VIRGINIA DCR STORMWATER DESIGN SPECIFICATION No. 14

WET POND

VERSION 2.0
January 1, 2013

SECTION 1: DESCRIPTION

Wet ponds consist of a permanent pool of water that promotes a better environment for gravitational settling, biological uptake and microbial activity. Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts as a barrier to re-suspension of sediments and other pollutants deposited during prior storms. When sized properly, wet ponds have a residence time that ranges from many days to several weeks depending on the volume of the permanent pool, which allows numerous pollutant removal mechanisms to operate. Wet ponds can also include extended detention of a portion of the Treatment Volume (*Tv*) above the permanent pool or a multiple cell design in order to improve performance and meet the Level 2 performance goal.

Wet ponds can also help to meet channel protection requirements by utilizing detention storage above the permanent pool and extended detention storage volumes to reduce peak flows from the 1-year design storm using the energy balance method described in the Virginia Stormwater Management Program (VSMP) regulations (4VAC50-60-66) (see **Table 14.1**).

Designers should note that a wet pond is typically the final element in the roof-to-stream pollutant removal sequence and provides no volume reduction credit, and **should therefore be considered *only* if there is remaining pollutant removal or Channel Protection Volume to manage after all other upland runoff reduction options have been considered and properly credited.**

In instances where a wet pond is proposed as an aesthetic amenity, the design parameters contained here represent good engineering design to maintain a healthy pond. The treatment volume requirements for water quality and detention requirements for channel protection may be more economically met through the upstream runoff reduction practices; however, the basic wet pond features related to aesthetics (pool volume and geometry) and safety (aquatic and safety benches, side slopes, maintenance, etc.) remain as important neighborhood or site design features.

SECTION 2: PERFORMANCE

There is no runoff volume reduction credit for wet ponds since the runoff reduction pathways of infiltration and extended filtration are generally limited. The wet pond functions as a basin that generally discharges a volume equivalent to the entire inflow runoff volume. While a minimal runoff reduction credit is awarded for Level 2 ED ponds, the soils appropriate for wet ponds limit the ability of the wet pond to achieve any measureable volume reduction.

Table 14.1. Summary of Stormwater Functions Provided by Wet Ponds

Stormwater Function	Level 1 Design	Level 2 Design
Annual Runoff Volume Reduction (RR) [1]	0%	0%
Total Phosphorus (TP) EMC Reduction[2] **by BMP Treatment Process**	50% (45%) [3]	75% (65%) [3]
Total Phosphorus (TP) Mass Load Removal	50% (45%) [3]	75% (65%) [3]
Total Nitrogen (TN) EMC Reduction[2] **by BMP Treatment Process**	30% (20%) [3]	40% (30%) [3]
Total Nitrogen (TN) Mass Load Removal	30% (20%) [3]	40% (30%) [3]
Channel Protection	Yes; detention storage can be provided above the permanent pool.	
Flood Mitigation	Yes; flood control storage can be provided above the permanent pool.	

[1] Runoff Reduction rates for ponds used for year round irrigation can be determined through a water budget computation.

[2] Change in event mean concentration (EMC) through the practice.

[3] Number in parentheses is slightly lower EMC removal rate in the coastal plain (or any location) if the wet pond is influenced by groundwater. See **Section 6.2** of this design specification and CSN Technical Bulletin No. 2. (2009).

Sources: CWP and CSN (2008), CWP (2007)

Leadership in Energy and Environmental Design (LEED®). The LEED® point credit system designed by the U.S. Green Building Council (USGBC) and implemented by the Green Building Certification Institute (GBCI) awards points related to site design and stormwater management. Several categories of points are potentially available for new development and redevelopment projects. **Chapter 6** of the 2013 *Virginia Stormwater Management Handbook* (2nd Edition) provides a more thorough discussion of the site planning process and design considerations as related to Environmental Site Design and potential LEED credits. However, VDCR is not affiliated with the USGBC or GBCI and any information on applicable points provided here is based only on basic compatibility. **Designers should research and verify scoring criteria and applicability of points as related to the specific project being considered through USGBC LEED resources.**

Table 14.2. Potential LEED® Credits for Wet Ponds[1]

Credit Category	Credit No.	Credit Description
Sustainable Sites	SS5.1	Site Development: Protect or Restore Habitat
Sustainable Sites	SS5.2	Site Development: Maximize Open Space[2]
Sustainable Sites	SS6.2	Stormwater Design: Quality Control[3]

[1] Actual site design and/or BMP configuration may not qualify for the credits listed. Alternatively, the project may actually qualify for credits not listed here. Designers should consult with a qualified individual (LEED AP) to verify credit applicability.

[2]Applicable to designs with natural form and with side slopes averaging 4:1 or flatter and vegetated.

[3] Must demonstrate that the system is designed for achieving 80% removal of TSS (Level 2).

SECTION 3: LEVEL 1 AND LEVEL 2 DESIGN TABLE

The major design goal for wet ponds in Virginia is to maximize nutrient removal. To this end, designers may choose to go with the baseline design (Level 1) or choose an enhanced design (Level 2) that maximizes nutrient removal. The basic criteria for the two levels of wet pond design are shown in **Table 14.3** below.

Table 14.3. Level 1 and 2 Wet Pond Design Guidance

Level 1 Design (RR:0 [1]; TP: 50 [5]; TN:30 [5])	Level 2 Design (RR:0 [1]; TP: 75 [5]; TN:40 [5])
Tv = [(1.0)(Rv)(A)/12] – volume reduced by upstream BMP	Tv = [1.5 (Rv) (A) /12] – volume reduced by upstream BMP
Single Pond Cell (with forebay) **Section 6.5**	Wet ED [2] (24 hr) and/or a Multiple Cell Design [3] **Sections 6.2 and 6.5**
Length/Width ratio OR Flow path = 2:1 or more; Length of shortest flow path / overall length [4] = 0.5 or more **Section 6.3**	Length/Width ratio OR Flow path = 3:1 or more; Length of shortest flow path/overall length[4] = 0.8 or more **Section 6.3**
Standard aquatic benches **Section 6.3**	Wetlands more than 10% of pond area **Section 6.3**
Turf in pond buffers **Section 6.7**	Trees, shrubs, and herbaceous plants in pond buffers; Shoreline landscaping to discourage geese **Section 6.7**
No Internal Pond Mechanisms	Aeration (preferably bubblers that extend to or near the bottom or floating islands **Section 6.8**

[1] Runoff volume reduction can be computed for wet ponds designed for water reuse and upland irrigation.

