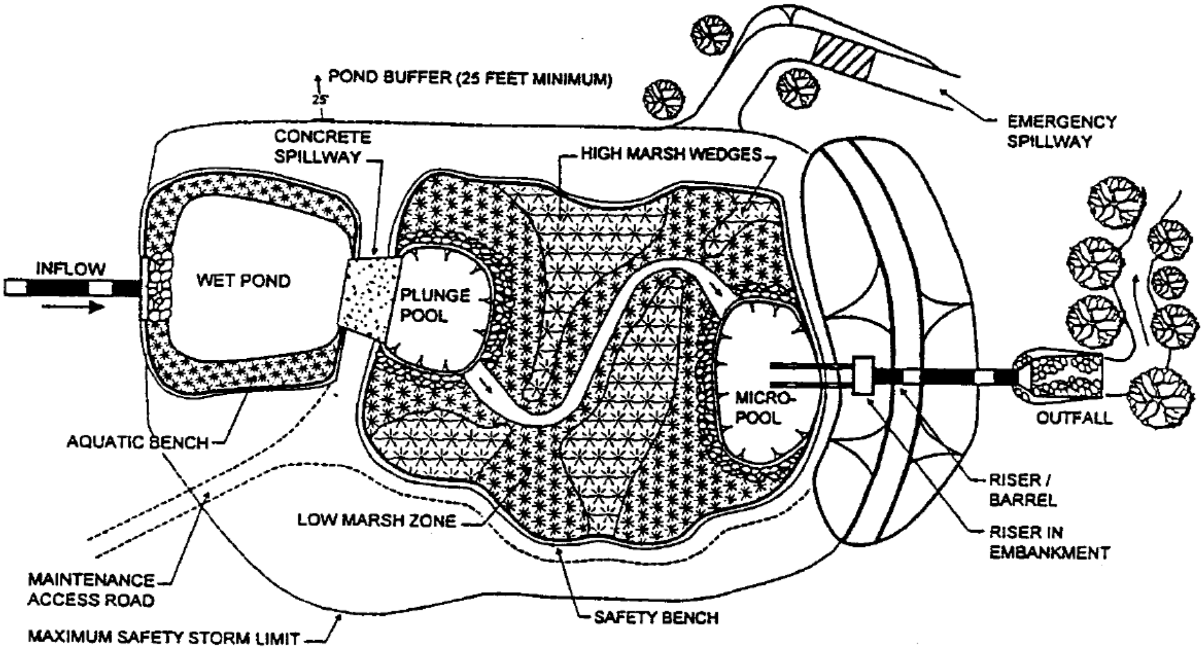


Figure PTP-03- 11 Pond/Wetland System
Source, Georgia Stormwater Management Manual

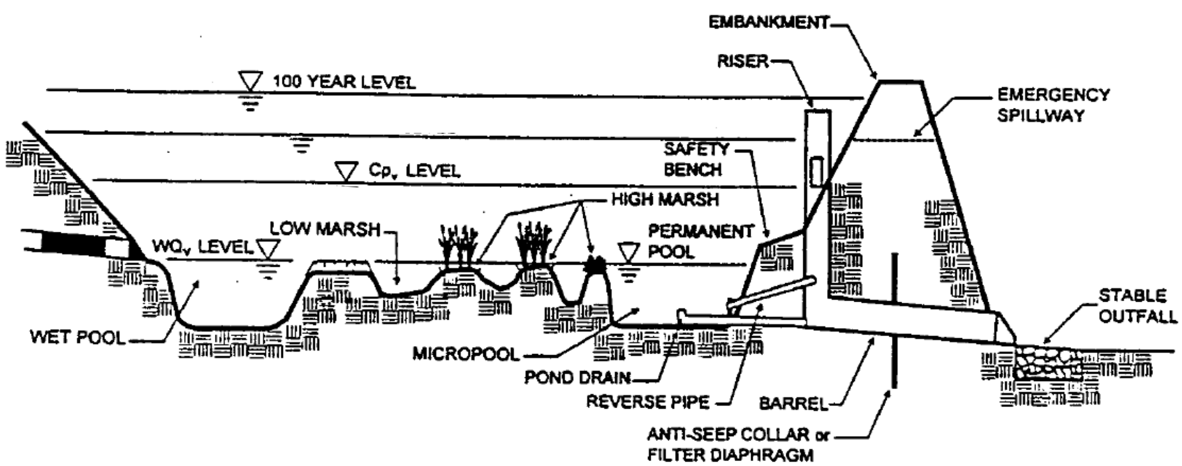


Figure PTP-03- 12 Pond/Wetland System
Source, Georgia Stormwater Management Manual

Maintenance

Regular inspections and maintenance are critical to the effective operation of constructed wetlands. Maintenance responsibility for a wetland facility and its buffer should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

One time Activity

- Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants after the second growing season.

