VIRGINIA DEQ STORMWATER DESIGN SPECIFICATION No. 14

WET POND

VERSION 1.9
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SECTION 1: DESCRIPTION

Wet ponds consist of a permanent pool of standing 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, which allows numerous pollutant removal mechanisms to operate. Wet ponds can also provide extended detention (ED) above the permanent pool to help meet channel protection requirements (see **Table 14.1**).

Designers should note that a wet pond is the final element in the roof-to-stream runoff reduction sequence, so one **should be considered *only* if there is remaining Treatment Volume or Channel Protection Volume to manage after all other upland runoff reduction options have been considered and properly credited.** Wet ponds may be allowed in certain coastal plain situations where the water table is within 3 feet of the ground surface.

SECTION 2: PERFORMANCE

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] Note that EMC removal rate is slightly lower in the coastal plain 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)

SECTION 3: 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 14.2** below. At this point, there is no runoff volume reduction credit for wet ponds.

Table 14.2. 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)	Wet ED [2] (24 hr) and/or a Multiple Cell Design [3]
Length/Width ratio OR Flow path = 2:1 or more	Length/Width ratio OR Flow path = 3:1 or more
Length of shortest flow path / overall length [4] = 0.5 or more	Length of shortest flow path/overall length[4] = 0.8 or more
Standard aquatic benches	Wetlands more than 10% of pond area
Turf in pond buffers	Pond landscaping to discourage geese
No Internal Pond Mechanisms	Aeration (preferably bubblers that extend to or near the bottom or floating islands

[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 Treatment Volume; Refer to Design Specification 15 for ED design
[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)
[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