[2] Extended Detention may be provided to meet a maximum of 50% of the Level 2 Treatment Volume; Refer to Design Specification 15 for ED design; **Section 6.2**

[3] At least three internal cells must be included, including the forebay

[4] In the case of multiple inflows, the flow path is measured from the dominant inflows (that comprise 80% or more of the total pond inflow) **Section 6.3**

[5] Due to groundwater influence, slightly lower TP and TN removal rates in coastal plain (**Section 7.2**) and CSN Technical Bulletin No. 2. (2009)

Sources: CSN (2009), CWP and CSN (2008), CWP (2007)

SECTION 4: TYPICAL DETAILS

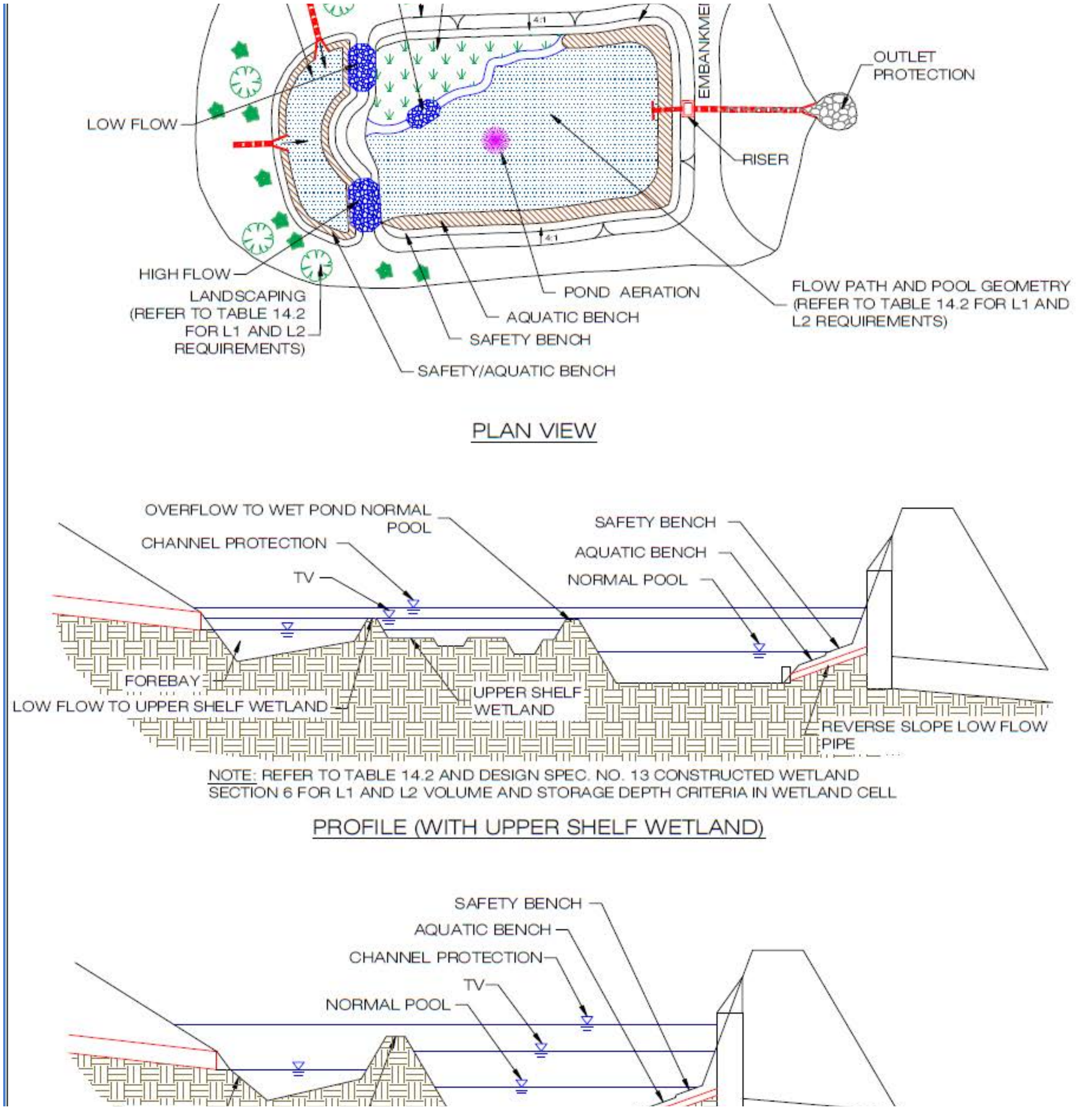

Figure 14.1. Wet Pond Design Schematics

SECTION 5: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

The following feasibility criteria should be evaluated when designing a wet pond.

Space Required. The surface area of a wet pond will normally be at least 1% to 3 % of its contributing drainage area, depending on the impervious cover, pond geometry, etc.

Contributing Drainage Area (CDA). A contributing drainage area of 10 to 25 acres or more is typically recommended for wet ponds to maintain a healthy permanent pool. Wet ponds can still function with drainage areas less than 10 acres, but designers should be aware that these "pocket" ponds will be prone to clogging and experience extreme fluctuations in seasonal water levels and be susceptible to creating nuisance conditions. A water balance should be calculated to assess whether the wet pond will draw down by more than 2 feet after a 30-day summer drought (see equations in **Section 6.2**).

Available Hydraulic Head. The depth of a wet pond is usually determined by the hydraulic head available on the site. The bottom elevation is normally the invert of the existing downstream conveyance system to which the wet pond discharges. Typically, a minimum of 6 to 8 feet of head are needed for a wet pond to function.

Minimum Setbacks. Local subdivision and zoning ordinances and design criteria should be consulted to determine minimum setbacks for impoundments to property lines, structures, and wells. Generally, wet ponds should be set back at least 20 feet from property lines, 25 feet from building foundations, and 50 feet from septic system fields and 100 feet from private wells. Setbacks are measured form the toe of the embankment on the downsteam side and the design high water on the upstream side.

Depth-to-Water Table and Bedrock. Shallow water table or depth to bedrock may make excavation difficult and expensive. Groundwater inputs can also reduce the pollutant removal rates of wet ponds (**Table 14.1**). Refer to **Section 7** for design variations when encountering high water table, bedrock, or karst topography

Soils. Highly permeable soils make it difficult to maintain a constant level for the permanent pool. Soil explorations should be conducted at proposed pond sites to identify soil infiltration and the presence of karst topography. Underlying soils of Hydrologic Soil Group (HSG) C or D should be adequate to maintain a permanent pool. Most group A soils and some group B soils will require a liner in order to maintain the permanent pool. A wet pond should be the option of last resort if karst topography is present. Refer to **Section 7** for additional guidance when designing near karst topography. At a minimum, an impermeable clay or (preferably) geosynthetic liner will be required (**Section 6.9**).