Monthly to Quarterly or After Major Storms (>1")

- Repair undercut or eroded areas
- Clean and remove debris and trash from inlet and outlet structures.
- Mow side slopes (minimum Spring and Fall).

Semi-Annual to Annual

- Clean and remove debris and trash from wetland.
- Remove invasive vegetation.
- Harvest wetland plants. Remove any harvested vegetation from the wetland.
- Monitor wetland vegetation and perform replacement planting as needed.
- Repair broken mechanical components, if needed.

Every 1 to 3 years

- Repair Pipe and Riser, if needed.
- Forebay maintenance and sediment removal, when needed.

2 to 7 years or after 50% of forebay capacity has been diminished

- Forebay maintenance and sediment removal, when needed.

5 to 25 years or after 25% of wetland volume has been lost

- Remove sediment from main wetland.
- Replace Pipe, if needed.

Inspection Checklist

One time Activity

- ❑ Ensure that at least 50% of wetland plants survive.
- ❑ Check for invasive wetland plants.

Monthly to Quarterly or After Major Storms (>1")

- ❑ Inspect low flow orifices and other pipes for clogging.
- ❑ Check the permanent pool area for floating debris, undesirable vegetation.
- ❑ Investigate the shoreline erosion.
- ❑ Monitor wetland plant composition and health.
- ❑ Look for broken signs, locks and other dangerous items.

Semi-Annual to Annual

- ❑ Monitor wetland plant composition and health.
- ❑ Identify invasive plants.
- ❑ Assure mechanical components are functional.

Every 1 to 3 years

- ❑ All routine inspection items above.
- ❑ Inspect riser, barrel, and embankment for damage
- ❑ Inspect all pipes.
- ❑ Monitor sediment deposition in facility and forebay.

2 to 7 years or after 50% of forebay capacity has been diminished

- ❑ Monitor sediment deposition in facility and forebay.

5 to 25 years or after 25% of wetland volume has been lost

- ❑ Remote television inspection of reverse slope pipes, underdrains, and other hard to access piping.

Design Criteria

- Constructed wetlands cannot be located within navigable water of the United States without obtaining a Section 404 permit under the Clean Water Act, and any other applicable State permit. Therefore, a 404 permit may be required for this practice.
- The surface area of a constructed wetland should be about 2% to 4% of the area that drains to them.
- Constructed wetlands require setbacks from property lines, private wells, and septic system tanks and leach fields.
- Pretreatment is required for constructed wetlands. Sediment forebays are the typical pretreatment measure.
- Outlets of inflow channels are to be stabilized with flared riprap aprons, or the equivalent. Inlet pipes to the constructed wetland can be partially submerged.
- In general, wetland designs are unique for each site and application. However, there are a number of geometric ratios and limiting depths for the design of a constructed wetland that must be observed for adequate pollutant removal, ease of maintenance, the support of wetland vegetation, and improved safety. Table PTP-03-01 provides the recommended physical specifications and geometry for the various constructed wetland design variants.

Table PTP-03- 1 Recommended Design Criteria for Constructed Wetlands
(Modified from Massachusetts DEP, 1997, Schueler, 1992)

Design Criteria	Shallow Wetland	ED Shallow Wetland	Pond/ Wetland	Pocket Wetland
Length:Width (min)	2:1	2:1	2:1	2:1
Extended Detention (ED)	No	Yes	Optional	Optional
Allocation of Permanent Pool and WQ_v Volume (pool/marsh/ED) in %	25/75/0	25/25/50	70/30/0	25/75/0
Allocation of Surface Area (deepwater/low marsh/high marsh/semi-wet)	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

- The required permanent pool volume is 0.5 inches of runoff from the watershed area draining to the wetland.
- Maximum depth of any permanent pool areas should generally not exceed 6 feet.
- The contours of the wetland should be irregular to provide a more natural landscaping effect.

Design Criteria (cont.)

- An emergency spillway shall be included in the constructed wetland design to safely pass flows that exceed the design storm flows.
- A maintenance right of way or drainage easement must be provided to the wetland facility from a public or private road. The practice, as well as all access roads and components of the wetland, must be located in the drainage easement.
- Safety features should be incorporated into the constructed wetland design.

Design Components

- Site Considerations:
  - **Physiographic Factors -** local terrain design constraints
    - Low Relief – Providing wetland drain can be problematic
    - High Relief – Embankment heights restricted per Kentucky Division of Water
    - 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)
  - **Location and Siting** – the following minimum setback are required for constructed wetlands:
    - From a property line – 10 feet
    - From a private well – 100 feet; if well is down gradient from a hotspot land use (ex: gas station) then the minimum setback is 250 feet
    - From a septic system tank/leach field – 50 feet
- Pre-treatment
  - **Sediment Forebay** – 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 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 should be sized to contain 10% of the computed wetland permanent pool volume in a pool 4 to 6 feet deep. The forebay storage volume counts toward the total permanent pool volume requirement and may be subtracted from the permanent pool volume for subsequent calculations.