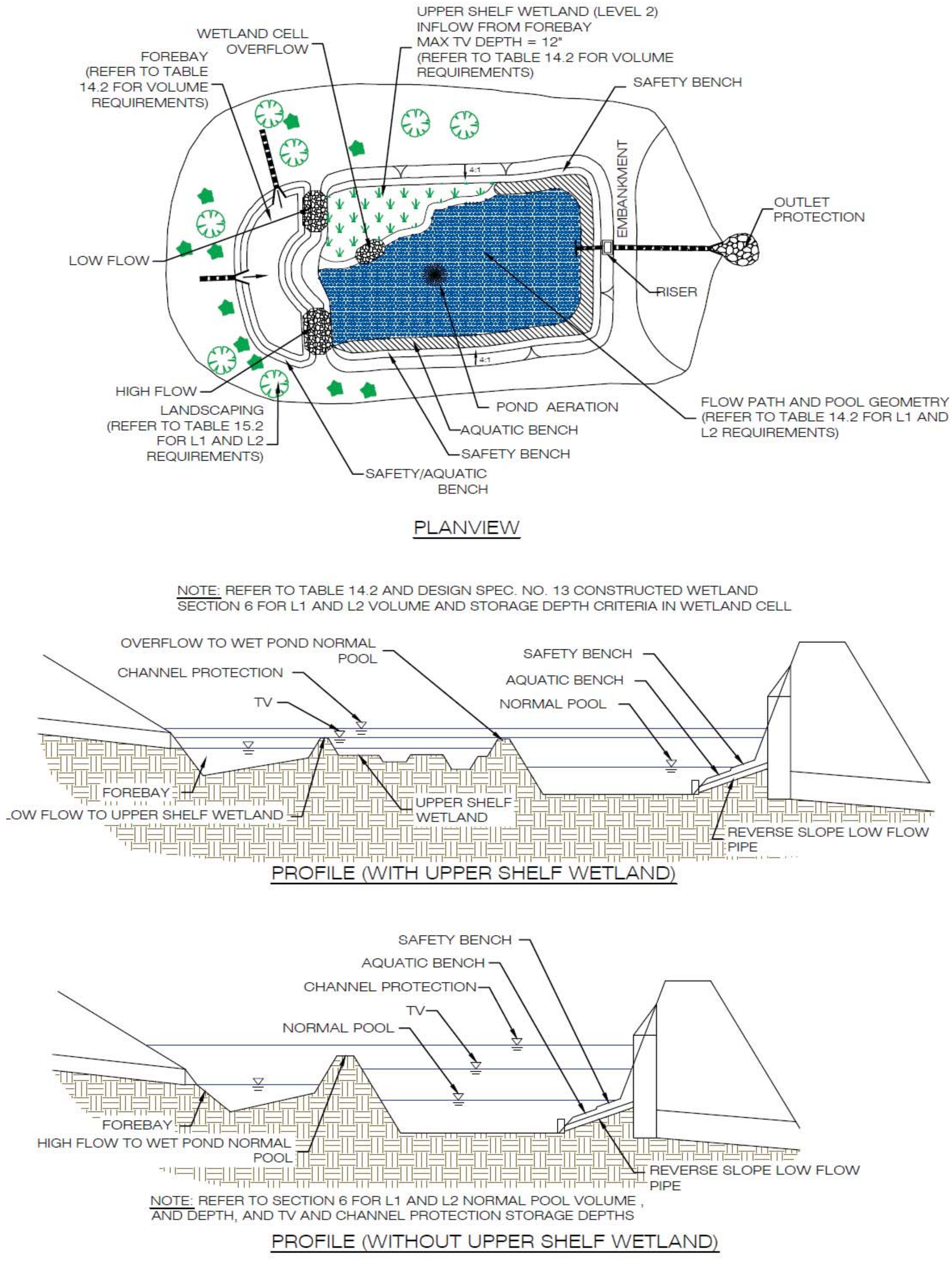

Figure 14.1. Wet Pond Design Schematics

SECTION 5: PHYSICAL FEASIBILITY & DESIGN APPLICATIONS

The following feasibility issues need to be considered when wet ponds are considered as the final BMP of the treatment train.

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 pond's depth.

Contributing Drainage Area. A contributing drainage area of 10 to 25 acres is typically recommended for wet ponds to maintain constant water elevations. 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, experience fluctuating water levels, and generate more 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 ordinances and design criteria should be consulted to determine minimum setbacks to property lines, structures, and wells. As a general rule, wet ponds should be set back at least 20 feet from property lines, 25 feet from building foundations, and 100 feet from septic system fields and private wells.

Depth-to-Water Table. The depth to the groundwater table can be a design concern for wet ponds. If the water table is close to the surface, it may make excavation difficult and expensive. Groundwater inputs can also reduce the pollutant removal rates of wet ponds.

Soils. Highly permeable soils make it difficult to maintain a constant level for the permanent pool in many parts of Virginia. Therefore it is important to directly address fluctuating water levels in the design. Soil infiltration tests need to be conducted at proposed pond sites to determine the need for a pond liner or other method that address water level fluctuation. 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. Geotechnical tests should be conducted to determine the infiltration rates and other subsurface properties of the soils beneath the proposed pond.

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 Virginia Stormwater Management Handbook (2010) 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 also strongly discouraged and will require both a Section 401 and Section 404 permit from the appropriate state or federal regulatory agency.

Design Applications

Wet ponds can be employed in several different design configurations, as illustrated in **Figure 14.1** above:

- Wet Pond with 100% of the permanent pool in a single cell (Level 1 design)
- Wet Extended Detention (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 Treatment Volume)
- Pond/Wetland Combination (see Stormwater Design Specification No. 13: Constructed Wetlands)

Wet ponds are widely applicable for most land uses and are best suited for larger drainage areas. It is important to stress that wet ponds are *not* intended to serve as stand-alone stormwater practices, due to their poor runoff volume reduction capability. Designers should always maximize 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.

SECTION 6: DESIGN CRITERIA

6.1. Overall Sizing

Wet ponds should be designed to capture and treat the remaining Treatment Volume (T_v) for the water quality design storm and the channel protection volume (if needed) discharged from the upstream runoff reduction practices, using the accepted local or state calculation methods. Designers can use a site-adjusted T_v or CN to reflect the use of upland runoff reduction practices.

