12.0 **Constructed Wetlands**

Definition: **Practices that mimic natural wetland areas to treat urban stormwater by incorporating permanent pools with shallow storage areas. Constructed Wetlands may provide stormwater detention for larger storms (Cv and Fv) above the RPv storage.**

Design variants include:

- 12-A **Traditional Constructed Wetlands**
- 12-B **Wetland Swales**
- 12-C **Ephemeral Constructed Wetlands**
- 12-D **Submerged Gravel Wetlands**
- 12-E Floating Wetlands (to be added at a later date)

Constructed Wetlands are shallow depressions that receive stormwater inputs for water quality treatment. The majority of the wetland surface area is covered by shallow (<1-foot deep) wetland area, with greater depths in the forebay and pools within the wetland. Wetlands possess variable microtopography to promote dense and diverse wetland cover. Runoff from each new storm displaces runoff from previous storms, and the long residence time allows multiple pollutant removal processes to operate. The wetland environment provides an ideal environment for gravitational settling, biological uptake, and microbial activity.

Submerged Gravel Wetlands (SGW) treat stormwater runoff primarily through filtration, sedimentation, physical and chemical sorption, microbially mediated transformation, uptake, and attenuation. Sedimentation occurs in the pretreatment forebay as well as above the wetland surface. Filtration, sorption, and transformation occur as the stormwater passes through the gravel substrate via microbe rich environment. While uptake occurs from the wetland vegetation most of the treatment is within the gravel substrate in a "plug flow" type system.

The Constructed Wetlands design variants all share commonalities but are also unique in their performance credits.

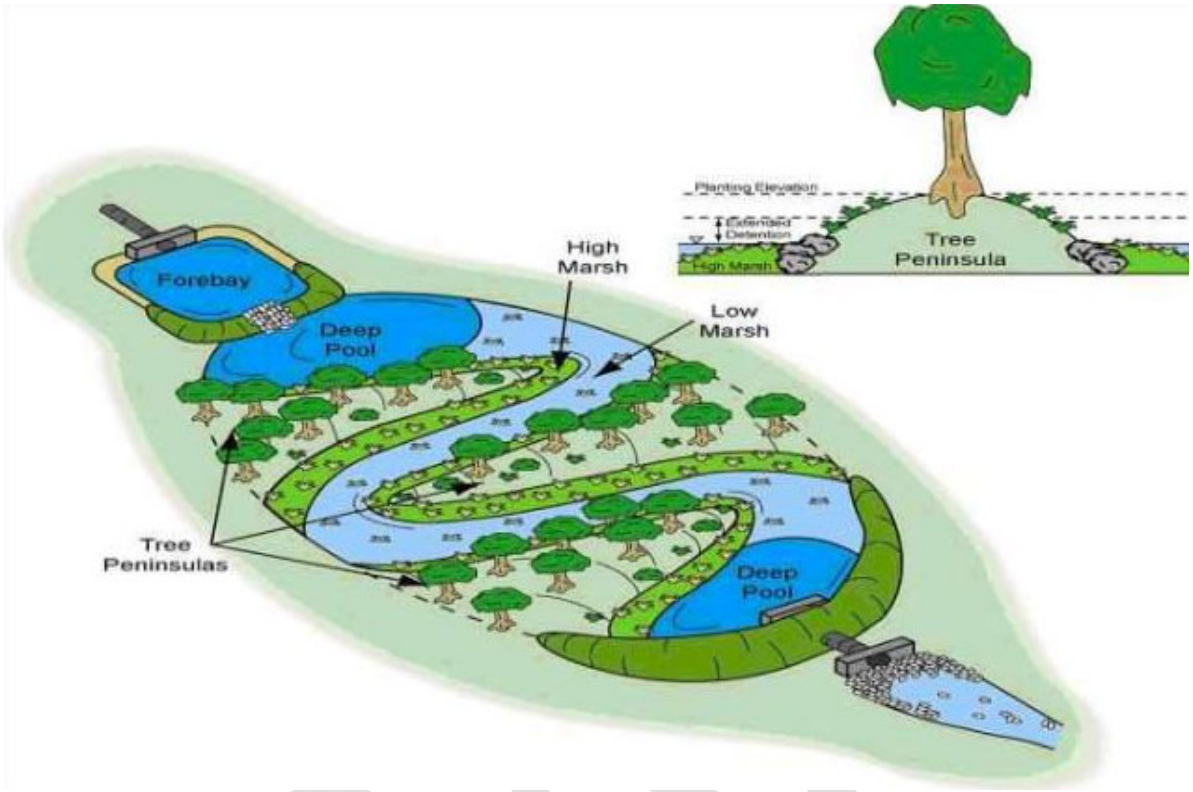

Figure 12.1 Typical Traditional Constructed Wetland

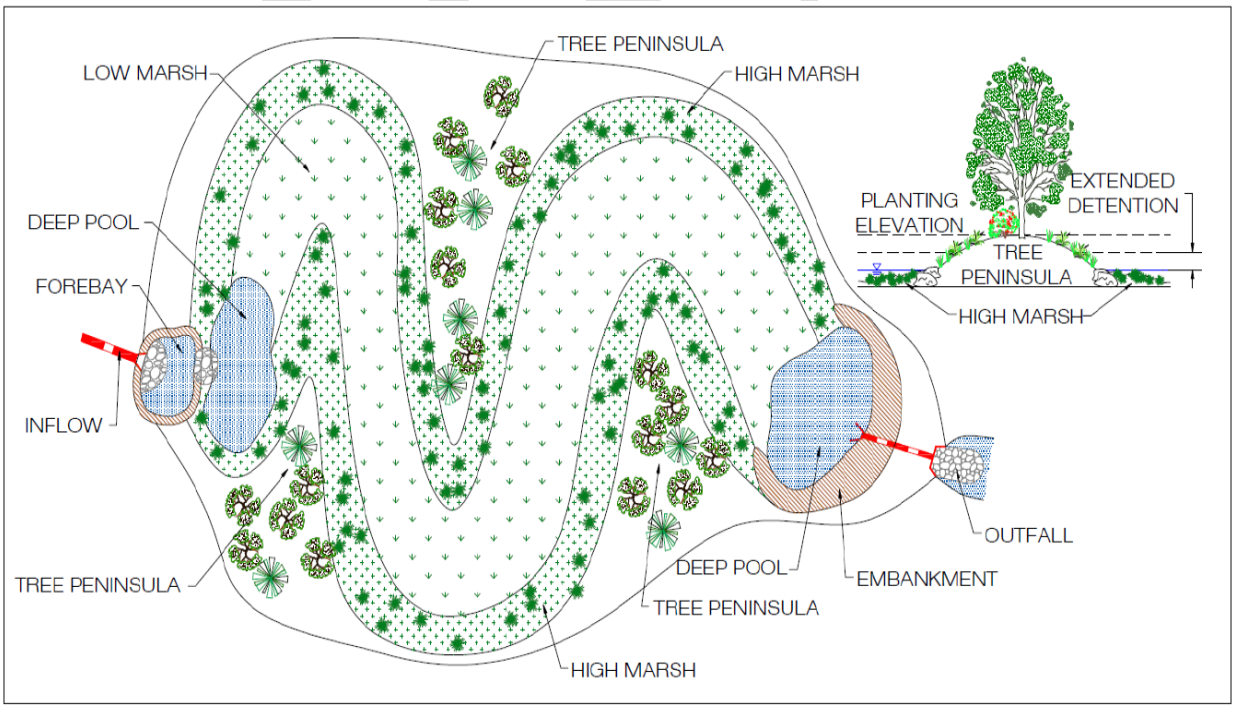

Figure 12.2 Typical Traditional Constructed Wetland Plan View

12.3 Typical Wetland Swale Section View

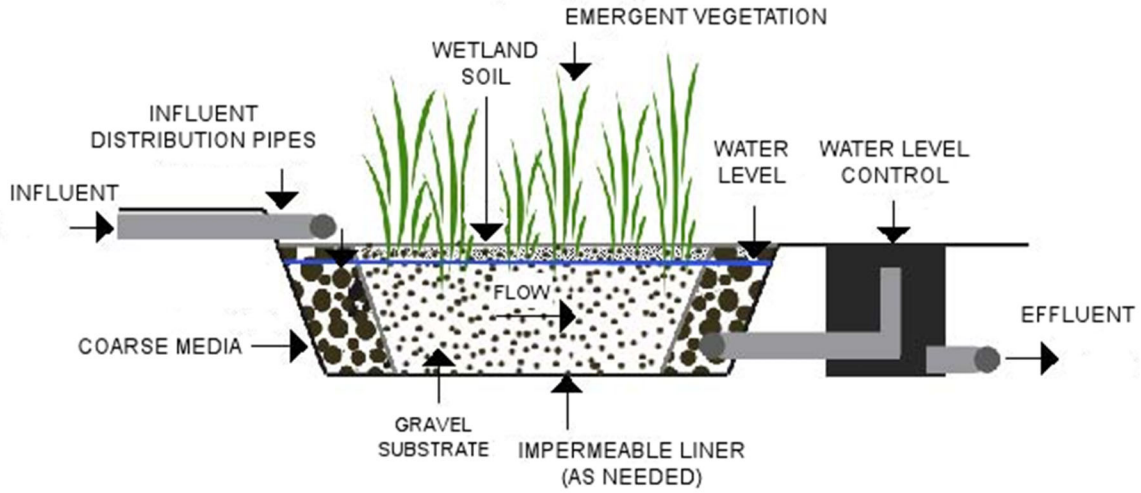

Figure 12.4 Typical Submerged Gravel Wetland Profile View

12.1 Constructed Wetland Stormwater Credits

Constructed wetlands receive 0% retention credit (R_v) and pollutant removals are outlined in Table 12.1.

