

URBAN Waterways

Stormwater Wetland Design Update: *Zones, Vegetation, Soil, and Outlet Guidance*

Many stormwater wetlands have been built in North Carolina since 2000, particularly in the Neuse, Tar-Pamlico, and Cape Fear River Basins. After examining many of these wetlands, N.C. State University researchers have revised existing design guidelines. Specific design focus points include:

- a redefinition of internal wetland zones,
- a revised list of herbaceous plants that have been found to commonly thrive in stormwater wetlands,
- a review of a proper growing medium, and
- the importance of a flexible outlet structure and its construction.

This fact sheet updates and revises *Designing Stormwater Wetlands for Small Watersheds* (AG-588-2) and is a companion to *Stormwater Wetland Construction Guidance* (AG-588-13).

RECENT RESEARCH

Stormwater wetlands reduce pollutant loads in stormwater runoff and thus have become preferred stormwater management tools. Studies across North Carolina have revealed that both stormwater wetlands and wet ponds trap sediment effectively, but stormwater wetlands remove nutrients and

mitigate temperatures more efficiently than wet ponds:

- A stormwater wetland studied in Johnston County reduced nitrogen and phosphorus concentrations by over 80 percent, well above state-assigned removal rates.
- Studies conducted in Charlotte found removal rates of 40 percent for total nitrogen and 55 percent for total phosphorus.
- A study in the mountains indicated that a well-vegetated stormwater wetland reduced outflow temperatures by 3 to 5°F more than wet ponds, which are unshaded and exposed to sunlight.

In areas with high water tables or a reliable base flow, which often are where stormwater wetlands are sited, a stormwater wetland is often the most efficient practice available for pollution removal. Figure 1 (page 2) highlights several wetlands that NCSU researchers have monitored.

INTERNAL WETLAND ZONES

Figure 2 (page 2) illustrates a stormwater wetland design, and Figure 3 (page 3) depicts a cross-section of the wetland's internal topography by zone. The internal topography of a stormwater wetland can be divided into five zones: deep pools, transitions between deep and shallow water, shallow water, temporary inundation areas, and the upper bank that ties the wetland into its

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Figure 1. Four N.C. stormwater wetlands that have been monitored with published results: (A) Smithfield Selma High School in Johnston County, (B) Shade Valley Elementary School in Charlotte, (C) Chowan Golf Course in Edenton, and (D) UNC-Asheville in Buncombe County.

surroundings. Each zone supports different vegetation and serves a particular purpose. By incorporating all these zones in a single wetland, the designer creates a system that dissipates stormwater flow energy by distributing that flow over the entire wetland, multiple and unique zones for pollutant treatment, a relatively diverse ecosystem for wetland plants and animals, and an aesthetically pleasing addition to the local landscape.