Geotechnical explorations should also be conducted at the proposed pond embankment to properly design the embankment cut-off trench and fill material.

Karst. Wet ponds are not recommended in or near karst terrain. An alternative practice or combination of practices should be employed at the site. See CSN Technical Bulletin No.1 (2008) and guidance in Chapter 6 (Appendix 6-A) of the latest edition of the Virginia

Stormwater Management Handbook for guidance on wet pond design in karst terrain.

Trout Streams. The use of wet ponds in watersheds containing trout streams is strongly discouraged because the discharge can cause stream temperature warming.

Use of or Discharges to Natural Wetlands. It can be tempting to construct a wet pond within an existing natural wetland, but wet ponds cannot be located within jurisdictional waters, including wetlands, without obtaining a section 404 permit from the appropriate state or federal regulatory agency. In addition, the designer should investigate the wetland status of adjacent areas to determine if the discharge from the wet pond will change the hydroperiod of a downstream natural wetland (see Cappiella et al., 2006b, for guidance on minimizing stormwater discharges to existing wetlands).

Perennial streams. Locating wet ponds on perennial streams is typically not allowed and will require both a Section 401 and Section 404 permit from the appropriate state or federal regulatory agency.

Design Applications

Wet ponds are applicable for most land uses and are best suited for larger development projects due to the large footprint required. While the pollutant reduction credit of a wet pond may be adequate to achieve compliance, the VRRM emphasizes the use of upland runoff reduction practices, such as rooftop disconnections, small-scale infiltration, rainwater harvesting, bioretention, grass channels and dry swales that reduce runoff volume at its source (rather than merely treating runoff at the terminus of the storm drain system). Upland runoff reduction practices can be used to satisfy some or all of the water quality requirements at many sites, which can help to reduce the footprint and volume of wet ponds.

The use of upland runoff reduction features may allow designers the flexibility to select the most practical design configuration when incorporating the combination of the Level 1 or Level 2 treatment volume (*Tv*) and the channel protection and flood control detention volume (where applicable). The design configurations as illustrated in **Figure 14.1** above include:

- Wet pond with 100% of the permanent pool in a single cell (Level 1 design)
- Wet ED and/or multi-cell wet pond meeting additional requirements for pond geometry, landscaping, etc. (note that ED may comprise no more than 50% of the total Level 2 Treatment Volume)
- Pond/Wetland Combination (see Stormwater Design Specification No. 13: Constructed Wetlands for additional guidance on the design of the wetland element).

SECTION 6: DESIGN CRITERIA

6.1. Overall Sizing

The wet pond is designed to manage the design *Tv* within the permanent pool, multiple permanent pool cells, or a combination of the permanent pool and extended detention storage. Designers should use the BMP design treatment volume, Tv_{BMP} (defined as the treatment volume based on the contributing drainage area, Tv_{DA}, less any volume reduced by upstream runoff reduction practices), to size and design the permanent pool volume, as well as any of the pond appurtenances (forebays, etc.). If additional detention storage is proposed for channel protection and/or flood control, designers should use the adjusted curve number reflective of the volume reduction provided by the upstream practices to calculate the developed condition peak flow rates (including the energy balance) to determine detention requirements. (Refer to Chapter 11 of the Virginia Stormwater Handbook.)

6.2. Treatment Volume Design

To qualify for the higher nutrient reduction rates associated with the Level 2 design, wet ponds must be designed with a *Tv* that is 50% greater than the T_v for the Level 1 design [i.e., $1.50(R_v)(A)$; **Table 14.3**)]. Research demonstrates that larger wet ponds with longer residence times enhance algal uptake and nutrient removal rates. (CWP 2008). Runoff treatment credit may be taken for the following:

Wet Pond – Level 1 design:

- The entire water volume below the normal pool elevation.

Wet ED and/or Multi-Cell Pond – Level 2 design (1.5 *Tv*):

- The entire water volume below the normal pool elevation (3 internal cells)
- Up to 50% of the *Tv* when provided in ED above the permanent pool elevation within one or multiple cells (refer to Stormwater Design Specification No. 15 for ED design).

Other Design Variants:

Wet ponds can be designed to promote runoff volume reduction through water reuse (e.g., pumping pond water back into the contributing drainage area for use in seasonal landscape irrigation). While this practice is not common, it has been applied to golf course ponds, and accepted computational methods are available (Wanielista and Yousef, 1993 and McDaniel and Wanielista, 2005). It is recommended that designers be allowed to take credit for annual runoff reduction achieved by pond water reuse, as long as acceptable modeling data is provided for documentation.

Treatment Volume Storage. The permanent pool volume equal to the *Tv* for Level 1 can consist of the forebay (or multiple forebays as needed – **Section 6.5**) and the main pool. A minimum depth of 4 feet and a maximum depth of 6 feet are recommended. The minimum depth encourages proper mixing while a maximum depth helps to minimize stratification and an imbalance between pool volume and surface area.

Level 2 wet pond can consist of multiple cells or an extended detention storage above the permanent pool. When incorporating multiple cells, wet ponds with a single inflow point and forebay may count the forebay as one cell; (however, multiple forebays do not count as multiple cells). The remaining Level 2 *Tv* should be divided among the remaining cells and may include a wetland cell and a deep pool cell. The deep pool cell should be designed similar to the single cell of a Level 1 pond (geometry, depth, etc.), and the wetland cell as described in the BMP Design Specification 13: Constructed Wetlands. In general, the design of multiple cells should incorporate multiple pollutant removal pathways for increased performance: longer flow paths, high surface area-to-volume ratios, and/or redundant treatment methods (e.g., combinations of the permanent pool, ED, and a shallow marsh/wetland). Non-erodible berms or simple weirs should be used instead of pipes to separate multiple pond cells. Refer to **Appendix D: Sediment Forebays** of the Introduction to the New Virginia Stormwater Design Specifications for additional guidance.

Maximum Extended Detention Levels. The maximum extended detention volume associated with the Level 2 *Tv* may not extend more than 12 inches above the wetland cell permanent pool at its maximum water surface elevation. The maximum ED and channel protection detention levels can be up to 5 feet above the wet pond permanent pool.

Water Balance Testing. A water balance calculation is recommended to document that sufficient inflows to the pond exist to compensate for combined infiltration and evapo-transpiration losses during a 30-day summer drought without creating unacceptable drawdowns (**Equation 14.1,** adapted from Hunt et al., 2007). The recommended minimum pool depth to avoid nuisance conditions may vary; however, it is generally recommended that the water balance maintain a minimum 24-inch reservoir.