Design Components

- Exit velocities from the forebay must be nonerosive.
- A fixed vertical sediment depth marker should 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.

- **Wetland Buffer** – a buffer works by filtering runoff, trapping sediment, absorbing nutrients, and attenuating high flows. The buffer should be a minimum of 25 feet.

- Treatment
  - **Permanent Pool** – the permanent pool is sized according to the entire area draining to the wetland. The total volume of the permanent pool is 0.5 inches of runoff per acre of drainage area.
  - **Flow Path** – a minimum dry weather flow path of 2:1 (length to width) is required from inflow to outlet across the constructed 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.
  - **Shallow Marsh Areas** – the constructed wetland should be designed with the recommended proportion of “depth zones.” Each of the three wetland design variants has depth zone allocations which are given as a percentage of the constructed wetland surface area. Target allocations are found in Table PTP-03-01.
    - 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.
  - **Micropool** – a 4- to 6-foot deep micropool must be included in the design at the outlet to prevent the outlet from clogging and resuspension of sediments.

Design Components

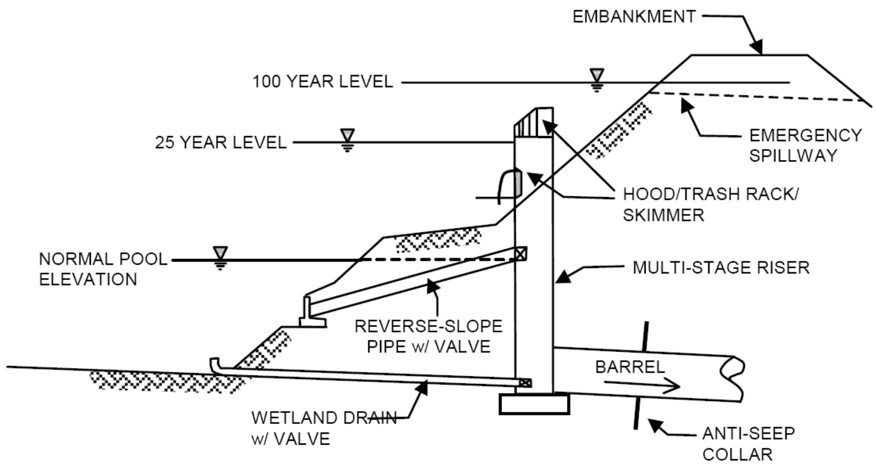


Figure PTP-03- 13 Typical Wetland Facility Outlet Structure
Source: Georgia Stormwater Management Manual

- **Outlet Structures** – Flow control from a constructed 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 PTP-04-09). 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 volume (WQ_v), 25 year storm flow (Q_{25}), and 100 year storm flow (Q_{100}). Note that the Q_{100} should be routed through the emergency spillway. The number of orifices on the principle spillway can vary and is usually a function of the wetland design.
  - Shallow Wetlands, Pocket Wetlands & Pond/Wetland Systems
    - An off-line shallow or pocket wetland providing only water quality treatment can use a simple overflow weir as the outlet structure.
    - For an on-line shallow/pocket wetland the riser configuration is typically comprised of a peak flow outlet, and extreme flood outlet (often a slot or weir).
    - The 25-yr (Q_{P25}) peak flow passes through openings or slots protected by trash racks further up on the riser.
    - Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular, V-notch, or proportional weir or an outlet pipe protected by a hood that extends at least 12 inches below the permanent pool.

Design Components

- Extended Detention Shallow Wetland
  - For an extended detention shallow wetland the riser configuration is typically comprised of an extended detention outlet (usually an orifice), peak flow outlet, and extreme flood outlet (often a slot or weir).
  - The extended detention outlet is sized to pass the extended detention water quality volume in 24 hours. This volume is surcharged on top of the permanent pool. 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 Q_{P25} passes through openings or slots protected by trash racks further up on the riser.
  - Alternative hydraulic control methods to an orifice can be used and include the use of a broad-crested rectangular, V-notch, or proportional weir, or an outlet pipe protected by a hood that extends at least 12 inches below the normal pool.
- 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 embankment 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 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.
- 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.
  - The wetland drain should be sized one pipe size greater than the calculated design diameter. The drain valve is typically a hand wheel activated knife or gate valve. Valve controls shall be located inside of the riser at a point where they will not normally be inundated and can be operated in a safe manner.