Table 12.1-A
Traditional Constructed Wetlands Performance Credits

Runoff Reduction	
RPv	**100%**
Cv	**Not Less Than 1%**
Fv	**Not Less Than 0%**
Pollutant Reduction	
TN Reduction	**Not less than 30% Removal Efficiency**
TP Reduction	**Not less than 40% Removal Efficiency**
TSS Reduction	**Not less than 80% Removal Efficiency**

Table 12.1-B
Wetland Swale Performance Credits

Runoff Reduction	
RPv -A/B Soil	**15% Annual Runoff Reduction**
RPv - C/D Soil	**10% Annual Runoff Reduction**
Cv	**Not Less Than 1% of RPv Allowance**
Fv	**Not Less Than 0%**
Pollutant Reduction	
TN Reduction	**100% of Load Reduction + Not less than 20% Removal Efficiency**
TP Reduction	**100% of Load Reduction + Not less than 30% Removal Efficiency**
TSS Reduction	**100% of Load Reduction + Not less than 60% Removal Efficiency**

Table 12.1-C

Ephemeral Constructed Wetland Performance Credits

Runoff Reduction* **	
RPv -A/B Soil	**40% Annual Runoff Reduction**
RPv - C/D Soil	**10% Annual Runoff Reduction**
Cv	**Not Less Than 1% of RPv Allowance**
Fv	**Not Less Than 0%**
Pollutant Reduction	
TN Reduction	**100% of Load Reduction + Not less than 20% Removal Efficiency**
TP Reduction	**100% of Load Reduction + Not less than 30% Removal Efficiency**
TSS Reduction	**100% of Load Reduction + Not less than 60% Removal Efficiency**

***NOTE: An Ephemeral Constructed Wetland constructed in accordance with the Sediment and Stormwater Plan Review Policy and Procedures for Poultry House Projects as a forebay having a volume equivalent to the full RPv shortfall volume is given full volume reduction credit. The Department will monitor the performance of the ephemeral constructed wetland forebays at these poultry house projects and may adjust the volume reduction credit as necessary.

Table 12.1-D
Submerged Gravel Wetland Performance Credits

Runoff Reduction	
Retention Allowance	**0%**
RPv	**100% of Detention Storage**
Cv	**100% of Detention Storage**
Fv	**100% of Detention Storage**
Pollutant Reduction	
TN Reduction	**Not less than 30% Removal Efficiency**
TP Reduction	**Not less than 40% Removal Efficiency**
TSS Reduction	**Not less than 80% Removal Efficiency**

12.2 Constructed Wetlands Practice Summary

Table 12.2 summarizes the various criteria for Constructed Wetlands.

Table 12.2 Constructed Wetlands Practice Summary

Feasibility Criteria (Section 12.3)	• **Constructed Wetlands shall not be located within existing jurisdictional wetlands.**
Conveyance Criteria (Section 12.4)	• **The principal spillway must be accessible from dry land.** • **A structure-pipe spillway shall be designed with anti-flotation, anti-vortex and trash rack devices on the structure.** • **The outfall pipe and all connections to the outfall structure shall be made watertight. Soil tight only joints are not acceptable.** • **Anti-seep collars shall be used in accordance with Pond Code 378, as amended.** • **When the principal spillway is composed of a weir wall discharging to a channel, the channel below the weir must be reinforced with riprap or other acceptable material to prevent scour.** • **When a low flow orifice is specified, it must be adequately protected from clogging by either an acceptable external trash rack or by internal orifice protection. Orifice diameters shall not be less than 3 inches.** • **The design shall specify an outfall that can discharge the maximum design storm event in a non-erosive manner at the project point of discharge.** • **Constructed Wetlands must be designed to pass the maximum design storm event (Fv) if the Fv is being routed through the Constructed Wetland rather than bypassing.** • **An earthen emergency spillway designed to convey the Fv shall be cut in natural ground or, if cut in fill, shall be constructed and stabilized with methods to prevent erosion and structural failure.** • **Inflow points into the Constructed Wetland must be stabilized to ensure that non-erosive conditions exist during storm events up to the conveyance event (Cv).** • **For Submerged Gravel Wetlands, the inflow volume shall enter the gravel substrate directly via a pipe manifold or inflow chimneys or as sheet flow through connected gravel layer.**

Pretreatment Criteria (Section 12.5)	• **Every inlet into a Constructed Wetland shall have pretreatment.**
	• **Exit velocities from the pretreatment shall be non-erosive during the largest design storm that is routed through the Constructed Wetland.**
	• **A forebay shall be located at each major inlet to trap sediment and preserve the capacity of the main treatment cell.**
	• **The following criteria apply to forebay design:**
	  ○ **A major inlet is defined as an individual storm drain inlet pipe or open channel conveying at least 10% of the Constructed Wetland's contributing RPv runoff volume.**
	  ○ **The forebay must be sized to contain 10% of the volume of runoff from the contributing drainage area for the Resource Protection event.**
	• **Discharge from the forebay shall be non-erosive.**

Design Criteria (Section 12.6)	• **Constructed Wetlands constructed to meet regulatory stormwater management requirements shall be designed and constructed in accordance with the USDA NRCS Pond Code 378 as amended.** • **Constructed Wetlands shall be designed so that they will dewater the Fv within 72 hours, or manage the Fv on site with no adverse impact. The extents of the Fv shall be clearly delineated.**

Design Criteria (Section 12.6) *cont.*	• **The lowest discharge elevation on the outlet device shall be located no lower than the seasonal high groundwater table as determined by the Soil Investigation Procedures.**
	• **All Traditional Constructed Wetlands shall be evaluated for feasibility and ability to maintain permanent pool, including the need for a liner, by a qualified, licensed geotechnical engineer or geologist. If the design professional chooses not to follow the recommendations of the geotechnical professional, a signed, sealed and dated letter from the design professional providing justification for removal of the liner from the design shall be provided to DNREC or their delegated Agency.**
	• **When the geotechnical engineer recommends a liner, acceptable options include the following:**
	  o **A clay liner having a minimum compacted thickness of six inches with an additional six inch layer of engineered wetland soil mix containing a minimum of 35% organic material above it. Clay used as a liner must meet the following specifications:**
	  ▪ **Permeability of 1x10-6 cm/sec using ASTM D-2434 procedure.**
	  ▪ **Plasticity index of not less than 15% using ASTM D-423/424 procedures.**
	  ▪ **Liquid limit of not less than 30% using ASTM D-2216 procedure.**
	  ▪ **Clay particles passing not less than 30% using ASTM D-422 procedure.**
	  ▪ **Compaction of 95% of standard proctor density using ASTM D-2216 procedure.**
	  o **Other acceptable measures as recommended by a qualified geotechnical professional.**
	• **Trash racks shall be provided for low-flow pipes and for all riser structure openings.**
	• **All metal trash racks shall be coated with a rust inhibitor to increase longevity of the device.**
	• **When a riser is used, it must be located such that it is accessible from the side slope for the purposes of inspection and maintenance.**
	• **Safety features:**
	  o **Any opening 12 inches or greater discharging to a closed drainage system shall include safety grates.**
	  o **The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.**
	  o **The emergency spillway exit channel must be designed to direct runoff to a point of discharge without impact to downstream structures.**
	• **All Constructed Wetlands must be designed so as to be accessible for maintenance.**
	• **Adequate maintenance access must extend to the forebay, safety bench, riser, and outlet structure.**
	• **A maintenance right-of-way or easement must extend to the Constructed Wetland from a public or private road.**
	• **Maintenance access must meet the following criteria:**
	  o **Minimum width of 15 feet.**
	  o **Profile grade that does not exceed 10H:1V.**
	  o **Minimum 10H:1V cross slope.**
	• **Maintenance set-aside area:**
	  o **The maintenance set-aside area shall accommodate the volume of 50% of the collective forebay volume.**
	  o **The maximum depth of the set aside area shall be 1 foot.**
	  o **The slope of the set aside area shall not exceed 5%.**