To qualify for the higher nutrient reduction rates associated with the Level 2 design, wet ponds must be designed with a Treatment Volume that is 50% greater than the T_v for the Level 1 design [i.e., 1.50(R_v)(A)]. Research has shown that larger wet ponds with longer residence times enhance algal uptake and nutrient removal rates. 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 T_v):

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

While most wet ponds have little or no runoff volume reduction capability, they 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.

6.2 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 (see **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. Required Geotechnical Testing

Soil borings should be taken below the proposed embankment, in the vicinity of the proposed outlet area, 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, (2) determine its adequacy for use as structural fill or spoil, (3) provide data for structural designs of the outlet works (e.g., bearing capacity and buoyancy), (4) determine compaction/composition needs for the embankment (5) determine the depth to groundwater and bedrock and (6) evaluate potential infiltration losses (and the potential need for a liner).

6.4. 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. 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. The following criteria apply to forebay design:

- A major inlet is defined as an individual storm drain inlet pipe or open channel serving at least 10% of the wet pond's contributing drainage area.
- The forebay consists of a separate cell (in both Level 1 and Level 2 designs), formed by an acceptable barrier (e.g., an earthen berm, concrete weir, gabion baskets, etc.).
- The forebay should be at least 4 feet deep and must be equipped with a variable width aquatic bench for safety purposes. The aquatic bench should be 4 to 6 feet wide at a depth of 1 to 2 feet below the water surface.
- The total volume of all forebays should be at least 15% of the total Treatment Volume (inclusive). The relative size of individual forebays should be proportional to the percentage of the total inflow to the wet pond. Similarly, any outlet protection associated with the end section or end wall should be designed according to state or local design standards.
- The bottom of the forebay may be hardened (e.g., with concrete, asphalt, or grouted riprap) to make sediment removal easier.
- 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.

6.5. Conveyance and Overflow

Internal Slope. The longitudinal slope through the pond should be at least 0.5% to 1% to promote positive flow through the pond practice.

Primary Spillway. The 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, at the following 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.

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

Emergency Spillway. Wet Ponds must be constructed with overflow capacity to pass the 100-year design storm event through either the Primary Spillway or a vegetated or armored Emergency Spillway. 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. Except for flat areas of the coastal plain, each wet pond 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 pond), 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 10-year design storm event. The channel immediately below the pond outfall must be modified to prevent erosion and conform to natural dimensions in the shortest possible distance. This is typically done by placing appropriately sized riprap over filter fabric, which can reduce flow velocities from the principal spillway to non-erosive levels (3.5 to 5.0 fps). Flared pipe sections, which discharge at or near the stream invert or into a step pool arrangement, should be used at the spillway outlet.

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 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.

6.6. 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 for diagrams and equations). These ratios must be at least 2L:1W for Level 1 designs and 3L:1W for Level 2 designs. Internal berms, baffles, or vegetated pennisulas 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.

Treatment Volume Storage. The total T_v storage may be provided by a combination of the permanent pool, a shallow marsh and/or extended detention storage. The permanent pool storage can be provided in multiple cells. Performance is enhanced when multiple treatment pathways are provided by using multiple cells, longer flow paths, high surface area-to-volume ratios, and/or redundant treatment methods (e.g., a combinations of the permanent pool, ED, and a shallow marsh). A berm or simple weir should be used instead of pipes to separate multiple pond cells.

Maximum Extended Detention Levels. The maximum extended detention volume associated with the T_v may not extend more than 12 inches above the wetland cell permanent pool (at least 10% of the Level 2 surface area) 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.

Stormwater Pond Benches. 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 flat bench located just outside of the perimeter of the permanent pool to allow for maintenance access and reduce safety risks. Except when the stormwater pond side slopes are 5H:1V or flatter, provide a safety bench that generally extends 8 to 15 feet outward from the normal water edge to the toe of the stormwater pond side slope The maximum slope of the safety bench is 5%.
- 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. Incorporate an aquatic bench that generally extends up to 10 feet inward from the normal shoreline, has an irregular configuration, and extends a maximum depth of 18 inches below the normal pool water surface elevation.