Equation 14.1. Water Balance Equation for Acceptable Water Depth in a Wet Pond

$$DP > ET + INF + RES - MB$$

Where:

DP	=	Average design depth of the permanent pool (inches)
ET	=	Summer evapo-transpiration rate (inches) (assume 8 inches)
INF	=	Monthly infiltration loss (assume 7.2 @ 0.01 inch/hour)
RES	=	Reservoir of water for a factor of safety (assume 24 inches)
MB	=	Measured baseflow rate to the pond, if any (convert to inches)

Design factors that will alter this equation are the measurements of seasonal base flow and infiltration rate. The use of a liner could eliminate or greatly reduce the influence of infiltration. Similarly, land use changes in the upstream watershed could alter the base flow conditions over time.

Translating the baseflow to inches refers to the depth within the pond. Therefore, the following equation can be used to convert the baseflow, measured in cubic feet per second (ft^3/s), to pond-inches:

$$\text{Pond inches} = ft^3/s * (2.592E6) * (12''/ft) / \text{SA of Pond } (ft^2)$$

Where:

2.592E6 = Conversion factor: ft^3/s to ft^3/month.
SA = suface area of pond in ft^2

6.3. Internal Design Geometry

Side Slopes. Side slopes for the wet pond should generally have a gradient of 4H:1V to 5H:1V. The mild slopes promote better establishment and growth of vegetation and provide for easier maintenance and a more natural appearance.

Long Flow Path. Wet pond designs should have an irregular shape and a long flow path from inlet to outlet to increase water residence time and pond performance. In terms of flow path geometry, there are two design considerations: (1) the overall flow path through the pond, and (2) the length of the shortest flow path (Hirschman et al., 2009).

- The overall flow path can be represented as the length-to-width ratio *OR* the flow path ratio (see the *Introduction to the New Virginia Stormwater Design Specifications*, as posted on the Virginia Stormwater BMP Clearinghouse web site). These ratios must be at least 2L:1W for Level 1 designs and 3L:1W for Level 2 designs. Internal berms, baffles, or vegetated peninsulas can be used to extend flow paths and/or create multiple pond cells.
- The shortest flow path represents the distance from the closest inlet to the outlet (see the *Introduction to the New Virginia Stormwater Design Specifications*, as posted on the Virginia Stormwater BMP Clearinghouse web site). The ratio of the shortest flow to the overall length must be at least 0.5 for Level 1 designs and 0.8 for Level 2 designs. In some cases – due to site geometry, storm sewer infrastructure, or other factors – some inlets may not be able to meet these ratios. However, the drainage area served by these "closer" inlets should constitute no more than 20% of the total contributing drainage area.

Safety Features. Several design features of impounding structures are intended to provide elements of safety. The perimeter of all pool areas greater than 4 feet in depth must be surrounded by two benches, as follows:

- A ***Safety Bench*** is a minimum 10 foot wide bench with a minimal cross slope (2%) located immediately above and adjacent to the permanent pool. A safety bench is not necessary if the stormwater pond side slopes above the permanent pool are 5H:1V or flatter.
- An ***Aquatic Bench*** is a shallow area just inside the perimeter of the normal pool that promotes growth of aquatic and wetland plants. The bench also serves as a safety feature, reduces shoreline erosion, and conceals floatable trash. The aquatic bench extends 10 feet inward from the permanent pool shoreline, from a depth of 0 to 18 inches (maximum) below the normal pool water surface elevation.
- Both the safety bench and the aquatic bench should be landscaped with vegetation that hinders or prevents access to the pool. Thick shoreline vegetation also serves to discourage geese.
- The principal spillway opening must be designed and constructed to prevent access by small children.

- End walls above pipe outfalls greater than 48 inches in diameter must be fenced to prevent a hazard.
- An emergency spillway and associated freeboard must be provided in accordance with applicable local or state dam safety requirements. The emergency spillway must be located so that downstream structures will not be impacted by spillway discharges.
- Warning signs prohibiting swimming should be posted.

6.4. Required Geotechnical Testing

Soil borings should be conducted within the footprint of the proposed embankment, in the vicinity of the proposed outlet structure, and in at least two locations within the proposed wet pond treatment area. Soil boring data is needed to (1) determine the physical characteristics of the excavated material to determine its adequacy as structural fill or other use, (2) determine the need and appropriate design depth of the embankment cut-off trench; (3) provide data for structural designs of the outlet works (e.g., bearing capacity and buoyancy), (4) determine the depth to groundwater and bedrock and (5) evaluate potential infiltration losses (and the potential need for a liner).

Additional guidance on geotechnical criteria for impoundment facilities can be found in **Appendix A: Earthen Embankments** of the Introduction to the New Virginia Stormwater Design Specifications, as posted on the Virginia Stormwater BMP Clearinghouse web site:

http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html

Guidance on soil explorations in general can be found in **Appendix 8-A** of **Stormwater Design Specification No. 8 (Infiltration).**

6.5. Pretreatment Forebay

Sediment forebays are considered to be an integral design feature to maintain the longevity of all wet ponds. A forebay must be located at each major inlet to trap sediment and preserve the capacity of the main treatment cell.

Refer to **Appendix D: Sediment Forebays** of the Introduction to the New Virginia Stormwater Design Specifications, as posted on the Virginia Stormwater BMP Clearinghouse web site for design forebay design information, at the following web address:

http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html

Other forms of pre-treatment for sheet flow and concentrated flow for minor inflow points should be designed consistent with pretreatment criteria found in Design Spec No. 9: Bioretention.

6.6. Conveyance and Overflow

Internal Slope. The longitudinal slope of the pond bottom should be at least 0.5% to 1%.

Principal Spillway. The principal spillway shall be designed with acceptable anti-flotation, anti-vortex and trash rack devices. The spillway must generally be accessible from dry land. Refer to **Appendix B: Principal Spillways** of the *Introduction to the New Virginia Stormwater Design Specifications*, as posted on the Virginia Stormwater BMP Clearinghouse web site:

http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html

Non-Clogging Low Flow Orifice. A low flow orifice must be provided that is adequately protected from clogging by either an acceptable external trash rack or by internal orifice protection that may allow for smaller diameters. Orifices less than 3 inches in diameter may require extra attention during design, to minimize the potential for clogging. There are many design options including, but not limited to:

- A submerged reverse-slope pipe that extends downward from the riser to an inflow point 1 foot below the normal pool elevation.
- Alternative methods may employ a broad crested rectangular or V-notch (or proportional) weir, protected by a half-round CMP that extends at least 12 inches below the normal pool elevation.
- Designers may develop

Emergency Spillway. Wet ponds must be constructed with overflow capacity to pass the 100-year design storm event through either the Primary Spillway (with two feet of freeboard to the settled top of embankment) or a vegetated or armored Emergency Spillway (with at least one foot of freeboard to the settled top of embankment). Refer to **Appendix C: Emergency Spillways** of the *Introduction to the New Virginia Stormwater Design Specifications*, as posted on the Virginia Stormwater BMP Clearinghouse web site (the URL is on the previous page).