Variant Specific Design Criteria (Section 12.6)	*Traditional Constructed Wetland (12-A)*
	• **The permanent pool volume, or the volume below the normal water surface elevation, shall be equivalent to a minimum of 50% of the RPv volume.**
	• **Traditional Constructed Wetlands shall be sized so that the RPv has a maximum ponding depth of 12 inches above the normal water surface elevation. The RPv shall dewater within 48 hours.**
	• **The Cv maximum ponding depth shall not exceed 12 inches above the normal water surface elevation for more than 12 hours.**
	• **The total length of the flow path compared to the linear length through the Traditional Constructed Wetland shall be a minimum ratio of 2:1.**
	• **When an inlet is located near the outlet, the ratio of the shortest flow path through the system to the overall length shall be a minimum of 0.5:1.**
	• **The drainage area served by any inlets located less than a 0.5:1 ratio shall constitute no more than 20% of the total contributing drainage area.**
	• **Traditional Constructed Wetlands shall be composed of the following zones:**
	  ○ **Zone 1: Deep Pools**
	  ▪ **The volume of water stored in the deep pools, also referred to as micropools, shall be at least 20% of the RPv volume.**
	  ▪ **A minimum of two deep pools in addition to the forebay shall be provided, one of which shall be located prior to the outlet location to provide for additional sediment deposition.**
	  ▪ **The deep pools shall be hydraulically connected within the water flow path.**
	  ▪ **The deep pools shall be designed with a side slope not steeper than 3:1.**
	  ▪ **A safety bench is required for deep pool depths greater than four feet.**
	  ○ **Zone 2: Transition Zone**
	  ▪ **Zone 2 is a short transition zone between the deeper pools and the low marsh zone, and ranges from a minimum of 6 inches to a maximum of 30 inches below the normal pool elevation.**
	  ▪ **The volume of water stored in the transition zone shall be a minimum of 20% of the RPv volume.**
	  ▪ **The transition zone shall have a maximum side slope of 3:1from the deep pool to the low marsh zone.**
	  ○ **Zone 3: Low Marsh Zone**
	  ▪ **The low marsh zone ranges from a maximum of 6 inches below the normal pool elevation to the normal pool elevation.**
	  ▪ **The volume of water stored in the low marsh zone shall be a minimum of 10% of the RPv volume.**
	  ▪ **The side slope within the low marsh zone shall not be steeper than 4:1.**
	  ○ **Zone 4: High Marsh Zone**
	  ▪ **The upper end of the marsh zone is the high marsh zone, which ranges from the normal pool elevation to a maximum of 12 inches above the normal pool elevation, allowing the RPv to inundate to the top of the high marsh zone.**
	  ▪ **The side slope within the high marsh zone shall not be steeper than 4:1.**
	  ○ **Zone 5: Floodplain**
	  ▪ **A low floodplain shall range between a minimum of 12 inches and a maximum of 18 inches above the normal water surface elevation and be planted with plants suited for infrequent to**

Variant Specific Design Criteria (Section 12.6) *cont.*	**temporary saturations.** ▪ **The side slope within the floodplain shall not be steeper than 4:1.** • **A minimum 10-foot-wide vegetated perimeter around the wetland area shall be planted with appropriate grasses, trees, and shrubs.** • **A simple water balance calculation shall be performed, using Equation 12.2 (Hunt et al., 2007), to ensure that the deep pools will not go completely dry during a 30-day summer drought.** *Wetland Swale (12-B):* • **Wetland swales shall contain the Cv event.** • **If the Fv event is not contained within the Wetland swale top of bank, then the area of inundation and discharge route shall be delineated.** • **The maximum RPv water surface elevation shall be no greater than 6 inches above the normal water surface elevation.** • **The average groundwater elevation shall be below the bottom of the Wetland Swale. Only the seasonal high groundwater may intersect the bottom of the Wetland Swale.** • **Wetland Swales shall not have side slopes steeper than 3:1.** • **The maximum longitudinal slope shall be an average of 1%.** • **A minimum 10-foot-wide vegetated perimeter on both sides of the wetland swale shall be planted with appropriate grasses, trees and shrubs.** *Ephemeral Constructed Wetland (12-C)* • **The RPv event shall pond a minimum of 6 inches and a maximum of 12 inches of water above the ground surface of the Ephemeral Constructed Wetland.** • **The Fv water surface shall be a maximum of 30 inches above the ground surface of the Ephemeral Constructed Wetland.** • **The average groundwater elevation as determined by the Soil Investigation Procedures shall be below the wetland bottom of the Ephemeral Constructed Wetland.** • **Only the seasonal high groundwater as determined by the Soil Investigation Procedures may intersect the bottom of the Ephemeral Constructed Wetland.** • **If the seasonal high groundwater intersects the bottom of the Ephemeral Constructed Wetland, the wetland shall be modeled considering the elevation of the seasonal high groundwater.** • **The side slopes of the buffer area and within the wetland shall be 4:1 or flatter.** • **A minimum 10-foot-wide vegetated perimeter around the wetland area shall be planted with appropriate grasses, trees, and shrubs.** *Submerged Gravel Wetland (12-D)* • **The maximum surface ponding depth for the RPv shall not be greater than the tolerance depths of the wetland plantings selected, or two feet, whichever is less.** • **The Submerged Gravel Wetland shall store the RPv volume within the stone substrate and wetland soils and above the soils in surface ponding.** • **Submerged Gravel Wetlands shall have no minimum detention time.** • **The gravel substrate shall be a minimum of 2 feet and a maximum of 4 feet in depth.** • **The gravel substrate shall be sized to contain a minimum of 25% of the RPv volume considering 40% void ratio.** • **The gravel substrate shall be composed of clean washed gravel, with a maximum of 2.0% passing the #200 sieve.** • **Gravel shall have a maximum diameter of 2.5 inches and a minimum diameter of 0.5 inches.** • **A porosity value of 0.4 shall be used for areas of stone in the design of gravel substrate.** • **Sand shall not be an acceptable substitute for gravel.** • **An engineered wetland soil layer containing a minimum of 15% organic material and a**

Variant Specific Design Criteria (Section 12.6) *cont.*	**maximum of 15% clay content shall be included on the surface of the Submerged Gravel Wetland. The wetland soil layer shall be a minimum of 8 inches thick.** • **A minimum 4 inch thick layer of clean, washed nominal ¼" gravel with a maximum of 2.0% passing the #200 sieve shall be installed between the gravel substrate and the wetland soil layer.** • **An underdrain shall be provided at an elevation 3 inches above the invert of the gravel substrate. The underdrain shall be a minimum of 4-inch perforated high density polyethylene pipe (HDPE) or polyvinyl chloride pipe (PVC).** • **The underdrain shall connect to the outlet structure. The discharge elevation shall be 4 inches below the wetland soil surface.** • **There shall be a minimum of 15 feet separation distance between all gravel substrate inflow points and all underdrain outlet points.** • **Side slopes above the gravel substrate shall not be steeper than 3:1.**
Landscaping Criteria (Section 12.7)	• **A planting plan is required for all Constructed Wetlands.** • **Invasive species shall not be specified within Constructed Wetlands.** • **The planting plan shall be certified by a qualified professional with demonstrated knowledge in wetland species.** • **Plants used in Constructed Wetlands shall be supplied by a certified wetland nursery using plants selected for the region.**
Construction Criteria (Section 12.8)	• **Approval from the Department or the appropriate Delegated Agency must be obtained before any planned Constructed Wetlands can be used as a sediment basin.** • **If a Constructed Wetlands serves as a sediment basin during project construction, the volume of the sediment basin must be based on the more stringent sizing rule.** • **The Sediment and Stormwater Plan must include conversion steps from sediment basin to permanent Constructed Wetlands in the construction sequence.** • **The Department or Delegated Agency must be notified and provide approval prior to conversion from sediment basin to the final configuration of the Constructed Wetlands.** • **Appropriate procedures must be implemented to prevent discharge of turbid waters when the sediment basin is being converted into a Constructed Wetlands.** • **Construction reviews are required during the following stages of construction, and shall be noted on the plan in the sequence of construction:** o **Pre-construction meeting** o **Initial site preparation including installation of erosion and sediment controls** o **Construction of the embankment, including installation of the principal spillway and the outlet structure as applicable** o **Excavation and grading including interim and final elevations** o **Construction of wetland features including grading of microtopography, introduction of soil amendments and staking of planting zones** o **Construction of the underdrain, installation of gravel substrate and wetland soils as applicable** o **Implementation of the planting plan and vegetative stabilization** o **Final inspection including development of a punch list for facility acceptance** • **All areas surrounding the Constructed Wetlands that are graded or denuded during construction must be planted with turf grass, native plantings, or other approved methods of soil stabilization.** • **Temporary seed, such as annual rye or winter wheat, may be used to stabilize the soil within the Constructed Wetland, but permanent species shall then be planted or seeded at next optimum planting date.** • **Stabilization matting shall be utilized in Wetland Swales and in all areas of concentrated flow or slopes 3:1 or steeper.**

Construction Criteria (Section 12.8) *cont.*	• **Upon facility completion, the owner shall submit Post Construction verification documents to demonstrate that the Constructed Wetlands has been constructed within allowable tolerances in accordance with the approved Sediment and Stormwater Management Plan and accepted by the approving agency. Allowable tolerances for Constructed Wetlands practices are as follows:** o **The constructed top of bank elevation may be no lower than the design elevation for top of bank.** o **The constructed volume of the Constructed Wetlands surface storage shall be no less than 90% of the design volume.** o **The constructed volume of the gravel substrate storage for Submerged Gravel Wetlands shall be no less than 90% of the design volume.** o **The constructed elevation of any structure shall be within 0.15 foot of the design.**
Maintenance Criteria (Section 12.9)	• **Before project completion the Owner shall submit a final post construction stormwater management Operation and Maintenance Plan for the entire stormwater management system.** • **Operation and Maintenance Plans remain valid for the life of the stormwater management system.** • **During the first two years following construction, the Constructed Wetland shall be reviewed twice each year by a qualified professional with demonstrated knowledge of wetland species, once in the spring and once in the fall after a storm event that exceeds 1/2 inch of rainfall.** • **The Operation and Maintenance Plan shall outline a detailed schedule for the monitoring and possible reinstallation of vegetation in the wetland and its buffer for the first two years of establishment.** • **Repair of critical structural features such as embankments and risers shall be performed by responsible personnel that have successfully completed the Department Contractor Training Program.** • **Project closeout shall not occur until a minimum of 70% of the wetland area is permanently vegetated.** • **Sediment removal in the pretreatment forebay shall occur when 50% of total forebay capacity has been lost.** • **The Department or the Delegated Agency shall be notified before a Constructed Wetland is drained.**

12.3 Wetland Feasibility Criteria

Constructed wetland designs are subject to the following site constraints:

Adequate Water Balance. Traditional Constructed Wetlands (12-A) should have enough water supplied from groundwater, runoff or baseflow so that the permanent pools are designed to remain moist after a 30-day summer drought. See *Section 12.6. Water Balance Testing* for deep pool design criteria.