Design Components

- **Detention Zone** – the detention zone is the overlying area in which runoff volumes are stored above the permanent pool elevation.
  - The volume of the extended detention must not comprise more than 50% of the total $WQ_{v.}$
  - The maximum water surface elevation for extended detention must not extend more than 3 feet above the permanent pool.
  - Storage for larger storm events can be provided above the maximum WQv elevation (normal pool or extended detention) within the wetland.
- **Safety Bench** – the perimeter of all deep pool areas (4 feet or greater in depth) should be surrounded by safety and aquatic benches similar to those for stormwater ponds.
- **Emergency spillway**
  - An emergency spillway is to be included in the constructed wetland design to safely pass the 100 year storm, Q_{100}. 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 foot of freeboard should 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.
- **Landscaping** – Indigenous wetland vegetation and landscaping.
  - Vegetation should consist of native species suitable in wetland soil beds, including the following species:
    - Barnyard Grass (Echinochloa Crusgalli)
    - Switch Grass (Panicum Virgatum)
    - Swamp Milkweed (Asclepias incarnate)
    - Giant Cane (Arundinaria gigantean)
    - Jewelweed (Impatiens capensis)
    - River Oat (Chasmanthium latifolia)
    - Deertongue (Panicum clandestinum)
    - Boneset (Eupatorium perfoliatum)

Design Components	

Design Components

- Safety Features
  - Fencing of wetlands is not generally desirable, but may be required by the City where deemed necessary. A preferred method is to manage the contours of deep pool areas through the inclusion of a safety bench (see above) to eliminate drop-offs 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.
- Maintenance Access
  - A maintenance right of way or easement must be provided to the wetland facility from a public or private road.
  - The maintenance access should be at least 12 feet wide, having 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.

Design Procedures

Step 1 – Make a preliminary judgment as to whether site conditions are appropriate for the use of a constructed wetland, and identify the function of the wetland in the overall treatment system.

- Consider basic issues for initial suitability screening, including:
  - Site drainage area
  - Soils
  - Slopes
  - Space required for wetland
  - Depth of water table
  - Minimum head
  - Receiving waters
- Determine how the wetland will fit into the overall stormwater treatment system.
  - Are other BMPs to be used in concert with the constructed wetland?
  - Will a pond be part of the wetland design and if so, where?

Step 2 – Confirm design criteria, site constraints, and applicability.

- Determine the design criteria that will be used.
- Determine any constraints the site will place on the constructed wetland such as a limited amount of surface area available for treatment
- Determine the TSS reduction provided, using the equations below for weighted TSS reduction, $TSS_{weighted}$, and TSS treatment train, TSS_{train}. The minimum TSS reduction required for the site is 80%.
  - The equation for determining the weighted TSS reduction for a site with multiple outlet points is below.

$$\%TSS_{weighted} = \frac{\sum_{n}^{1}(TSS_1 A_1 + TSS_2 A_2 + \ldots + TSS_n A_n)}{\sum_{n}^{1}(A_1 + A_2 + \ldots + A_n)}$$

    Where TSS_1 is the TSS reduction for the BMP treating area 1, A_1 in acres; TSS_2 is the TSS reduction for the BMP treating area 2, A_2 in acres; etc.

  - Where runoff is treated by two or more BMPs in series, the TSS reduction provided is calculated with the following equation for a treatment train:

$$TSS_{train} = A + B - \frac{(A \times B)}{100}$$

    Where A is the TSS reduction provided by the first BMP and B is the TSS reduction provided by the next BMP.

Design Procedures

Step 3 – Perform field verification of site suitability.

- If the initial evaluation indicates that a wetland would be a good BMP for the site, it is recommended that a sufficient number of soil borings be taken to ensure that wetland conditions (hydrologic and vegetative) can be maintained after construction. The number of borings will vary depending on size of the site, parent material and design complexity. For example, a design that requires compacted earth material to form a dike will likely require more borings than one without this feature.
- It is recommended that the minimum depth of the soil borings be five feet below the bottom elevation of the proposed bioretention system.
- The field verification should be conducted by a qualified geotechnical professional.

Step 4 – Compute runoff control volumes and permanent pool volume.

- Calculate the Permanent Pool Volume, Water Quality Volume (WQ_v), Q_{25}, and Q_{100}. Refer to Appendix B for more information on detention and stormwater quantity management requirements.
    - The required water quality treatment volume is 1.1 inches of runoff from the new impervious surfaces created from the project.
    - The storage volume of other BMPs used upstream of the constructed wetland in the treatment train counts toward the total WQ_v requirement and may be subtracted from it.
    - Determine Water Quality Volume (WQ_V).

      $$WQv = [P\ Rv)(A)]/12$$

      Where:

      P = is the average rainfall, (inches)
      R_V = 0.05 + 0.009(I), where I is the percent impervious cover
      A = the area of imperviousness, (acres)
- Calculate the Permanent Pool Volume.
    - The required permanent pool volume is 0.5 inches of runoff from the drainage area to the wetland.
    - Determine Permanent Pool Volume.

      $$V = [(0.5)(A)]/12$$

      Where:

      V = is the permanent pool volume, (acre-ft)
      A = total watershed area draining to the wetland, (acres)

Design Procedures

Step 5 – Perform water balance calculations to ensure sufficient inflows to maintain a constant wetland pool and sustain wetland vegetation during prolonged dry weather conditions.