Pond Drain. Wet ponds should be equipped with 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 pond, or a pond in the coastal plain where a low level outlet is available), a pump wet well should be provided to accommodate a temporary pump intake when needed to drain the pond.

- The drain pipe should have an upturned elbow or protected intake within the pond, to prevent sediment deposition, and a diameter capable of draining the pond within 24 hours.
- The pond drain must 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.

Adequate Outfall Protection. The design must specify an outfall that will be stable for the maximum (pipe-full) design discharge (the 10-year design storm event or the maximum flow when surcharged during the emergency spillway design event, whichever is greater). The channel immediately below the pond outfall must be modified to prevent erosion and conform to natural dimensions in the shortest possible distance. Outlet protection should be provided consistent with state or local guidance.

Inlet Protection. Inlet areas should be stabilized to ensure that non-erosive conditions exist during storm events up to the overbank flood event (i.e., the 10-year storm event). Inlet pipe inverts should generally be located at or slightly below the permanent pool elevation.

Dam Safety Permits. Wet ponds with high embankments or large drainage areas and impoundments may be regulated under the Virginia Dam Safety Act (§ 10.1-606.1 et seq., Code of Virginia) and the Virginia Dam Safety Regulations (4 VAC 50-20 et seq.). Refer to Design Specification Appendix A: Earthen Embankments for additional information.

6.7. Landscaping and Planting Plan

A landscaping plan must be provided that indicates the methods used to establish and maintain vegetative coverage in the pond and its buffer. Minimum elements of a plan include the following:

- Delineation of pondscaping zones within both the pond and buffer
- Selection of corresponding plant species
- The planting plan
- The sequence for preparing the wetland benches (including soil amendments, if needed)
- Sources of native plant material
- The landscaping plan should provide elements that promote diverse wildlife and waterfowl use within the stormwater wetland and buffers. **However, to the extent possible, the aquatic and safety benches should be planted with dense shoreline vegetation to help establish a safety barrier, as well as discourage resident geese.**
- Woody vegetation may not be planted or allowed to grow within 15 feet of the toe of the embankment nor within 25 feet from the principal spillway structure.
- A vegetated buffer of native plants that requires minimal maintenance should be provided that extends at least 25 feet outward from the maximum water surface elevation of the wet pond. Permanent structures (e.g., buildings) should not be constructed within the buffer area. Existing trees should be preserved in the buffer area during construction.
- The soils in the stormwater buffer area are often severely compacted during the construction process, to ensure stability. The density of these compacted soils can be so great that it effectively prevents root penetration and, therefore, may lead to premature mortality or loss of vigor. As a rule of thumb, planting holes should be three times deeper and wider than the diameter of the root ball for ball-and-burlap stock, and five times deeper and wider for container-grown stock.
- Avoid species that require full shade, or are prone to wind damage. Extra mulching around the base of trees and shrubs is strongly recommended as a means of conserving moisture and suppressing weeds.

For more guidance on planting trees and shrubs in wet pond buffers, consult the following:

- Cappiella et al (2006)
- DCR's Riparian Buffer Modification & Mitigation Guidance Manual, available online at: http://www.dcr.virginia.gov/chesapeake_bay_local_assistance/ripbuffmanual.shtml
- Appendix E: Landscaping of the Introduction to the New Virginia Stormwater Design Specifications , as posted on the Virginia Stormwater BMP Clearinghouse web site:

http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html

6.8. Maintenance Features

The following wet pond maintenance criteria should be addressed during the design, in order to facilitate on-going maintenance:

- ***Maintenance Access.*** Good access is needed so crews can remove sediments, make repairs and preserve pond treatment capacity).
  - Adequate maintenance access must extend to the forebay, safety bench, riser, and outlet structure and must have sufficient area to allow vehicles to turn around.
  - The riser should be located within the embankment for maintenance access, safety and aesthetics. Access to the riser should be provided by lockable manhole covers and manhole steps within easy reach of valves and other controls.
  - Access roads must (1) be constructed of materials that can withstand the expected frequency of use, (2) have a minimum width of 12 feet, and (3) have a profile grade that does not exceed15%. Steeper grades are allowable if appropriate stabilization techniques are used, such as a gravel road.
  - A maintenance right-of-way or easement must extend to the stormwater pond from a public or private road.
- ***Pond Aerators.*** Electric or mechanical aeration is used to place as much oxygen into contact with water as economically practical. That is can be accomplished by mixing large quantities of water (both volume and total surface area) with atmospheric oxygen. Aerators can be utilized on a continuous, seasonal, or temporary basis as needed to maintain minimum oxygen levels. Several different types and scales of aeration devices are available. Most aeration equipment will require electricity at the pond bank.

6.9. Wet Pond Material Specifications

Wet ponds 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, filter fabric for lining banks or berms, and a liner when required.

- ***Liners.*** When a stormwater pond is located over highly permeable soils or fractured bedrock, a liner may be needed to sustain a permanent pool of water. If geotechnical tests confirm the need for a liner, acceptable options include the following: (1) a clay liner following the specifications outlined in **Table 14.5** below; (2) a 30 mil poly-liner; (3) bentonite; (4) use of chemical additives; or (5) an engineering design, as approved on a case-by-case basis by the local review authority. A clay liner should have a minimum thickness of 12 inches with an additional 12 inch layer of compacted soil above it, and it must meet the specifications outlined in **Table 14.4**. Other synthetic liners can be used if the designer can supply supporting documentation that the material will achieve the required performance.