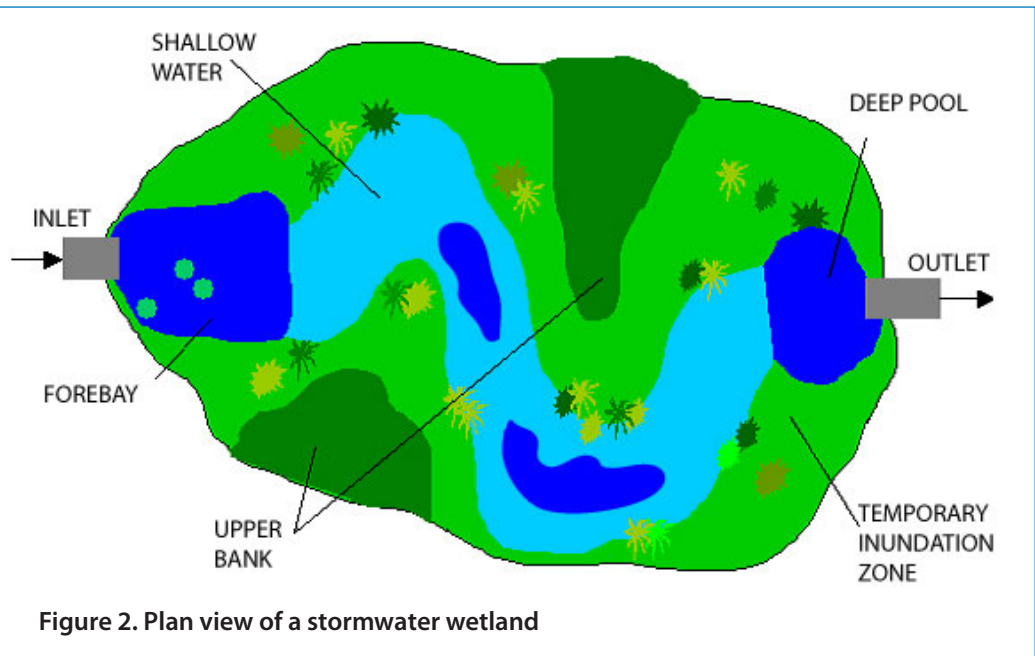


Figure 2. Plan view of a stormwater wetland

DEEP POOLS—ZONE I

Deep pools serve several functions in a stormwater wetland. They dissipate flow energy, trap the sediment coming in with stormwater, and provide an anaerobic environment for enhanced nitrate treatment. They also provide additional water storage that increases both infiltration and evaporation, thereby reducing out-

flow volumes in locations where water tables are low. Deep pools also provide refuge for aquatic organisms during dry periods.

The deep pool is an important component of a mosquito-resistant stormwater wetland because it provides year-round habitat for mosquito predators

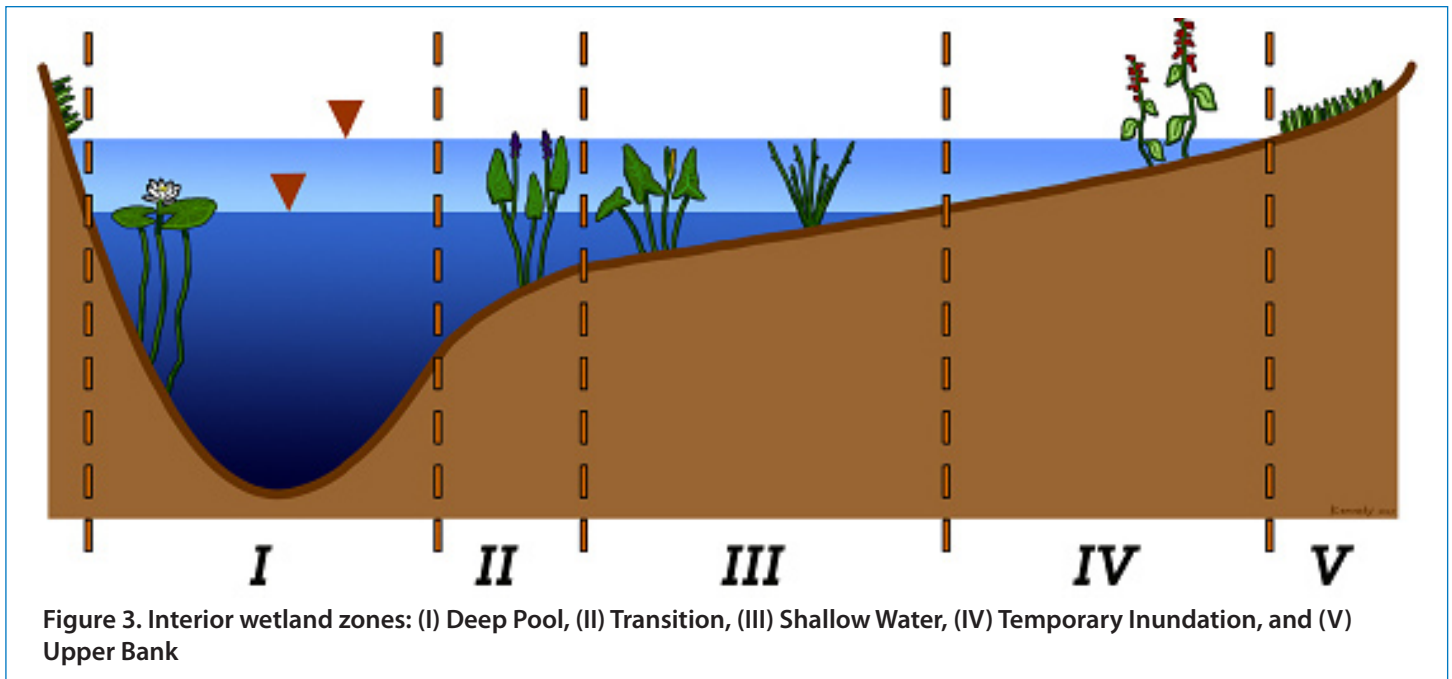


Figure 4. Small deep pool with water lilies

that require water to thrive. Several deep pools should pockmark a stormwater wetland to allow easier predator travel from the deep pools to all parts of the stormwater wetland — and thus easier access to mosquito habitats. Figure 4 shows a small deep pool.