- Check maximum drawdown during periods of high evaporation and during an extended period of no appreciable rainfall to ensure that wetland vegetation will survive.

- The water balance calculation for a constructed wetland can be expressed as follows:

$$\Delta V = PA + R_o - Of$$

Where:
V = wetland water volume for the permanent pool (ac-ft)
P = precipitation (ft)
A = area of water surface (ac)
R_o = runoff (ac-ft)
Of = overflow (ac-ft)

$$R_o = 0.9PR_v$$

Where Rv = 0.05 + 0.009(I)

This wetland water balance is conservative and simplified, assuming the following:

- Assume that the change in volume, ΔV , is zero, meaning the water level in the wetland doesn't change significantly over time.
- The average annual precipitation value for Bowling Green is 51.63. This is the value that should be used for P. (http://www.crh.noaa.gov/images/lmk/pdf/Normals_Bowling_Green.pdf).
- There is no inflow from baseflow. This simplification will not apply for wetlands constructed in or intercepting a stream.
- There are no losses from infiltration. An impermeable liner must be used, as a significant portion of the City has karst features, making the maintenance of a permanent pool and wetland areas difficult without the liner.
- There is no loss due to evaporation or evapotranspiration.
- For most designs, the overflow rate, Of, is zero.

Step 6 – 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 constructed wetland. The forebay should be sized to contain 10% of the computed wetland permanent pool volume in a pool 4 to 6 feet deep. The forebay storage volume counts toward the total permanent pool volume requirement and may be subtracted from the permanent pool volume for subsequent calculations.

Step 7 – Allocate the remaining permanent pool and WQ_v volumes among marsh, micropool, and ED volumes.

Taking into consideration that 10% of the required permanent pool volume has already been allocated to the sediment forebay; the remaining required volume may be allocated between marsh, micropool, and ED volumes using the recommended criteria from Table PTP-03-01.

Design Procedures

Step 8 – 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 (deepwater, high marsh, low marsh, and semi-wet). A stage-storage relationship should be developed to describe the storage requirements and to set the elevation of the permanent pool, the extended detention volume (if applicable), the Q_{25}, and Q_{100}.

- Things to consider as part of the wetland layout include:
  - Provide maintenance access (12' width for trucks/machinery)
  - Use minimum length to width ratios from Table PTP-03-01

Use allocation of surface area from Table PTP-03-01

Step 9 – Compute extended detention orifice release rate and size.

ED Shallow Wetland: Based on the elevations established in Step 8 for the extended detention portion of the water quality volume, the extended detention orifice is sized to release this volume in 24 hours. The extended detention 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 one foot below the elevation of the permanent pool, is a recommended design. Adjustable gate valves can also be used to achieve this equivalent diameter.

Step 10 – Calculate Q_{25} release rate and water surface elevation.

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

Step 11 – Design embankment(s) and spillway(s).

Size emergency spillway, calculate the Q_{100} water surface elevation, set top of embankment elevation, and analyze safe passage of the Q_{100}.

Step 12 – Investigate potential pond/wetland hazard classification.

The design and construction of stormwater management ponds and wetlands are required to follow the latest version of the State of Kentucky dam safety rules (www.water.ky.gov/damsafety).

Step 13 – Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features. See Design Components Section.

Step 14 – 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.

Example Design

Proposed development of an undeveloped site into an office building and associated parking.

<u>Base Data</u>
Total Drainage Area = 5 ac
Site Area = 3.54 ac
Soils Type "C"

Pre-Development
Impervious Area = 0 ac; or I = 0%
Meadow (CN = 71)

Post-Development
Impervious Area = 1.72 ac; or I = 1.72/3.54 = 49%
Open Space, Fair (CN = 79)
Paved parking lots, roofs, driveways, etc. (CN =98)

<u>Hydrologic Data</u>

	Pre	Post
CN	71	89

WQ_v Depth = 1.1 in

<u>Precipitation</u>

I_{WQ}	2.45 in/hr
2yr, 24hr	3.54 in
25yr, 24hr	5.88 in
100yr, 24hr	7.43 in

Example Design

Problem: Design a water quality treatment plan for this site. A pocket wetland and several bioretention systems constructed meet the required TSS reduction of 80% for the site. The total drainage area to the wetland is 5 ac. Try designing a pocket wetland to treat the runoff from the impervious area. Note that this design example does not include bioretention system design.