Contributing Drainage Area (CDA). The contributing drainage area should be large enough to sustain a permanent water level within the stormwater wetland. If the only source of wetland hydrology is stormwater runoff, then typically more than 2 to 3 acres of drainage area is needed to maintain constant water elevations. Smaller drainage areas are acceptable if the bottom of the wetland intercepts the groundwater table or if the designer and the landowner are willing to accept

periods of relative dryness (i.e., Ephemeral Constructed Wetlands, 12-C), and the plant species are chosen to accommodate this design variable. The minimum recommended drainage area for Submerged Gravel Wetlands, 12-D, is one acre.

Space Requirements. Constructed Wetlands normally require a footprint that takes up about 10% of the contributing drainage area, depending on the average depth of the wetland.

Site Topography. Wetlands are best applied when the grade of contributing slopes is less than 8%. Reference *Specification 6.0. Restoration Practices* for additional information on a step pool approach to Constructed Wetlands that can be applied on steep sloped areas.

Available Hydraulic Head. The permanent pool elevation is typically fixed by the elevation of the existing downstream conveyance system to which the wetland will ultimately discharge. Because the storage needed for storm events in Constructed Wetlands is shallow, the amount of head needed is typically less than for Wet Ponds, usually a minimum of 2 to 4 feet.

Minimum Setbacks. See Appendix 8 Stormwater Facility Setbacks for recommended setbacks.

Proximity to Utilities. See Appendix 8 Stormwater Facility Setbacks for recommended siting with respect to utilities.

Depth to Water Table. The depth to the groundwater table is not a major constraint for Constructed Wetlands because a high water table can help maintain the permanent pool elevation. However, designers should keep in mind that high groundwater inputs may reduce pollutant removal rates, increase excavation costs, and reduce the storage volume. For Ephemeral Constructed Wetlands, 12-C, the normal groundwater elevation should be below the bottom of the wetland although the seasonal high groundwater may fluctuate within the storage area.

Soils. Soil tests should be conducted in accordance with Soil Investigation Procedures to determine the infiltration rates and other subsurface properties of the soils underlying the proposed wetland. Highly permeable soils will make it difficult to maintain a healthy permanent pool. Underlying soils of HSG C or D should be adequate to maintain a permanent pool. Most HSG A soils and HSG B soils are only suitable for variants 12-B or 12-C.

Use of, or Discharges to, Natural Wetlands. **Constructed Wetlands shall not be located within existing jurisdictional wetlands**. Constructed wetland should be constructed off-line from and designed to avoid impacts to federal or state jurisdictional waters, including perennial and intermittent streams and ditches, and tidal and non-tidal wetlands. Designers should request a jurisdictional determination from the federal regulatory agency (U.S. Army Corps of Engineers, Philadelphia District, 215-656-6728) and the state regulatory agency (Delaware Department of Natural Resources and Environmental Control, Wetland and Subaqueous Lands Section, 302-739-9943) to ensure that all federal and state jurisdictional areas are identified. An environmental consultant can be hired to assist with the determination.

Wetlands swales are discouraged in residential subdivisions. Wetland swales will periodically contain standing water which can been viewed as an impediment to regular maintenance, including mowing and become a cause for concern of the residence with respect to mosquitos and odors.

12.4 Constructed Wetland Conveyance Criteria

The longitudinal slope profile within individual wetland cells should generally be flat from inlet to outlet, at 1% maximum. The recommended maximum elevation drop between wetland cells should be 1 foot or less.

While many different options are available for setting the normal pool elevation, it is strongly recommended that removable flashboard risers be used, given their greater operational flexibility to adjust water levels following construction (see Hunt et al, 2007). A weir or spillway can also be designed to accommodate passage of the larger storm flows at relatively low ponding depths.

Principal Spillway. The principal spillway may be composed of a structure-pipe configuration or a weir-channel configuration. **The principal spillway must be accessible from dry land. A structure-pipe spillway shall be designed with anti-flotation, anti-vortex and trash rack devices on the structure. The outfall pipe and all connections to the outfall structure shall be made watertight. Soil tight only joints are not acceptable. Anti-seep collars shall be used in accordance with Pond Code 378, as amended. When the principal spillway is composed of a weir wall discharging to a channel, the channel below the weir must be reinforced with riprap or other acceptable material to prevent scour.**

Non-Clogging Low Flow Orifice. **When a low flow orifice is specified, it must be adequately protected from clogging by either an acceptable external trash rack or by internal orifice protection. Orifice diameters shall not be less than 3 inches.**

Outfall Protection. **The design shall specify an outfall that can discharge the maximum design storm event in a non-erosive manner at the project point of discharge.** If necessary, the channel immediately below the Constructed Wetland outfall may be modified to prevent erosion and conform to natural dimensions in the shortest possible distance. This can be accomplished by placing appropriately sized riprap over stabilization geotextile in accordance with HEC-14 Hydraulic Design of Energy Dissipators for Culverts and Channels and Delaware Erosion and Sediment Control Handbook Specification 3.3.10 Riprap Outlet Protection or 3.3.11 Riprap Stilling Basin, which can reduce flow velocities from the principal spillway to non-erosive levels (3.5 to 5.0 fps) based upon the channel lining material. Flared pipe sections, which discharge at or near the stream invert or into a step pool arrangement, should be used at the spillway outlet.

When the discharge is to a manmade pipe or channel system, the system should be adequate to convey the required design storm peak discharge in a non-erosive manner. Care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance. Excessive use of rip-rap should be avoided. The final release rate of the facility should be modified if any increase in flooding or stream channel erosion would result at a downstream structure, highway, or natural point of restricted streamflow unless

downstream improvements are made to accommodate the increase.

Emergency Spillway. Constructed Wetlands must be designed to pass the maximum design storm event (Fv) if the Fv is being routed through the Constructed Wetland rather than bypassing. An earthen emergency spillway designed to convey the Fv shall be cut in natural ground or, if cut in fill, shall be constructed and stabilized with methods to prevent erosion and structural failure.

Inflow Points. **Inflow points into the Constructed Wetland must be stabilized to ensure that non-erosive conditions exist during storm events up to the conveyance event (Cv).** Inlet pipe inverts should generally be located at the permanent pool elevation. **For Submerged Gravel Wetlands, the inflow volume shall enter the gravel substrate directly via a pipe manifold or inflow chimneys or as sheet flow through connected gravel layer.**

12.5 Constructed Wetland Pretreatment Criteria

Sediment regulation is critical to sustain Constructed Wetlands. **Every inlet into a Constructed Wetland shall have pretreatment. Exit velocities from the pretreatment shall be non-erosive during the largest design storm that is routed through the Constructed Wetland. A forebay shall be located at each major inlet to trap sediment and preserve the capacity of the main treatment cell. The following criteria apply to forebay design:**

- **A major inlet is defined as an individual storm drain inlet pipe or open channel conveying at least 10% of the Constructed Wetland's contributing RPv runoff volume.**
- The preferred forebay configuration consists of a separate cell, formed by an acceptable barrier such as a concrete weir, riprap berm, gabion baskets, etc. Riprap berms are the preferred barrier material.
- The forebay should be 3 to 4 feet deep. **The forebay must be sized to contain 10% of the volume of runoff from the contributing drainage area for the Resource Protection event.** The relative size of individual forebays should be proportional to the percentage of the total inflow to the Constructed Wetland. The storage volume within the forebay may be included in the calculated required storage volume for the Constructed Wetland.
- The recommended minimum length of the forebay is 10 feet. The forebay should have a length to width ratio of 2:1 or greater. Length is measured with the direction of flow into the Constructed Wetland.
- The forebay should be equipped with a metered rod in the center of the pool (as measured lengthwise along the low flow water travel path) for long-term monitoring of sediment accumulation. Metered wooden stakes may need to be replaced frequently in Constructed Wetland forebays; alternative materials should be considered for longevity.
- Vegetation may be included within forebays to increase sedimentation and reduce resuspension and erosion of previously trapped sediment.
- **Discharge from the forebay shall be non-erosive.**

12.6 Constructed Wetland Design Criteria

Constructed Wetlands constructed to meet regulatory stormwater management requirements shall be designed and constructed in accordance with the USDA NRCS Pond Code 378 as amended. Constructed Wetlands shall be designed so that they will dewater the Fv within 72 hours, or manage the Fv on site with no adverse impact. The extents of the Fv shall be clearly delineated. The lowest discharge elevation on the outlet device shall be located no lower than the seasonal high groundwater table as determined by the Soil Investigation Procedures.