Per some local codes, wetlands with deep pools may require fencing along their perimeter because of depth. The bottom elevation of a deep pool should be at least 18 inches deeper than the designed water elevation at *normal pool* — the water elevation within the wetland after complete drawdown following a storm event. The depth of the deep pool should be 30 inches, if possible. Because deep pools shelter aquatic organisms, they must be deep enough to retain water during a drought.

A four-week drought in the summer can be used to calculate a maximum pool depth to ensure year-round water in the pools. A month without rainfall is

extremely rare in the humid Southeast. For example, from July 2003 through June 2007, the N.C. Climate Center recorded less than 1.0 inch of rainfall at Raleigh-Durham Airport in only one month: September 2005 with 0.83 inch (<http://www.nc-climate.ncsu.edu/cronos/>). Remember that even a relatively small storm event (such as 0.50 inch) can contribute 3 to 6 inches of water depth to a stormwater wetland.

Assuming a four-week summer drought, it is reasonable and conservative to expect up to 10 inches of water loss due to evapotranspiration (evaporation plus transpiration by the wetland plants). If the wetland does not intersect shallow groundwater — and is therefore *perched* — an infiltration loss also may occur. This loss will generally be low since perched stormwater wetlands should be sited in areas that have very low infiltration rates. These rates may vary from 0.01 in/hr (recommended) to 0.05 in/hr. Assuming a water loss rate of 0.01 in/hr, approximately 0.25 in/day will exit the wetland due to infiltration. In a week, slightly less than 2 inches would exit the wetland, so it is reasonable to estimate 8 inches of water loss during a one-month drought. A simple water balance equation (equation 1, page 4) can be used to determine the minimum depth necessary for deep pools.

The initial deep pool into which runoff enters the wetland is called the *forebay*. The forebay has two purposes: (1) to dissipate the entering runoff's energy and (2) provide a storage zone where gross solids and sediment will settle. The forebay's size should be approximately 10 to 15 percent of the total wetland surface area. A study conducted by N.C. State in 2004 and 2005 confirmed this to be a reasonable sizing

standard. Once a forebay fills with gross solids and sediment, the collected material must be removed. This is reviewed in *Stormwater Wetland and Wet Pond Maintenance* (AGW-588-7).

Deep pools (including the forebay) should occupy between 20 and 25 percent of the total wetland surface area.

EQUATION 1

$$DP = RF_M + EF + WS/WL - ET - INF - RES$$

Where

DP = Depth of pool (inches)

RF_M = Monthly rainfall during a drought (inches)

EF = Fraction of rainfall that enters stormwater wetland from the watershed (0.20 to 0.25 estimate)

WS/WL = Ratio of watershed area to wetland surface area

ET = Monthly evapotranspiration water loss (inches)

INF = Monthly infiltration water loss (inches)

RES = Reservoir of water for a factor of safety (inches)

EXAMPLE

During July, 1.0 inch of rain fell. Of this rainfall, 20 percent entered the stormwater wetland (RF = 0.2). The watershed-to-wetland surface area ratio (WS/WL) is 20. ET losses are 8 inches — probably a conservative estimate. Exact ET losses due to stormwater wetlands have yet to be determined. (Monthly evapotranspiration loss can be found at the State Climate Office Web site, part of the N.C. ECONET monitoring network). The infiltration rate is 0.01 in/hr. The designer would like to keep 6 inches of water in reserve as a factor of safety.

Calculate the amount that will infiltrate from the wetland:

$$INF = (0.01 \text{ in/hr} \times 24 \text{ hr/d} \times 31 \text{ d}) = 7.4 \text{ in}$$

With this information, the depth of the deep pool should be:

$$DP = 1 \text{ in} \times 0.20 \times 20 - 7.4 \text{ in} - 8 \text{ in} - 6 \text{ in} = -17.4 \text{ in}$$

Therefore, the deep pool zone should be a minimum of 17 to 18 inches deeper than the normal pool level.