Step 1 – Make a preliminary judgment as to whether site conditions are appropriate for the use of a pocket wetland, and identify the function of the wetland in the overall treatment system.

- Consider basic issues for initial suitability screening, including:
  - The site has type "C" soils
  - Sufficient space is available for a wetland
  - Minimum head
  - Receiving waters
- Determine how the wetland will fit into the overall stormwater treatment system.
  - A pocket wetland will be used in conjunction with bioretention systems to achieve an 80% TSS removal.
  - Pretreatment will be accomplished with sediment forebays at each inlet into the wetland.

Step 2 – Confirm design criteria, site constraints, and applicability.

- The following minimum criteria will be used in the design.
  - Try a pocket wetland
  - Minimum length:width ratio of 2:1
  - WQ_v allocation of 25% pool, 75% marsh
  - Surface Area allocation of 10% deepwater, 45% low marsh, 40% high marsh, 5% semi-wet.
- Determine any constraints the site will place on the constructed wetland:
  - No active karst areas exist on the site.
- Determine the weighted TSS reduction.
  The entire water quality volume is treated by bioretention systems and the pocket wetland. Bioretention systems are rated at 80% TSS reduction, while wetlands are rated at 75% TSS reduction.
- Determine the treatment train TSS reduction.
  After the water quality volume is treated by bioretention it is then treated in the wetland before leaving the site. Bioretention Systems have an 80% TSS reduction.
  Constructed wetlands have a 75% TSS reduction.

$$TSS_{train} = A + B - \frac{(A \times B)}{100}$$

Where:

A = 80% for the bioretention systems

B = 75% for the pocket wetland

Example Design

$$TSS_{train} = 80 + 75 - \frac{(80 \times 75)}{100}$$

$$TSS_{train} = 95\% \checkmark$$

The TSS reduction for the site is 95%, since all runoff goes through bioretention systems and then into the pocket wetland.

$\boxed{\textbf{Step 3}}$ – Perform field verification of site suitability.

- Field soil tests show that a wetland would be a good BMP for the site. The tests indicate wetland conditions, both hydrologic and vegetative, can be maintained after construction.
- To maintain the permanent water levels, an impermeable liner will be installed.

$\boxed{\textbf{Step 4}}$ – Compute runoff control volumes and get a first estimate of the permanent pool volume.

- Calculate the Water Quality Volume (WQ_v).

Total Water Quality Volume:

WQv = [*P Rv*)(*A*)]/12
Where:
P = 1.1 inches
Rv = 0.05 + 0.009(I)
I = 49
Rv = 0.05 + 0.009(49) = 0.491
A = 1.72 acres

WQv = (1.1in x 0.491 x 1.72ac)/12 = 0.077 acre-ft = **3372 ft^3** ✓

- Calculate the Q_{25} and Q_{100} peak flows.

The pre- and post development volumes for both 25-yr and 100-yr 24-hour return frequency storms (Q_{P25} and Q_{P100}) should be calculated to determine the required water quantity controls. For this design example, water quantity control is addressed by additional storage volume in the wetland and outlets to accommodate the Q_{P25} and Q_{P100}.

Example Design

- Calculate the Permanent Pool Volume.

V = [(0.5)(A)]/12

Where:
A = 5 acres

V = [(0.5)(5)]/12 =0.21 acre-ft = **9075 ft³**✓

Step 5 – Perform water balance calculations to ensure sufficient inflows to maintain a constant wetland pool and sustain wetland vegetation during prolonged dry weather conditions.

$$\Delta V = PA + R_o - Of$$
$$0 = PA + 0.9PR_v - Of$$

0 = (4.3 ft)(A) + (0.9 [0.05 + [0.009 x 49]) – 0

Solve for A: **A = 0.103 ac or 4476.5 ft²**

This is the surface area required for the wetland.

Step 6 – Determine pretreatment volume.

There is 1 inlet providing greater than 10% of the total design storm inflow to the wetland. Sediment forebay can provide up to 10% of the WQ_v storage.

Sediment Forebay Volume = 0.10 (3372ft^3) = **337.2 ft^3**

Set 3' depth, 5' bottom width, 22.5' long

Step 7 – Allocate the remaining permanent pool and WQ_v volumes among marsh, micropool, and ED volumes. WQ_v = 3372 ft^3.