Liners. All Traditional Constructed Wetlands shall be evaluated for feasibility and ability to maintain permanent pool, including the need for a liner, by a qualified, licensed geotechnical engineer or geologist. If the design professional chooses not to follow the recommendations of the geotechnical professional, a signed, sealed and dated letter from the design professional providing justification for removal of the liner from the design shall be provided to DNREC or their delegated Agency. When the geotechnical engineer recommends a liner, acceptable options include the following:

- **A clay liner having a minimum compacted thickness of six inches with an additional six inch layer of engineered wetland soil mix containing a minimum of 35% organic material above it. Clay used as a liner must meet the following specifications:**
  - **Permeability of 1x10-6 cm/sec using ASTM D-2434 procedure.**
  - **Plasticity index of not less than 15% using ASTM D-423/424 procedures.**
  - **Liquid limit of not less than 30% using ASTM D-2216 procedure.**
  - **Clay particles passing not less than 30% using ASTM D-422 procedure.**
  - **Compaction of 95% of standard proctor density using ASTM D-2216 procedure.**
- **Other acceptable measures as recommended by a qualified geotechnical professional.**

Trash Racks. Trash racks shall be provided for low-flow pipes and for all riser structure openings. Open weirs that discharge to an open channel will not require trash racks. Synthetic trash rack materials options are available and should be considered. **All metal trash racks shall be coated with a rust inhibitor to increase longevity of the device.**

Non-clogging Low Flow (Extended Detention) Orifice: The low flow extended detention orifice should be protected from clogging by an external trash rack. The preferred method is a hood apparatus over the orifice that reduces gross pollutants such as floatables and trash, as well as oil and grease and sediment.

Orifices less than 3 inches in diameter may require extra attention during design, to minimize the potential for clogging. As an alternative, internal orifice protection may be used (i.e., an orifice internal to a perforated vertical stand pipe with 0.5-inch perforations or slots that are protected by wirecloth and a stone filtering jacket). Floating skimmers, seepage berms, French drains or other similar measures may be a better alternative to provide the 48-hour detention required for Wet ED Ponds if the orifice diameter is too small.

Riser: **When a riser is used, it must be located such that it is accessible from the side slope for the purposes of inspection and maintenance.** The riser may be located within the embankment for maintenance access, safety, and aesthetics. Where appropriate, access to the riser may be provided by manhole covers and manhole steps within easy reach of valves and other controls.

Pond Drain: Constructed Wetlands should have a drain pipe that can completely or partially drain the permanent pool. In cases where a low level drain is not feasible (such as in an excavated Constructed Wetland), the Operation and Maintenance Plan should include requirements for dewatering the Constructed Wetland.

- The drain pipe should have an upturned elbow or protected intake within the Constructed Wetland to help keep it clear of sediment deposition, and a diameter capable of draining the Constructed Wetland within 24 hours.
- The Constructed Wetland drain should be equipped with an adjustable valve located within the riser, where it will not be normally inundated and can be operated in a safe manner.

Care should be exercised during Constructed Wetland drawdowns to prevent downstream discharge of sediments or anoxic water and rapid drawdown. The Department or the Delegated Agency should be notified before a Constructed Wetland is drained.

Adjustable Gate Valve: If desired to adjust the pond permanent pool elevation, both the outlet pipe and the Constructed Wetland drain should be equipped with an adjustable gate valve (typically a hand wheel activated knife gate valve) or pump well and be sized one pipe size greater than the calculated design diameter. Valves should 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. To prevent vandalism, the hand wheel should be chained to a ringbolt, manhole step or other fixed object.

Safety Features:

- **Any opening 12 inches or greater discharging to a closed drainage system shall include safety grates.**
- **The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.**
- **The emergency spillway exit channel must be designed to direct runoff to a point of discharge without impact to downstream structures.**
- Stormwater management systems designed with a permanent pool that are reasonably accessible to the public should consider barriers around the system to restrict public access. The barrier should not inhibit facility function or maintenance access.~~Fencing of the perimeter of Constructed Wetland is discouraged.~~
- -The preferred method to reduce risk is to manage the contours of the Constructed Wetland to eliminate drop-offs or other safety hazards.
- Warning signs may be posted.

Maintenance Reduction Features: The following Constructed Wetland maintenance issues can be

addressed during the design, in order to make on-going maintenance easier:

Maintenance Access. **All Constructed Wetlands must be designed so as to be accessible for maintenance.** Good access is needed so crews can remove sediments, make repairs and preserve Constructed Wetland treatment capacity.

- **Adequate maintenance access must extend to the forebay, safety bench, riser, and outlet structure.**
- **A maintenance right-of-way or easement must extend to the Constructed Wetland from a public or private road.**
- **Maintenance access must meet the following criteria:**
  - **Minimum width of 15 feet.**
  - **Profile grade that does not exceed 10H:1V.**
  - **Minimum 10H:1V cross slope.**
- Local ordinances and design criteria should be consulted to determine minimum setbacks to property lines. When not specified in local code, the top of bank of Constructed Wetlands should be set back at least 15 feet from property lines to ensure maintenance access.

- **Maintenance Set-Aside Area**: Adequate land area adjacent to the Constructed Wetland should be provided for in the Operation and Maintenance Plan as a location for disposal of sediment removed from the Constructed Wetland when maintenance is performed. The maintenance set-aside area is necessary on all sites adjacent to the Constructed Wetland to adequately dewater sediment removed from the pond prior to spreading and seeding or transporting from the site.
  - **The maintenance set-aside area shall accommodate the volume of 50% of the collective forebay volume.**
  - **The maximum depth of the set aside area shall be 1 foot.**
  - **The slope of the set aside area shall not exceed 5%**.

The area and slope of the set aside area may be modified if an alternative area or method of disposal is approved by the Department or Delegated Agency.

Variant 12-A, **Traditional Constructed Wetlands:**

Wetland Sizing. Traditional Constructed Wetlands provide water quality enhancement for stormwater volumes remaining after upstream practices have provided runoff reduction. Additionally, stormwater wetlands can be sized to control flows from the Cv and Fv storms. The available storage volume of storm events in Constructed Wetlands is equal to the volume provided above the permanent pool, or the normal water surface elevation. **The permanent pool volume, or the volume below the normal water surface elevation, shall be equivalent to a minimum of 50% of theRPv volume** to maintain a healthy system.

To reduce impact on the aquatic plantings, **Traditional Constructed Wetlands shall be sized so that the RPv has a maximum ponding depth of 12 inches above the normal water surface elevation. The RPv shall dewater within 48 hours**. **The Cv maximum ponding depth shall not exceed 12 inches above the normal water surface elevation for more than 12 hours.**

Internal Design Geometry. Traditional Constructed Wetlands can be designed in several ways, all of which promote diverse emergent and aquatic vegetation, as well as anaerobic and aerobic conditions within the water to promote pollutant removal. In all cases, varied topography within each component of the wetland is encouraged to provide diverse ecology (e.g., hummocks, forested peninsulas, horizontal tree stumps, boulders, etc). Research and experience have shown that the internal design geometry and depth zones are critical in maintaining the pollutant removal capability and plant diversity of stormwater wetlands. Wetland performance is enhanced when the wetland has multiple cells, longer flowpaths, and a high ratio of surface area to volume.

Flow Path. Whenever possible, constructed wetlands should be irregularly shaped with long, sinuous flow paths. **The total length of the flow path compared to the linear length through the Traditional Constructed Wetland shall be a minimum ratio of 2:1. When an inlet is located near the outlet, the ratio of the shortest flow path through the system to the overall length shall be a minimum of 0.5:1. The drainage area served by any inlets located less than a 0.5:1 ratio shall constitute no more than 20% of the total contributing drainage area.**

One continuous winding system can be designed that distributes the runoff through wetland areas and deeper permanent pools. The flow through the Traditional Constructed Wetland should be limited to maximum of 1% average slope excluding any drops or riffles. See below for more detailed information on the various components.

If a more varied range in elevation is desired, a more step-pool approach can be taken, where the different cells can be separated in elevation by bio or compost logs, sand berms anchored with rocks/boulders, or other stabilized protection. Forested peninsulas can also be extended across 95% of the width of the wetland, creating two separate zones. Riffles, or rock lined slopes of a maximum of 8%, can also be used to adjust the grades. The elevation difference between the wetland cells should not exceed 1 foot.

Inundation Zones.

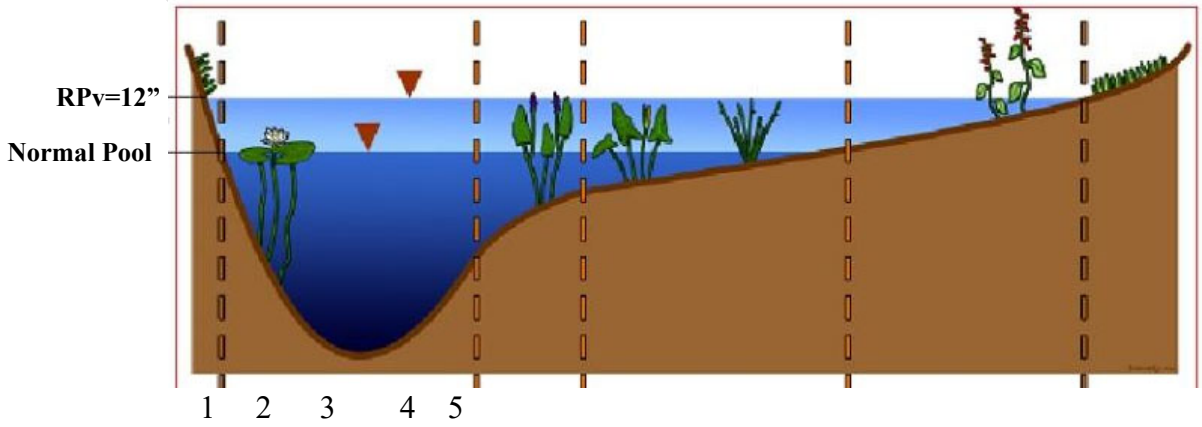

Figure 12.4. Traditional Constructed Wetland Inundation Zones: (1) Deep Pool (depth -36 to -18 inches), (2) Transition Zone (depth -18 to -6 inches), (3) Low Marsh Zone (depth -6 inches to normal pool), (4) High Marsh Zone (normal pool to +12 inches), and (5) Floodplain (+12 to +30 inches) (adapted from Hunt et al,. 2007).