The basic material specifications for **Earthen Embankments**, **Principal Spillways**, **Vegetated Emergency Spillways** and **Sediment Forebays** shall be as specified in **Appendices A through D** of the *Introduction to the New Virginia Stormwater Design Specifications*, as posted on the Virginia Stormwater BMP Clearinghouse web site, at the following URL:

http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html

Table 14.4. Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	Cm/sec	1 x 10^{-6}
Plasticity Index of Clay	ASTM D-423/424	%	Not less than 15
Liquid Limit of Clay	ASTM D-2216	%	Not less than 30
Clay Particles Passing	ASTM D-422	%	Not less than 30
Clay Compaction	ASTM D-2216	%	95% of standard proctor density

Source: DCR (1999)

SECTION 7: REGIONAL & SPECIAL CASE DESIGN ADAPTATIONS

7.1. Karst Terrain

Karst regions are found in much of the Ridge and Valley province of Virginia. The presence of karst complicates both land development in general and stormwater design in particular. Designers should always conduct geotechnical investigations in areas of karst terrain to assess this risk and rule out the presence of karst during the project planning stage. If these studies indicate that less than 3 feet of vertical separation exists between the bottom of the ED pond and the underlying soil-bedrock interface, ED ponds should not be used due to the risk of sinkhole formation, groundwater contamination, and frequent facility failures (see CSN Technical Bulletin No. 1, 2008, and Appendix 6-C of Chapter 6 of the Virginia Stormwater Management Handbook, 2010). At a minimum, designers must specify the following:

- A minimum of 6 feet of unconsolidated soil material exists between the bottom of the basin and the top of the karst layer.
- Maximum temporary or permanent water elevations within the basin do not exceed 6 feet.
- Annual maintenance inspections must be conducted to detect sinkhole formation. Sinkholes that develop should be reported immediately after they have been observed, and should be repaired, abandoned, adapted or observed over time following the guidance prescribed by the appropriate local or state groundwater protection authority (see **Section 9.3**)
- A liner is installed that meets the requirements outlined in **Table 14.5**.

Table 14.5. Required Groundwater Protection Liners for Ponds in Karst Terrain (WVDEP, 2006 and VA DCR, 1999)

Situation	Criteria
Pond *not* excavated to bedrock	24 inches of soil with a maximum hydraulic conductivity of 1 x 10^{-5} cm/sec.
Pond excavated to or near bedrock	24 inches of clay[1] with a maximum hydraulic conductivity of 1 x 10^{-6} cm/sec.
Pond excavated to bedrock within a wellhead protection area, in a recharge area for a domestic well or spring, or in a known faulted or folded area	Synthetic liner with a minimum thickness of 60 mil.
[1] Clay properties as follows: Plasticity Index of Clay = Not less than 15% (ASTM D-423/424) Liquid Limit of Clay = Not less than 30% (ASTM D-2216) Clay Particles Passing = Not less than 30% (ASTM D-422) Clay Compaction = 95% of standard proctor density (ASTM D-2216)	

Source: WVDEP (2006) and VA DCR (1999)

7.2. Coastal Plain

The flat terrain, low hydraulic head and high water table of many coastal plain sites can constrain the application of wet ponds. Excavating ponds below the water table creates what are known as dugout ponds, where the treatment volume is displaced by groundwater, reducing the pond's mixing and treatment efficiency and creating nuisance conditions. In addition, pond drains may not be practicable in extremely flat terrain.

Wet ponds are considered an *"acceptable"* stormwater practice for use in the coastal plain where the water table is within four feet of the land surface. However, constructed wetlands are a preferred alternative in such settings, if space is available. The following are important design considerations pertaining to wet ponds located in coastal plain settings:

- ***Adjustments to the Nutrient Removal Credit****.* Numerous research findings indicate that the criteria in this design specification for wet ponds *cannot* achieve the same level of nutrient removal that can be achieved in the rest of Virginia (based on current design, detention times, the influence of groundwater and other factors). Therefore, slightly lower nutrient removal rates are assigned to coastal plain wet ponds, to reflect real world performance data for phosphorus and nitrogen removal. Specifically, Level 1 and 2 total removal rates for TP are now proposed to be 45% and 65% respectively, and Level 1 and 2 TN removal rates are reduced to 20% and 30%, respectively. These slightly lower removal rates are supported by pond research and the detention time relationships (see CSN Technical Bulletin No. 2, 2009).
- ***Pocket Ponds.*** Another issue relates to wet ponds with a small contributing drainage area that are solely supplied by runoff and groundwater, and often have fluctuating water levels that create nuisance conditions. There is virtually no research data on these "pocket ponds" that are frequently installed on small commercial sites. Rather than mandating an arbitrary minimum drainage area, it is recommended instead that these pocket ponds must meet the minimum design geometry requirements for all ponds (i.e., a sediment forebay cell, aquatic benches, maximum side-slopes no steeper than 5H: 1V, and a length-to-width ratio of 2:1 for Level 1 designs or 3:1 for Level 2 designs). Designers should strictly adhere to the same design requirements that apply to other wet ponds. This should greatly reduce the number of small nuisance ponds with inadequate designs and insufficient functions (i.e., by reducing or eliminating essential pond design elements), that are forced into sites that are too small.

7.3. Steep Terrain

The use of wet ponds is highly constrained at development sites with steep terrain. Some adjustment can be made by terracing pond cells in a linear manner, using a 1 to 2 foot armored elevation drop between individual cells. Terracing may work well on longitudinal slopes with gradients up to approximately 10%.

7.4. Cold Climate and Winter Performance

Pond performance decreases when snowmelt runoff delivers high pollutant loads. Ponds can also freeze in the winter, which allows runoff to flow over the ice layer and exit without treatment. Inlet and outlet structures close to the surface may also freeze, further diminishing pond performance. Salt loadings are higher in cold climates due to winter road maintenance. The following design adjustments are recommended for wet ponds installed in higher elevations and colder climates:

- Treat larger runoff volumes in the spring by adopting seasonal operation of the permanent pool (see MSSC, 2005).
- Plant salt-tolerant vegetation in pond benches.
- Do not submerge inlet pipes, and provide a minimum 1% pipe slope to discourage ice formation.
- Locate low flow orifices so they withdraw at least 6 inches below the typical ice layer.
- Place trash racks at a shallow angle to prevent ice formation.
- Oversize riser and weir structures to avoid ice formation and pipe freezing.
- If winter road sanding is prevalent in the contributing drainage area, increase the forebay size to accommodate additional sediment loading.

7.5. Linear Highway Sites

Wet ponds are poorly suited to treat runoff within open channels located in the highway right of way, unless storage is available in a cloverleaf interchange or in an expanded right-of-way. Guidance for pond construction in these areas is provided in Profile Sheet SR-5 in Schueler et al (2007).

SECTION 8: CONSTRUCTION

8.1. Construction Sequence

The following is a typical construction sequence to properly install a wet pond. The steps may be modified to reflect different wet pond designs, site conditions, and the size, complexity and configuration of the proposed facility.

Step 1: Use of Wet Pond as an E&S Control. A wet pond may serve as a sediment basin during project construction. If this is done, the volume should be based on the more stringent sizing rule (erosion and sediment control requirement vs. water quality treatment requirement). Installation of the permanent riser should be initiated during the construction phase, and design elevations should be set with final cleanout of the sediment basin and conversion to the post-construction wet pond in mind. The bottom elevation of the wet pond should be lower than the bottom elevation of the temporary sediment basin. Appropriate procedures should be implemented to prevent discharge of turbid waters when the basin is being converted into a wet pond.