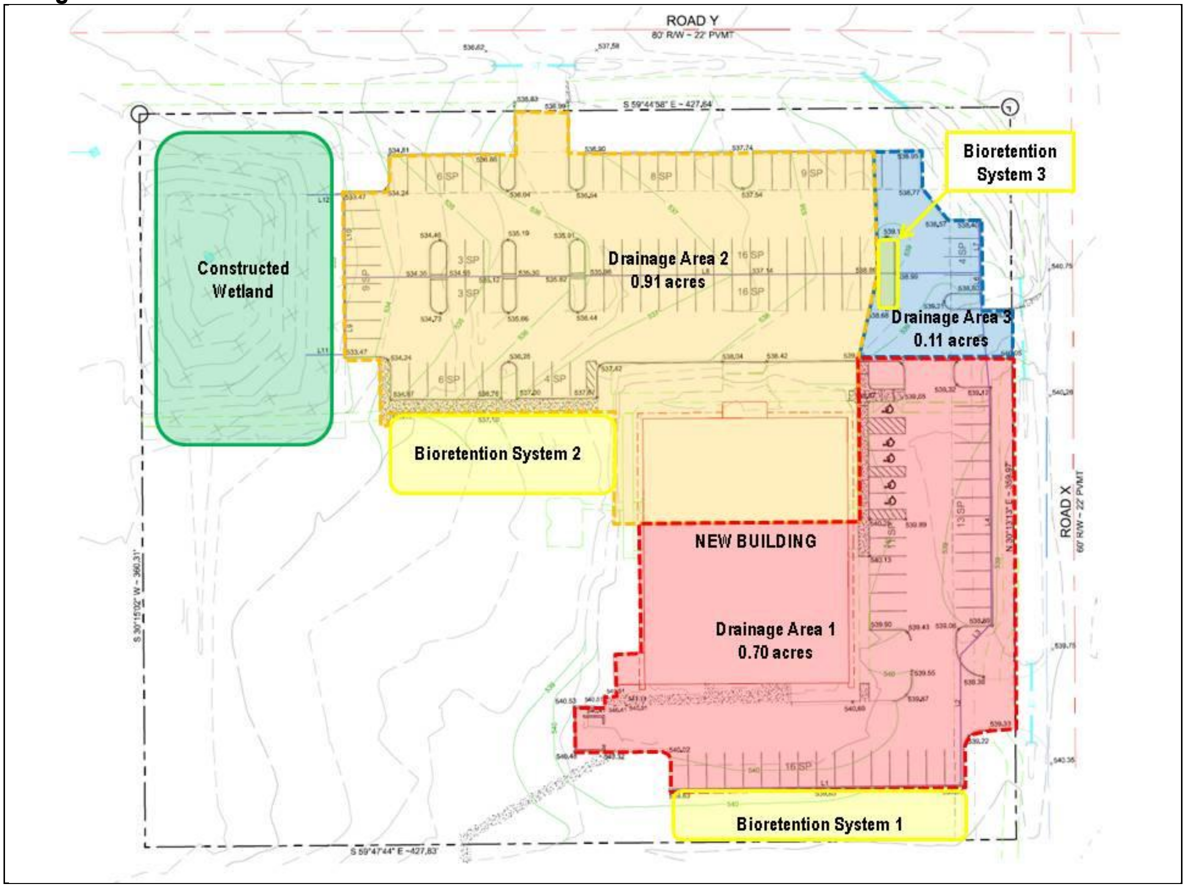
Marsh Volume = 0.75 (Volume Permanent Pool – Forebay volume)

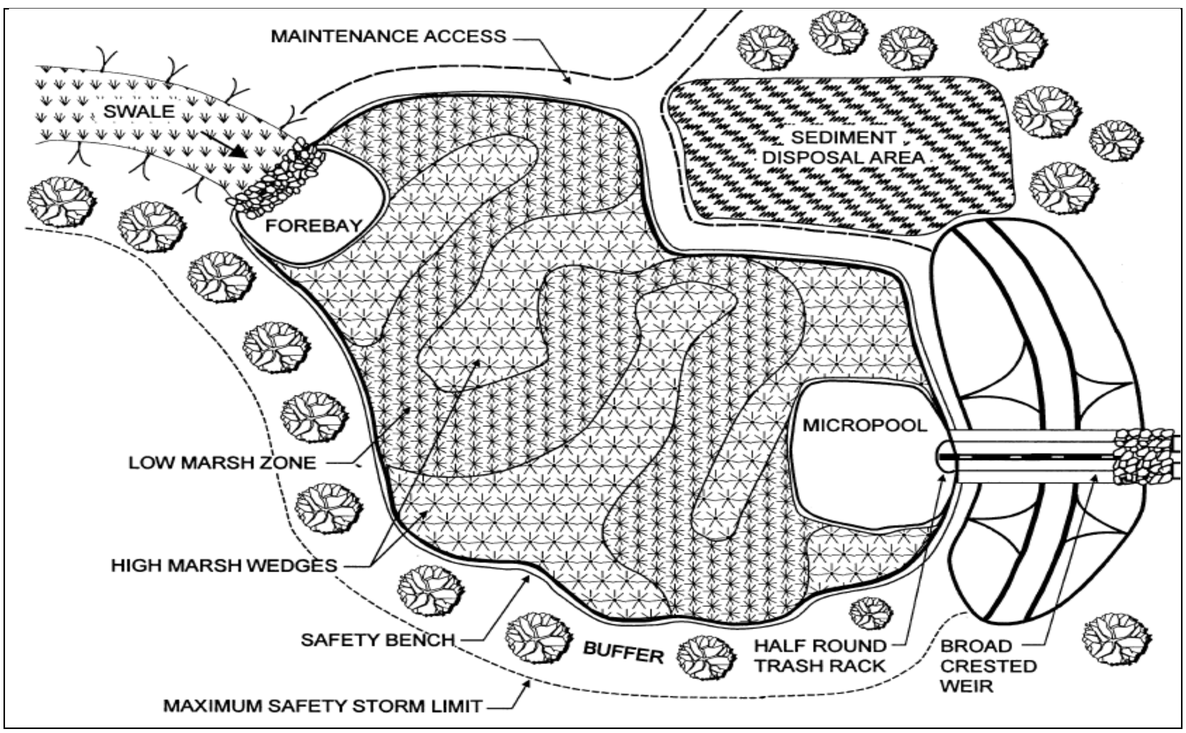
Marsh Volume = 0.75 (3372 ft3 – 337.2 ft3) = **2276.1 ft^3**