Traditional Constructed Wetlands shall be composed of the following zones:

***Zone 1: Deep Pools*. The volume of water stored in the deep pools, also referred to as micropools, shall be at least 20% of the RPv volume. A minimum of two deep pools in addition to the forebay shall be provided, one of which shall be located prior to the outlet location to provide for additional sediment deposition.** Deep pools can help to provide fish habitat, cooler water temperatures, energy dissipation, and sedimentation. **Deep pools shall range from a minimum of 30 inches to a maximum of 6 feet in depth below the normal pool elevation and shall be designed to remain permanently saturated.** If groundwater will not support the permanent pool elevation in the summer months, then the minimum deep pool elevation should be lowered to 22 inches. **The deep pools shall be hydraulically connected within the water flow path. The deep pools shall be designed with a side slope not steeper than 3:1. A safety bench is required for deep pool depths greater than four feet.**

***Zone 2: Transition Zone.* Zone 2 is a short transition zone between the deeper pools and the low marsh zone, and ranges from a minimum of 6 inches to a maximum of 30 inches below the normal pool elevation. The volume of water stored in the transition zone shall be a minimum of 20% of the RPv volume. The transition zone shall have a maximum side slope of 3:1from the deep pool to the low marsh zone.** It is advisable to install biodegradable erosion control fabrics or similar materials during construction to prevent erosion or slumping of this transition zone.

Zone 3: Low Marsh Zone. Most of the wetland surface area will exist between the two marsh zones, zones 3 and 4. **The low marsh zone ranges from a maximum of 6 inches below the normal pool elevation to the normal pool elevation.** Therefore, it should normally be saturated and planted with species that thrive in this wet condition. **The volume of water stored in the low marsh zone shall be a minimum of 10% of the RPv volume. The side slope within the low marsh zone shall not be steeper than 4:1.** Because this zone provides essential wetland function in between storm events, it should have a surface area between 75 and 125% of the high marsh zone surface area.

***Zone 4: High Marsh Zone*. The upper end of the marsh zone is the high marsh zone, which ranges from the normal pool elevation to a maximum of 12 inches above the normal pool elevation, allowing the RPv to inundate to the top of the high marsh zone.** Where conditions allow, the RPv ponding depth should be reduced to be closer to 6 inches, which will increase the plant survivability. **The side slope within the high marsh zone shall not be steeper than 4:1,** and typically much flatter marsh zones are designed to increase storage**.**

Zone 5: Floodplain. Any storm events above the RPv event should inundate into the floodplain

area. **A low floodplain shall range between a minimum of 12 inches and a maximum of 18 inches above the normal water surface elevation and be planted with plants suited for infrequent to temporary saturations**, depending on weather patterns. An upper floodplain of elevations ranges +18 to +30 inches provides storage for the higher storm events, including the Fv. The two floodplains areas can be combined for smaller drainage areas less than 10 acres. Also, if the Constructed Wetland is connected to a Wet Pond, then the Wet Pond can be used for the storage of the higher storm events, and the floodplain storage within the Constructed Wetland can be reduced. **The side slope within the floodplain shall not be steeper than 4:1,** and typically much flatter floodplains are designed to increase storage**.**

Vegetated Perimeter. **A minimum 10-foot-wide vegetated perimeter around the wetland area shall be planted with appropriate grasses, trees, and shrubs.** The emergency spillway should either be grass or riprap. Existing vegetation can and should remain in the perimeter area, so long as noxious species are eradicated and invasive species are controlled.

Water Balance Testing. Traditional Constructed Wetlands can be scaled to accommodate small drainage areas, although a water balance calculation shall be provided when the contributing drainage area is less than 5 acres.

A simple water balance calculation shall be performed, using Equation 12.2 (Hunt et al., 2007), **to ensure that the deep pools will not go completely dry during a 30-day summer drought.**

Equation 12.2. The Hunt Water Balance Equation for Acceptable Water Depth in a Stormwater Wetland

$$DP = RF_m * EF * WS/WL - ET - INF - RES$$

Where: DP = Depth of pool, inches
- RF_m = Monthly rainfall during drought, inches (assume 1 inch, or use historically data)
- EF = Fraction of rainfall that enters the stormwater wetland (Rational runoff coefficient)
- WS/WL = Ratio of contributing drainage area to the normal pool wetland surface area
- ET = Summer evapotranspiration rate, inches (assume 7 inches)
- INF = Monthly infiltration loss (assume 7.2 inches, or 0.01 inch/hour for 30 days, unless a higher infiltration rate is known)
- RES = Reservoir of water for a factor of safety, inches (assume 6 inches)

Variant 12-B, **Wetland Swales:**

Wetland Swale Sizing. Wetland swales are designed similar to traditional vegetated swales in that they should convey the Cv and Fv events with non-erosive velocities. **Wetland swales shall contain the Cv event** (no freeboard required). **If the Fv event is not contained within the**

Wetland swale top of bank, then the area of inundation and discharge route shall be delineated. The maximum RPv water surface elevation shall be no greater than 6 inches above the normal water surface elevation. There is no minimum or maximum drainage area, though typically swales are designed for less than 5 acres of contributing area.

Internal Geometry. Wetland swales should be designed as a two-stage system. The low-flow channel requires a minimum width of 1 foot, and should be designed with a permanent to semi-permanent water elevation of 4 to 6 inches. This can be accomplished through inception with the seasonal high groundwater or through the use of check dams or other control structures that back the water up to that level during wet conditions. The low-flow channel should support plants that tolerate mostly wet conditions. The width of the low-flow channel should be maximum 6 feet to prevent additional low-flow channels from forming within (or braiding); very large drainage areas may require increased widths, but typically the low-flow channel will fall in the 2 to 4-foot-width range. To increase functionality, the low-flow channel should be meandered within the total confines of the Wetland Swale (i.e., the top of bank does not need to meander, but the low-flow channel should).

At the water surface elevation of the RPv event (within +/- 0.1'), a shallow floodplain bench shall be provided, which alleviates shear stress on the sides of the banks. The total bench width should be minimum 4 feet and is generally split on either side of the low-flow channel, though the dimensions can alter as the low-flow channel meanders through the swale section, with increased bench widths on the inside of a curve. Vegetation planted on the benches should also support wet periods, though will be inundated less frequently then the plants in the low-flow channel.

Deep pools should not be incorporated into the Wetland Swales for safety purposes as most people assume swales are traversable and would not suspect a deep portion. **The average groundwater elevation shall be below the bottom of the Wetland Swale. Only the seasonal high groundwater may intersect the bottom of the Wetland Swale.**

Side Slopes. **Wetland Swales shall not have side slopes steeper than 3:1.**

Longitudinal Slope: **The maximum longitudinal slope shall be an average of 1%.** Grade breaks similar to variant 12-A can be used as necessary.

Vegetated Perimeter. **A minimum 10-foot-wide vegetated perimeter on both sides of the wetland swale shall be planted with appropriate grasses, trees and shrubs.** Existing vegetation can and should remain in the perimeter area, so long as invasive species are eradicated and invasive species are controlled.

Variant 12-C, **Ephemeral Constructed Wetlands:**

Ephemeral Constructed Wetland Sizing. Ephemeral Constructed Wetlands are designed without a permanent pool because the intent is for them to be wet only in the spring and fall months. **The RPv event shall pond a minimum of 6 inches and a maximum of 12 inches of water above the**

ground surface of the Ephemeral Constructed Wetland. The Fv water surface shall be a maximum of 30 inches above the ground surface of the Ephemeral Constructed Wetland. An emergency spillway may be necessary for the 100-year and larger events, but traditionally no other outlets are provided. If freezing in the winter is a concern, or for maintenance purposes, a drain pipe can be provided, but the Ephemeral Constructed Wetland should only be drained in late November after amphibian breeding seasons. The wetland can be modeled with the design infiltration rate and are allowed to hold the RPv event for greater than 48 hours.

Ephemeral Constructed Wetlands should mimic those found naturally, which typically are ponded low areas. These shallow areas fill up with runoff during wet conditions and will dry up during periods of little to no rain. These fluctuations typically provide more diversity in vegetation and animals. The shallow ponded area should be planted with a variety of vegetation that can tolerate both wet and dry conditions.