DEEP TO SHALLOW WATER TRANSITIONS—ZONE II

A stormwater wetland should be designed with two major internal regions: the deep pools discussed above and a shallow water zone. The average depth of each is quite different (18 to 30 inches for deep pools and 2 to 4 inches for shallow water). These deep and shallow zones should be connected with a maximum slope of 1.5:1 (1.5 horizontal feet per 1 vertical foot of elevation change). Slopes steeper than this are not recommended inside the wetland to ensure soil stability and safety.

The *transition zone* consists of the gentle slopes that connect the deep pools and shallow water. Only

a few plants can tolerate the transition zone's depth. Those that do survive enhance the wetland's effectiveness because they support both nitrification and denitrification. The transition zone tends to occupy the smallest amount of surface area in a stormwater wetland. The water depth for this zone should be between 6 and 9 inches when the wetland is at normal pool. Note that this zone incorporates *all* depths between the deep pools (18 inches) and shallow water zone (4 inches).

SHALLOW WATER—ZONE III

Shallow water zones also retain water following draw-down of the wetland after a storm event. At low flows, water entering the wetland should follow the course of the shallow water zone. During extended drought periods, shallow zones will eventually become dry. Until they dry, they form connections between deep pools that allow aquatic passage for small fish, amphibians, and invertebrates. Shallow zones are important in pollutant treatment because they are better oxygenated than deep pools and support nutrient transformations such as nitrification.

One of the most important revisions to earlier stormwater wetland design

guidance is the recommended depth of the shallow water zone. *Designing Stormwater Wetlands for Small Watersheds* (AG-588-2) specified a depth of 6 to 12 inches. Since that guidance was published in 2000, researchers have observed that most wetland plants could not tolerate water this deep for extended periods. To obtain a wider range of plant life, thus avoiding a vegetation monoculture, we now recommend average shallow water depths of 2 to 4 inches at normal pool.

One common concern among designers is the ability of shallow water plants to survive a drought. As Figure 5 shows, once established, shallow water

plants can tolerate being dry (not inundated) during drought periods. Remember that naturally occurring wetlands also become dry occasionally. In fact, wetting and drying cycles enhance a wetland's ability to treat many pollutants effectively. Even during droughts, soils in a wetland remain moist within a foot of the surface. As long as wetland plant roots can reach these moist soils, they will survive most droughts.



Figure 5. A stormwater wetland in Durham during the drought of 2002. Note the pickerelweed (a plant that usually flourishes in 3 to 6 inches of water) that is “high and dry.”

TEMPORARY INUNDATION—ZONE IV

Formerly referred to as *shallow land*, the temporary inundation zone acts as an internal floodplain. It surrounds the channel of shallow water and extends to the wetland's lower bank. It is designed for complete inundation when any storm larger than the design water-quality event occurs in the watershed. This zone has no significant standing water several days after a storm. The elevation of the ground surface is above the invert of the low-flow drawdown, to be discussed later. At normal pool, the elevation of land above the waterline will range from 0 to (nominally) 12 inches. The actual vertical extent of the temporary inundation zone depends on the depth to which the designer wishes to store the water-quality volume (see the “Water Quality Volume” sidebar).

Like the shallow water zone, the temporary inundation zone allows a variety of vegetation to be grown, giving the wetland the potential to be a diverse ecosystem. The temporary inundation zone often includes a narrow strip of land that can be termed the *lower bank*. The lower bank is the part of a bank that is inundated when the water-quality volume is captured.

WATER QUALITY VOLUME

This term, often interchangeable with the term *first flush*, is the volume of water designed to be captured so that 90 percent of the annual stormwater pollutant load can be treated. It relies on the idea that most of the pollutants delivered to a stream or estuary come from many relatively small storms. Of approximately 110 storms that pass over Raleigh-Durham Airport annually, nearly 100 of them are less than or equal to 1.0 inch. Researchers believe that on a long-term basis, capturing all the water from a 1.0 to 1.5-inch storm event would allow for 90 percent of the annual pollutant load to be treated. Note that in this case, *treated* does not mean *removed*. The North Carolina Department of Environment and Natural Resources (NCDENR) has set the water quality volume to be that generated by a 1.0-inch storm for most of the state and 1.5 inches for the 20 coastal counties (including those counties bordering the Albemarle and Pamlico Sounds).