Micropool Volume = = 0.25 (Permanent Pool – Forebay volume)

Micropool Volume = = 0.25 (3372 ft3 – 337.2 ft3) = **758.7 ft^3**

Example Design





Example Design

Step 8 – Determine wetland location and preliminary geometry, including distribution of wetland depth zones.

- Determine the distribution of wetland surface area among the various depth zones (deepwater, high marsh, low marsh, and semi-wet).

	Allocation		Vol, ft3	SA, ft2	Configuration	Vol provided, ft3
Forebay	10%		337.2		3' deep, 5' bottom, 22.5' long	337.5
Pool	25%		758.7		trapezoidal, 3:1; 5' depth, 10' bottom x 7' long	875
Marsh	75%		2276.1	2276.1	Assume 1' average depth in marsh	
low marsh		45%		1024.2	1' deep x 1024.2' long; trapezoidal, 3:1 side slopes; serpentine channel	7681.5
high marsh		50%		1138.1	0.5' deep, 50' x 23'	575
semi-wet		10%		227.6	35' x 40'	0
ED	0%					
						9469

Note that the required storage in the permanent pool is 9075 ft^3. The actual storage provided by the configuration will be 9469 ft^3.

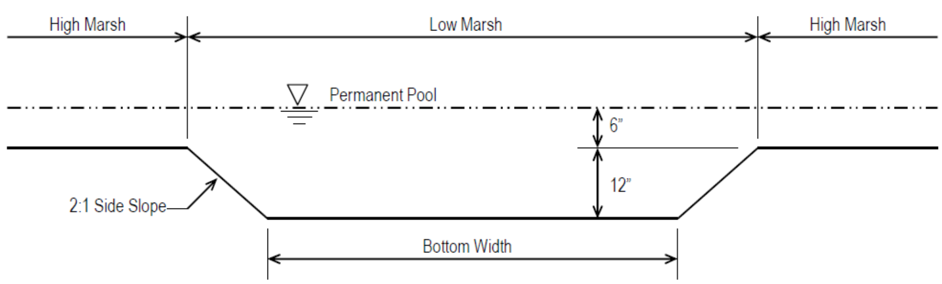


Figure PTP-04- 14 Wetland Cross Sectional View

Design Procedures

Step 9 – Compute extended detention orifice release rate and size.

- A pocket wetland is being designed which does not have extended detention.

Step 10 – Calculate the Q_{P25} release rate and water surface elevation.

- This example focuses on the WQ_v treatment. Therefore, to complete the design a stage-storage-discharge relationship for Q_{P25} outlet structure should be developed to determine the release rate and water surface elevation.

Step 11 – Design embankment(s) and spillway(s).

- This example focuses on the WQ_v treatment. Therefore, to complete the design size emergency spillway, calculate Q_{P100} water surface elevation, set top of embankment elevation, and analyze safe passage of the Q_{P100}.

Step 12 – Investigate potential pond/wetland hazard classification.

- The design and construction of stormwater management ponds and wetlands are required to follow the latest version of the State of Kentucky dam safety rules (www.water.ky.gov/damsafety).

Step 13 – Design inlets, sediment forebay(s), outlet structures, maintenance access, and safety features.

- This example focuses on the WQv treatment. To complete the design refer to the information provided in the Design Components Section.
- Forebay dimensions were calculated in Step 6

Step 14 – 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.