The seasonal high groundwater may fluctuate into the bottom of the Ephemeral Constructed Wetland**,** but **the average groundwater elevation as determined by the Soil Investigation Procedures shall be below the wetland bottom of the Ephemeral Constructed Wetland. Only the seasonal high groundwater as determined by the Soil Investigation Procedures may intersect the bottom of the Ephemeral Constructed Wetland. If the seasonal high groundwater intersects the bottom of the Ephemeral Constructed Wetland, the wetland shall be modeled considering the elevation of the seasonal high groundwater.**

Depending on the existing grades, an embankment may be required to contain the wetland pool. **Constructed Wetlands constructed to meet regulatory stormwater management requirements shall be designed and constructed in accordance with the USDA NRCS Pond Code 378 as amended.** A core trench should extend down to a limiting layer or minimum 4 feet below ground surface, which will help prevent lateral migration of water through the embankment, compromising the construction.

For Ephemeral Constructed Wetlands functioning as forebays on poultry house projects, forebays located in HSG C/D should be no deeper than 1 foot as measured from the invert of the overflow weir to the bottom of the forebay. Forebays located in HSG A/B should be no deeper than 2 feet as measured from the invert of the overflow weir to the bottom of the forebay.

Side Slopes. **The side slopes of the buffer area and within the wetland shall be 4:1 or flatter.**

Vegetated Perimeter. **A minimum 10-foot-wide vegetated perimeter around the wetland area shall be planted with appropriate grasses, trees, and shrubs** (the emergency spillway should either be grass or riprap). Existing vegetation can and should remain in the perimeter area, so long as noxious species are eradicated and invasive species are controlled.

Variant 12-D, **Submerged Gravel Wetlands**

Submerged Gravel Wetland Sizing. The maximum surface ponding depth for the RPv shall

not be greater than the tolerance depths of the wetland plantings selected, or two feet, whichever is less. The Submerged Gravel Wetland shall store the RPv volume within the stone substrate and wetland soils and above the soils in surface ponding. Submerged Gravel Wetlands shall have no minimum detention time.

Gravel substrate. The gravel substrate shall be a minimum of 2 feet and a maximum of 4 feet in depth. The gravel substrate shall be sized to contain a minimum of 25% of the RPv volume considering 40% void ratio. The gravel substrate shall be composed of clean washed gravel, with a maximum of 2.0% passing the #200 sieve. Gravel shall have a maximum diameter of 2.5 inches and a minimum diameter of 0.5 inches. A porosity value of 0.4 shall be used for areas of stone in the design of gravel substrate. Sand shall not be an acceptable substitute for gravel.

Wetland soil. **An engineered wetland soil layer containing a minimum of 15% organic material and a maximum of 15% clay content shall be included on the surface of the Submerged Gravel Wetland. The wetland soil layer shall be a minimum of 8 inches thick.** The wetland soil layer should not be included in the storage volume computations.
A minimum 4 inch thick layer of clean, washed nominal ¼" gravel with a maximum of 2.0% passing the #200 sieve shall be installed between the gravel substrate and the wetland soil layer.

Underdrain. An underdrain shall be provided at an elevation 3 inches above the invert of the gravel substrate. The underdrain shall be a minimum of 4-inch perforated high density polyethylene pipe (HDPE) or polyvinyl chloride pipe (PVC). The underdrain shall connect to the outlet structure. The discharge elevation shall be 4 inches below the wetland soil surface.

Flow Path. **There shall be a minimum of 15 feet separation distance between all gravel substrate inflow points and all underdrain outlet points.**

Side Slopes. **Side slopes above the gravel substrate shall not be steeper than 3:1.**
Constructed Wetland Material Specifications:
Wetlands are generally constructed with materials obtained on-site, except for the plant materials, inflow and outflow devices (e.g., piping and riser materials), possibly stone for inlet and outlet stabilization, and stabilization fabric for lining banks or berms. In some instances, clay may need to be imported to provide a permanent pool elevation in certain areas of the constructed wetland that may not otherwise support a permanent pool. Plant stock should be nursery grown, unless otherwise approved by the local regulatory authority, and should be healthy and vigorous native species free from defects, decay, disfiguring roots, sun-scald, injuries, abrasions, diseases, insects, pests, and all forms of infestations or objectionable disfigurements, as determined by the local regulatory authority.

12.7 Constructed Wetland Landscaping Criteria

A planting plan is required for all Constructed Wetlands. Native species are recommended

and **invasive species shall not be specified within Constructed Wetlands. The planting plan shall be certified by a qualified professional with demonstrated knowledge in wetland species. Plants used in Constructed Wetlands shall be supplied by a certified wetland nursery using plants selected for the region.** The planting plan should outline a detailed schedule for the care, maintenance and possible reinstallation of vegetation in the wetland and its buffer for the first 10 years of establishment.

The plan should outline a realistic, long-term planting strategy to establish and maintain desired wetland vegetation. The plan should indicate how wetland plants will be established within each inundation zone (e.g., wetland plants, seed-mixes, volunteer colonization, and tree and shrub stock) and whether soil amendments are needed to get plants started. Reference the Landscaping Criteria Appendix for additional Constructed Wetland landscaping specifications.

For Ephemeral Constructed Wetlands functioning as forebays on poultry house projects, since the forebay is likely to be subjected to prolonged periods of saturation especially on HSG C/D soils, the recommendations for Zone 4, High Marsh may be used to select plant materials for the forebay area under those soil conditions.

12.8. **Constructed Wetland Construction**

The construction sequence for the wetland variants depends on site conditions, design complexity, and the size and configuration of the proposed facility. The following two-stage construction sequence is recommended for installing a wetland facility and establishing vigorous plant cover.

Approval from the Department or the appropriate Delegated Agency must be obtained before any planned Constructed Wetlands can be used as a sediment basin. If a Constructed Wetlands serves as a sediment basin during project construction, the volume of the sediment basin must be based on the more stringent sizing rule.

The Sediment and Stormwater Plan must include conversion steps from sediment basin to permanent Constructed Wetlands in the construction sequence. The Department or Delegated Agency must be notified and provide approval prior to conversion from sediment basin to the final configuration of the Constructed Wetlands. Appropriate procedures must be implemented to prevent discharge of turbid waters when the sediment basin is being converted into a Constructed Wetlands.

Construction Review. Multiple construction reviews are critical to ensure that Constructed Wetlands are properly constructed. **Construction reviews are required during the following stages of construction, and shall be noted on the plan in the sequence of construction:**

- **Pre-construction meeting**
- **Initial site preparation including installation of erosion and sediment controls**
- **Construction of the embankment, including installation of the principal spillway and the outlet structure as applicable**
- **Excavation and grading including interim and final elevations**

- **Construction of wetland features including grading of microtopography, introduction of soil amendments and staking of planting zones**
- **Construction of the underdrain, installation of gravel substrate and wetland soils as applicable**
- **Implementation of the planting plan and vegetative stabilization**
- **Final inspection including development of a punch list for facility acceptance**

Stage 1 Construction Sequence: Wetland Facility Construction.

Step 1: Stabilize Drainage Area. Constructed wetlands should only be constructed after the contributing drainage area to the wetland is completely stabilized. If the proposed wetland site will be used as a sediment trap or basin during the construction phase, the construction notes should clearly indicate that the facility will be de-watered, dredged and re-graded to design dimensions after the original site construction is complete.

Step 2: Assemble Construction Materials on-site, make sure that they meet design specifications, and prepare any staging areas.

Step 3: Install Erosion and Sediment (E&S) Controls prior to construction, including temporary dewatering devices, sediment basins, and stormwater diversion practices. **All areas surrounding the Constructed Wetlands that are graded or denuded during construction must be planted with turf grass, native plantings, or other approved methods of soil stabilization.** In some cases, a phased or staged E&S Control plan may be necessary to divert flow around the stormwater wetland area until installation and stabilization are complete.

Step 4: Excavate the Core Trench for the Embankment and Construct the Embankment (if required). Install the Outlet Pipe and Emergency Spillway.

Step 5: Install the Riser or Outflow Structure and ensure that the top invert of the overflow weir is constructed level and at the proper design elevation (flashboard risers are strongly recommended by Hunt et al, 2007).

Step 6: Clear and Strip the wetland project area to the desired sub-grade.

Step 7: Construct any Internal Berms in 8 to 12-inch lifts and compact with appropriate equipment.

Step 8: Excavate/Grade until the appropriate elevation and desired contours are achieved for the bottom and side slopes of the wetland. This is normally done by "roughing up" the interim elevations with a skid loader or other similar equipment to achieve the desired topography across the wetland. Spot surveys should be made to ensure that the interim elevations are 3 to 6 inches below the final elevations for the wetland.

Step 9: Install Micro-Topographic Features and Soil Amendments within wetland area. Because most stormwater wetlands are excavated to sub-soil, they often lack the nutrients and organic

matter needed to support vigorous growth of wetland plants. Therefore, it is strongly recommended to add compost, topsoil, or wetland mulch to all depth zones in the wetland. The importance of soil amendments in excavated wetlands cannot be over-emphasized; poor plant survival and sparse wetland plant coverage are likely if soil amendments are not added. The planting soil should be a high organic content loam or sandy loam, placed by mechanical methods, and spread by hand. Planting soil depth should be at least 4 inches for shallow wetlands. No machinery should be allowed to traverse over the planting soil during or after construction. Planting soil should be tamped, but it should not be overly compacted.