Step 2: Stabilize the Drainage Area. Wet ponds should only be constructed after the contributing drainage area to the pond is completely stabilized. If the proposed pond 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 3: Assemble Construction Materials on-site, make sure they meet design specifications, and prepare any staging areas.

Step 4: Install E&S Controls prior to construction, including temporary de-watering devices and stormwater diversion practices. All areas surrounding the pond that are graded or denuded during construction must be planted with turf grass, native plantings, or other approved methods of soil stabilization.

Step 5: Clear and Strip the project area to the desired sub-grade.

Step 6: Excavate the Core Trench and Install the Spillway Pipe.

Step 7: Install the Riser or Outflow Structure, and ensure the top invert of the overflow weir is constructed level at the design elevation.

Step 8: Construct the Embankment and Any Internal Berms in 8- to 12-inch lifts, or as directed by geotechnical recommendations, and compact as required with appropriate equipment.

Step 9: Excavate/Grade until the appropriate elevation and desired contours are achieved for the bottom and side slopes of the pond.

Step 10: Construct the Emergency Spillway in cut or structurally stabilized soils.

Step 11: Install Outlet Protection, including emergency and primary outlet apron protection.

Step 12: Stabilize Exposed Soils with temporary seed mixtures appropriate for the pond buffer. All areas above the normal pool elevation should be permanently stabilized by hydroseeding or seeding over straw.

Step 13: Plant the Pond Buffer Area, following the pondscaping plan (**Section 6.7**).

8.2. Construction Inspection

Multiple inspections are critical to ensure that stormwater ponds are properly constructed. Inspections are recommended during the following stages of construction:

- Pre-construction meeting
- Initial site preparation (including installation of E&S controls)
- Excavation/Grading (interim and final elevations)
- Installation of the embankment, the riser/primary spillway, and the outlet structure
- Implementation of the pondscaping plan and vegetative stabilization
- Final inspection (develop a punchlist for facility acceptance)

Upon final inspection and acceptance, the GPS coordinates for all wet ponds should be logged for entry into the VSMP Authority's BMP maintenance tracking data base.

A construction phase inspection checklist for Wet Ponds can be accessed at the end of this specification.

In order to facilitate and anticipate maintenance, contractors should measure the actual constructed pond depth at three areas within the permanent pool (forebay, mid-pond and at the riser), and they should mark and geo-reference them on an as-built drawing. This simple data set will enable maintenance inspectors to determine pond sediment deposition rates in order to schedule sediment cleanouts.

SECTION 9: MAINTENANCE

9.1. Maintenance Agreements

The Virginia Stormwater Management regulations (4 VAC 50-60) specify the circumstances under which a maintenance agreement must be executed between the owner and the VSMP authority, and sets forth inspection requirements, compliance procedures if maintenance is neglected, notification of the local program upon transfer of ownership, and right-of-entry for local program personnel.

- Restrictive covenants or other mechanism enforceable by the VSMP authority must be in place to help ensure that wet ponds are maintained, as well as to pass the knowledge along to any subsequent property owners.
- Access to wet ponds should be covered by a drainage easement to allow access by the VSMP authority to conduct inspections and perform maintenance when necessary.
- All wet ponds must include a long term maintenance agreements consistent with the provisions of the VSMP regulations, and must include the recommended maintenance tasks and a copy of an annual inspection checklist.
- The maintenance agreement should also include contact information for owners to get local or state assistance to solve common nuisance problems, such as mosquito control, geese, invasive plants, vegetative management and beaver removal.

9.2. First Year Maintenance Operations

Successful establishment of wet ponds requires that the following tasks be undertaken during the first year following construction.

***Initial inspections*.** For the first six months following construction, the site should be inspected at least twice after storm events that exceed a 1/2-inch of rainfall.

Planting of Aquatic Benches. The aquatic benches should be planted with emergent wetland species, following the planting recommendations contained in Stormwater Design Specification No. 13 (Constructed Wetlands).

Spot Reseeding. Inspectors should look for bare or eroding areas in the contributing drainage area or around the pond buffer, and make sure they are immediately stabilized with grass cover.

Watering. Trees planted in the pond buffer need to be watered during the first growing season. In general, consider watering every 3 days for first month, and then weekly during the remainder of the first growing season (April - October), depending on rainfall.

9.3. Maintenance Inspections

Maintenance of a wet pond is driven by annual inspections that evaluate the condition and performance of the pond, including the following:

- Measure sediment accumulation levels in the forebay.
- Monitor the growth of wetland plants, trees and shrubs planted. Record the species and their approximate coverage, and note the presence of any invasive plant species.
- Inspect the condition of stormwater inlets to the pond for material damage, erosion or undercutting.
- Inspect the banks of upstream and downstream channels for evidence of sloughing, animal burrows, boggy areas, woody growth, or gully erosion that may undermine embankment integrity.
- Inspect the pond outfall channel for erosion, undercutting, rip-rap displacement, woody growth, etc.
- Inspect the condition of the principal spillway and riser for evidence of spalling, joint failure, leakage, corrosion, etc.
- Inspect the condition of all trash racks, reverse-sloped pipes, or flashboard risers for evidence of clogging, leakage, debris accumulation, etc.
- Inspect maintenance access to ensure it is free of woody vegetation, and check to see whether valves, manholes and locks can be opened and operated.
- Inspect internal and external side slopes of the pond for evidence of sparse vegetative cover, erosion, or slumping, and make needed repairs immediately.

Based on inspection results, specific maintenance tasks will be triggered. Example maintenance inspection checklists for Wet Ponds can be accessed in Appendix C of Chapter 9 of the *Virginia Stormwater Management Handbook* (2010).

9.4 Common Ongoing Maintenance Tasks

Maintenance is needed so stormwater ponds continue to operate as designed on a long-term basis. Routine stormwater pond maintenance, such as removing debris and trash, is needed several times each year (See **Table 14.6**). More significant maintenance (e.g., removing accumulated sediment) is needed less frequently but requires more skilled labor and special equipment. Inspection and repair of critical structural features (e.g., embankments and risers) needs to be performed by a qualified professional (e.g., a structural engineer) who has experience in the construction, inspection, and repair of these features.