Safety Features.

- 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.
- Both the safety bench and the aquatic bench should be landscaped with vegetation that hinders or prevents access to the pool.
- Warning signs prohibiting swimming should be posted.
- Local governments and homeowner associations may require fencing of wet ponds at their discretion. Fencing is required at or above the maximum water surface elevation in the rare situations when the pond slope is a vertical wall.

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.
- 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 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)
- 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.

6.8. Maintenance Reduction Features

The following wet pond maintenance issues can be addressed during the design, in order to make on-going maintenance easier:

- ***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 load-bearing materials or be built to 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.

- ***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 14.4** 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.

Table 14.4. Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	Cm/sec	1×10^{-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: Virginia Stormwater Management Handbook (1999)

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, and filter fabric for lining banks or berms.

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

When reinforced concrete pipe is used for the principal spillway to increase its longevity, "O"-ring gaskets (ASTM C-361) should be used to create watertight joints, and they should be inspected during installation.

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 karst terrain to assess this risk ~~in~~ during the project planning stage. Because of the risk of sinkhole formation, groundwater contamination, and frequent facility failures, use of wet ponds is highly restricted in karst regions (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 does 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 Virginia Stormwater Management Handbook, 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 Virginia Stormwater Management Handbook (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: Clear and Strip the project area to the desired sub-grade.

Step 5: 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 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, compact the lifts 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 Pipes*, **including downstream rip-rap 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 (see **Section 8.5** below).

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)

A construction phase inspection checklist for Wet Ponds can be accessed in at the CWP website at:

http://www.cwp.org/Resource_Library/Controlling_Runoff_and_Discharges/sm.htm
(scroll to Tool6: Plan Review, BMP Construction, and Maintenance Checklists)

For larger wet ponds, use the expanded construction inspection form provided in Appendix B of CWP (2004).

To facilitate 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

Section 4 VAC 50-60-124 of the regulations specifies the circumstances under which a maintenance agreement must be executed between the owner and the local program. This section 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. Access to wet ponds should be covered by a drainage easement to allow inspection and maintenance.

It is also recommended that the maintenance agreement include a list of qualified contractors that can perform inspection or maintenance services, as well as 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. The CWP *Pond and Wetland Maintenance Guidebook* (2004) provides some excellent templates of how to respond to these problems.

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. Inspections and Ongoing Maintenance Tasks

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) or at the CWP website at:

http://www.cwp.org/Resource_Library/Controlling_Runoff_and_Discharges/sm.htm
(scroll to Tool6: Plan Review, BMP Construction, and Maintenance Checklists)

For a more detailed maintenance inspection checklist, see Appendix B in CWP *Stormwater Pond and Wetland Maintenance Guidebook* (2004).

Maintenance is needed so stormwater ponds continue to operate as designed on a long-term basis. Wet ponds normally have fewer routine maintenance requirements than other stormwater control measures. Stormwater pond maintenance activities vary regarding the level of effort and expertise required to perform them. Routine stormwater pond maintenance, such as mowing and 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	Frequency
• Mowing – twice a year • Remove debris and blockages • Repair undercut, eroded, and bare soil areas	Quarterly or after major storms (>1 inch of rainfall)
• Mowing	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

9.4. Sediment Removal

Frequent sediment removal from the forebay is essential to maintain the function and performance of a wet pond. Maintenance plans should schedule cleanouts approximately every 5 to 7 years, or when inspections indicate that 50% of forebay sediment storage capacity has been filled. 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 retrofit 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, wet ponds should be shaded and should provide shorter extended detention times (e.g., 12 hours vs. 24 hours).

Safety Risk. Pond safety is an important community concern, since both young children and adults have perished by drowning in wet ponds through a variety of accidents, including falling through thin ice cover. 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 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).

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