Step 10: Stabilize Exposed Soils above the normal pool elevation with permanent seed mixtures appropriate for a wetland environment by hydro-seeding or seeding under straw per the Landscape Plan. Outside of optimum seeding and planting dates, **temporary seed, such as annual rye or winter wheat, may be used to stabilize the soil within the Constructed Wetland, but permanent species shall then be planted or seeded at next optimum planting date. Stabilization matting shall be utilized in Wetland Swales and in all areas of concentrated flow or slopes 3:1 or steeper.**

Step 11: Post Construction Verification Documentation. **Upon facility completion, the owner shall submit Post Construction verification documents to demonstrate that the Constructed Wetlands has been constructed within allowable tolerances in accordance with the approved Sediment and Stormwater Management Plan and accepted by the approving agency. Allowable tolerances for Constructed Wetlands practices are as follows:**

- **The constructed top of bank elevation may be no lower than the design elevation for top of bank.**
- **The constructed volume of the Constructed Wetlands surface storage shall be no less than 90% of the design volume.**
- **The constructed volume of the gravel substrate storage for Submerged Gravel Wetlands shall be no less than 90% of the design volume.**
- **The constructed elevation of any structure shall be within 0.15 foot of the design.**

When the allowable tolerances are exceeded for Constructed Wetlands surface area or volume or structure elevations, supplemental calculations must be submitted to the approval agency to determine if the Constructed Wetlands, as constructed, meets the design requirements.

Stage 2 Construction Sequence: Establishing the Wetland Vegetation.

Step 12: Open Up the Wetland Connection (if desired). Once the final grades are attained, the pond and/or contributing drainage area connection can be opened to allow the wetland cell to fill up to the normal pool elevation. Gradually inundate the wetland to minimize erosion of unplanted features. If the wetland area is connected, then it will need to be dewatered to the lowest planting elevation (i.e., the low marsh zone) prior to planting.

Step 13: Finalize the Wetland Landscaping Plan (if needed). At this stage the engineer, landscape

architect, and wetland expert work jointly to refine the initial wetland landscaping plan *after* the Constructed Wetland has been constructed and the normal pool elevation has been established if there have been any changes to the planting zones from the initial design. This can allow the designer to select appropriate species and additional soil amendments, based on field confirmation of soils properties and the actual depths and inundation frequencies occurring within the wetland, and also confirm plant availability.

Step 14: Measure and Stake Planting Depths at the onset of the planting season. Depths in the wetland should be measured to the nearest inch to confirm the original planting depths of the planting zone. Surveyed planting zones should be marked on the post construction verification, and their locations should also be identified in the field, using stakes or flags. If necessary, dewater to the bottom of the low marsh zone prior to staking and planting.

Step 15: Propagate the Constructed Wetland. Three techniques are used in combination to propagate the emergent community over the wetland bed:

a. *Initial Planting of Container-Grown Wetland Plant Stock.* The transplanting window extends from early April to mid-June. Planting after these dates is quite chancy because emergent wetland plants need a full growing season to build the root reserves needed to get through the winter. If at all possible, the plants should be ordered at least 6 months in advance to ensure the availability and on-time delivery of desired species.
b. *Broadcasting Wetland Seed Mixes*. The higher wetland elevations should be established by broadcasting wetland seed mixes to establish diverse emergent wetlands. Seeding of wetland seed mixes as a ground cover is recommended for all zones above 3 inches below the normal pool elevation. Hand broadcasting or hydroseeding can be used to spread seed, depending on the size of the wetland cell.
c. *Allowing "Volunteer Wetland Plants to Establish*. The establishment of volunteer species should be encouraged with the exception of noxious weeds and invasive species. Typically, if properly managed, the constructed wetland will fill out with volunteer species and establishment of the planted and seeded species within 3 to 5 years.

Step 16: Install Anti-Goose Protection to Protect Newly Planted or Newly Growing Vegetation. This is particularly critical for newly established emergent and herbaceous plants, as predation by Canada geese can quickly decimate wetland vegetation. Anti-Goose protection can consist of netting, webbing, or string installed in a crisscross pattern over the surface area of the wetland, above the level of the emergent plants.

Step 17: Plant the Wetland Floodplain and Buffer Area. This zone generally extends from 1 to 3 feet above the normal pool elevation. Consequently, plants in this zone are less frequently inundated but still should be able to tolerate periods of flooding and soil saturation. The buffer area can be planted with species that do not need wet conditions, and can be planted in the spring or fall.

12.9 **Constructed Wetland Maintenance Criteria**

Before project completion, the Owner shall submit a final post construction stormwater management Operation and Maintenance Plan for the entire stormwater management system. Operation and Maintenance Plans remain valid for the life of the stormwater management system. The Operation and Maintenance Plan will specify the property owner's primary maintenance responsibilities and authorize the Department or Delegated Agency staff to access the property for maintenance review or corrective action in the event that proper maintenance is not performed.

Operation and Maintenance Plans should clearly outline how vegetation in the Constructed Wetland and its buffer will be managed or harvested in the future. Periodic mowing of the Constructed Wetland buffer is only required along the maintenance access and the embankment. The remaining buffer can be managed as a meadow (mowing every other year) or forest. The maintenance plan should schedule a shoreline cleanup at least once a year to remove trash and floatables.

Maintenance of a Constructed Wetland is driven by annual maintenance reviews that evaluate the condition and performance of the Constructed Wetland. Based on maintenance review results, specific maintenance tasks may be required. Additional reviews are required during the first two years of establishment.

During the first two years following construction, the Constructed Wetland shall be reviewed twice each year by a qualified professional with demonstrated knowledge of wetland species, once in the spring and once in the fall after a storm event that exceeds 1/2 inch of rainfall. The Operation and Maintenance Plan shall outline a detailed schedule for the monitoring and possible reinstallation of vegetation in the wetland and its buffer for the first two years of establishment.

Repair of critical structural features such as embankments and risers shall be performed by responsible personnel that have successfully completed the Department Contractor Training Program.

Additional trips to the project site are recommended for watering, maintenance, etc, which is described below.

- Spot Reseeding. Maintenance personnel should look for bare or eroding areas in the contributing drainage area, around the wetland buffer, and in the wetland cells, to ensure that they are immediately stabilized with grass cover.

- Watering. Trees and shrubs planted in the buffer and on wetland islands and peninsulas need watering during the first growing season. In general, consider watering every three days for first month, and then weekly during the first growing season (April - October), depending on rainfall. In the summer months, and times of prolonged drought, all of the plantings may need watering to ensure survival.

- Reinforcement Plantings. Regardless of the care taken during the initial planting of the wetland and buffer, it is probable that some areas will remain non-vegetated and some species will not survive. Poor survival can result from many unforeseen factors, such as predation, poor quality plant stock, water level changes, and drought. Thus, it is advisable to budget for an additional round of reinforcement planting after one or two growing seasons. Construction contracts should include a care and replacement warranty extending at least two growing seasons after initial planting, to selectively replant portions of the wetland that fail to fill in or survive. **Project closeout shall not occur until a minimum of 70% of the wetland area is permanently vegetated**, which may take several growing seasons and additional plantings.

- Invasive Species. Designers should expect significant changes in wetland species composition to occur over time. Reviews should carefully track changes in wetland plant species distribution over time. Noxious plants and undesired invasive plants should be dealt with as soon as they begin to colonize the wetland. As a general rule, control of noxious weeds and undesirable invasive species (e.g., cattails and Phragmites) should commence as soon as they are spotted and before their coverage exceeds more than 5% of a wetland cell area. Herbicides must be applied by a Certified aquatic pesticide applicator through the Department of Agriculture and be aquatic safe (i.e., Glyphosate-based products). Extended periods of dewatering may also work because early manual removal provides only short-term relief from invasive species. While it is difficult to exclude invasive species completely from stormwater wetlands, their ability to take over the entire wetland can be reduced if the designer creates a wide range of depth zones and a complex internal structure within the wetland.

Annual, On-going Maintenance: Managing vegetation is an important ongoing maintenance task at every Constructed Wetland and for each inundation zone.

- Vegetation Management. Thinning or harvesting of excess forest growth will be needed periodically to guide the forested wetland into a more mature state and prevent it from becoming overgrown. Thinning or harvesting operations should be scheduled to occur approximately 5 and 10 years after the initial wetland construction. Removal of woody species on or near the embankment, structural components such as inflow and outflow pipes, and maintenance access areas should be conducted every 2 years.

- Mowing. Regular mowing operations only need to occur along maintenance accessways and should occur at minimum twice a year. Reference the Landscape Plan for additional requirements; some upland meadow areas may also require occasional mowing.

- Sediment Removal. **Sediment removal in the pretreatment forebay shall occur when 50% of total forebay capacity has been lost.** The owner can plan for this maintenance activity to occur every 5 to 7 years.

- Sediment Deposits. Sediment removed from the forebay should be deposited in the designated maintenance set aside area for dewatering, prior to leveling and stabilization or removal from the site. Sediments excavated from Constructed Wetlands are not usually considered toxic or

hazardous. They can be safely disposed of by either land application or land filling. Sediment testing may be needed prior to sediment disposal if the contributing area serves a hotspot land use.

- Care should be exercised during Constructed Wetland drawdowns to prevent downstream discharge of sediments or anoxic water and rapid drawdown. **The Department or the Delegated Agency shall be notified before a Constructed Wetland is drained.**

12.10 References

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