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

Table 14.6. Typical Wet Pond Maintenance Tasks and Frequency

Maintenance Items[1]	Frequency[1]
• Remove debris and blockages • Repair undercut, eroded, and bare soil areas	Quarterly or after major storms (>1 inch of rainfall)
• Mowing embankment	Twice a year
• Shoreline cleanup to remove trash, debris and floatables • A full maintenance inspection • Open up the riser to access and test the valves • Repair broken mechanical components, if needed	Annually
• Pond buffer and aquatic bench reinforcement plantings	One time –during the second year following construction
• Forebay Sediment Removal	Every 5 to 7 years
• Repair pipes, the riser and spillway, as needed	From 5 to 25 years

[1]Maintenance items and required frequency should be verified with local requirements

9.4. Sediment Removal

Frequent sediment removal from the forebay is essential to maintain the function and performance of a wet pond. For planning purposes, maintenance plans should anticipate cleanouts approximately every 5 to 7 years, or when inspections indicate that 50% of forebay sediment storage capacity has been filled. (Absent an upstream eroding channel or other source of sediment, the frequency of sediment removal should decrease as the drainage area stabilizes.) The designer should also check to see whether removed sediments can be spoiled on-site or must be hauled away. Sediments excavated from wet ponds 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 wet pond serves a hotspot land use.

SECTION 10: COMMUNITY & ENVIRONMENTAL CONCERNS

Wet ponds can generate the following community and environmental concerns that need to be addressed during design.

Aesthetic Issues. Many residents feel that wet ponds are an attractive landscape feature, promote a greater sense of community and are an attractive habitat for fish and wildlife. Designers should note that these benefits are often diminished where wet ponds are under-sized or have small contributing drainage areas.

Existing Wetlands. A wet pond should never be constructed within an existing *natural* wetland. Discharges from a wet pond into an existing natural wetland should be minimized to prevent pollution damage and changes to its hydroperiod.

Existing Forests. Construction of a wet pond may involve extensive clearing of existing forest cover. Designers can expect a great deal of neighborhood opposition if they do not make a concerted effort to save mature trees during pond design and construction.

Stream Warming Risk. Wet ponds can warm streams by 2 to 10 degrees Fahrenheit, although this may not be a major problem for degraded urban streams. To minimize stream warming, landscaping plans for wet ponds should emphasize shading with a combination of emergent vegetation and overstory shading. When a Level 2 design is required (and all upgradient runoff reduction options have been exhausted), designers should utilize the multiple cells, and not the ED option..

Safety Risk. Pond safety is an important community concern. Gentle side slopes and safety benches should be provided to avoid potentially dangerous drop-offs, especially where wet ponds are located near residential areas.

Mosquito Risk. Mosquitoes are not a major problem for larger wet ponds (Santana *et al*., 1994; Ladd and Frankenburg, 2003, Hunt et al, 2005). However, fluctuating water levels in smaller or under-sized wet ponds could pose some risk for mosquito breeding. Mosquito problems can be minimized through simple design features and maintenance operations described in MSSC (2005).

Geese and Waterfowl. Wet ponds with extensive managed turf and shallow shorelines can attract nuisance populations of resident geese and other waterfowl, whose droppings add to the nutrient and bacteria loads, thus reducing the removal efficiency for those pollutants. Several design and landscaping features can make wet ponds much less attractive to geese (see Schueler, 1992).

Harmful Algal Blooms. Designers are cautioned that recent research on wet ponds in the coastal plain has shown that some ponds can be hotspots or incubators for algae that generate harmful algal blooms (HABs). The type of HAB may include cyanobacteria, raphidophytes, or dinoflagellates, and the severity appears to be related to environmental conditions and high nutrient inputs. Given the known negative effects of HABs on the health of shellfish, fish, wildlife and humans, this finding is a cause for concern for coastal stormwater managers. At this time, it is not possible to develop design guidelines to avoid HAB problems in coastal wet ponds. A summary of recent pond research on this emerging issue can be found in Appendix A of Technical Bulletin No. 2, Stormwater Design in the Coastal Plain of the Chesapeake Bay Watershed (CSN,2009).

Sample Construction Inspection Checklist for Wet Ponds: The following checklist provides a basic outline of the anticipated items for the construction inspection of a wet pond. Inspectors should review the plans carefully, and adjust these items and the timing of inspection verification as needed to ensure the intent of the design and the inspection is met. Finally, users of this information may wish to incorporate these items into a VSMP Authority Construction Checklist format consistent with the format used for erosion and sediment control and BMP construction inspections.

Pre-Construction Meeting

☐ Pre-construction meeting with the contractor designated to install the wet pond has been conducted.

☐ Identify the tentative schedule for construction and verify the requirements and schedule for interim inspections and sign-off.

☐ Subsurface investigation and soils report supports the placement of a wet pond in the proposed location.

☐ Impervious cover has been constructed/installed and area is free of construction equipment, vehicles, material storage, etc.

☐ All pervious areas of the contributing drainage areas have been adequately stabilized with a thick layer of vegetation and erosion control measures have been removed.

☐ **Certification of Stabilization Inspection:** Inspector certifies that the drainage areas are adequately stabilized in order to convert the sediment pond or trap (if used for sediment control) into a permanent wet pond.

Construction of Wet Pond Embankment and Principal Spillway

☐ Stormwater has been diverted around or through the area of the wet pond embankment to a stabilized conveyance; and perimeter erosion control measures to protect the facility during construction have been installed.

☐ Materials for construction of the embankment and principal spillway are available and meet the specifications of the approved plans.

☐ Construction of key trench, principal spillway, including the riser and barrel, anti-seepage controls, outlet protection, etc., is built in accordance with approved plans.

☐ Geotechnical analysis and approval of the core (if required) and embankment material has been provided, and the material has been placed in lifts and compacted in accordance with the approved plans.

☐ **Certification of Embankment and Principal Spillway Inspection:** Inspector certifies that each element of the embankment and principal spillway has been constructed in accordance with the approved plans.

Excavation of Wet Pond

- ☐ Excavation of the wet pond geometry (including bottom width, side slopes, check dams, weir overflow and outlet protection, etc.) achieves the elevations in accordance with approved plans.
- ☐ Excavation of internal micro-topographic features: deep pool, forebays, etc., is in accordance with approved plans.
- ☐ Impermeable liner, when required, meets project specifications and is placed in accordance with manufacturers specifications.
- ☐ **Certification of Excavation Inspection:** Inspector certifies that the excavation has achieved all the appropriate grades, grade transitions, and wet pond geometry as shown on the approved plans.

Landscaping Plan and Stabilization

- ☐ Exposed soils on pond side slopes above permanent pool elevation are stabilized with specified seed mixtures, stabilization matting, mulch, etc., in accordance with approved plans.
- ☐ Appropriate number and spacing of plants are installed and protected on the aquatic bench and pond buffer in accordance with the approved plans.
- ☐ All erosion and sediment control practices have been removed.
- ☐ Follow-up inspection and as-built survey/certification has been scheduled.
- ☐ GPS coordinates have been documented for the wet pond installation.

SECTION 11: REFERENCES

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