UPPER BANK—ZONE V

The upper bank consists of the upland area surrounding the stormwater wetland. The upper bank's surface area is not included as part of the wetland surface area, but it is necessary to tie the wetland topography back into the surrounding land. A wide variety of vegetation is able to survive in this zone, provided it can grow on slopes. The upper bank should not be sloped any steeper than 3:1, especially in sandy soils. (Designers may need to exceed this maximum slope recommendation in retrofit applications.) A 3:1 slope will minimize erosion and allow a reasonable grade for maintenance, such as mowing or pruning. Precautionary stabilization measures are discussed in a companion factsheet, *Stormwater Wetland Construction Guidance* (AG-588-13).

SELECTING VEGETATION

Since the publication of AG-588-2, researchers have refined the list of plants for stormwater wetlands. Many more species of wetland vegetation can flourish in non-stormwater wetlands than in stormwater wetlands. Most previous lists of plants recommended for stormwater wetlands were based on naturally occurring or constructed wastewater treatment wetlands. Experience and research indicates that much of the previously recommended vegetation does not tolerate the extreme conditions of a stormwater wetland.

Unlike naturally occurring wetlands and wastewater treatment wetlands, stormwater wetlands have relatively dramatic and frequent changes in water surface. A stormwater wetland's water depth measured from a point in the shallow water zone can vary from 3 to 15 inches and back to 3 inches in as few as three days.

Over a long term, many plants cannot handle the periodic water fluctuation (hydroperiod) unique to stormwater wetlands. Based upon observing approximately 20 stormwater wetlands across North Carolina that are at least two years old, researchers have identified a select group of plants to be reliably able to survive in stormwater wetlands. This list has been divided into two tiers. The plants listed in Tier 1 are those that have developed extensive colonies inside observed wetlands (Table 1). These are the most dominant species within a stormwater wetland. Tier 2 plants survive and can add color to a wetland, but rarely have out-competed the plants listed as Tier 1 when establishing large colonies (Table 2). Several of the species listed

in Tables 1 and 2 are depicted in Figure 6.

Cattails (*Typha* spp.) are conspicuously absent from both lists. Despite being a native species, cattails are well adapted to develop monocultures that shelter mosquitoes from their predators. In short, if a stormwater wetland is to be located near a population center, such as a commercial center parking lot or a residential neighborhood, keep cattail populations under control. If cattails colonize more than 15 percent of a stormwater wetland located near populated areas, remove the majority — if not all — of them. When stormwater wetlands are constructed in rural areas, such as along highways in eastern North Carolina, it is reasonable to allow cattail growth. Cattails tolerate relatively high pollutant loads and propagate easily.

See the extensive discussion of why cattails are discouraged in stormwater wetlands in *Mosquito Control for Stormwater Managers* (AGW-588-4). Methods of removing cattails are described in *Stormwater Wetland and Wet Pond Maintenance* (AGW-588-7).



Table 1. Stormwater Wetland Vegetation — Tier 1. Research indicates these plants reliably colonize stormwater wetlands. They are listed in order of water tolerance, from most water tolerant to least.

Common Name	Scientific Name	Zone(s)	Comments
Fragrant water lily	<i>Nymphaea odorata</i>	I and II	Deepest fringe of Zone II only. Although this species is listed as native to North Carolina by the U. S. Department of Agriculture, some vegetation experts do not recommend its use.
Spatterdock	<i>Nuphar lutea</i>	I and II	Deepest fringe of Zone II only. Although this species is listed as native to North Carolina by the U. S. Department of Agriculture, some vegetation experts do not recommend its use.
Softstem bulrush	<i>Schoenoplectus tabernaemontani</i>	II and III	Former scientific name: <i>Scirpus validus</i>
Pickernelweed	<i>Pontedaria cordata</i>	II and III	Bright and showy purple-blue flowers
Broadleaf Arrowhead	<i>Sagittaria latifolia</i>	III	Broad leaves. White flowers in summer.
Bulltongue Arrowhead	<i>Sagittaria lancifolia</i>	III	White flowers in summer
Burreed or bur-reed	<i>Sparganium spamericanum</i>	III	Tolerates flowing water zones near inlets and outlets
Lizard's tail	<i>Saururus cernuus</i>	III and IV	Can dominate in drier years. Distinctive thin white flowers.
Woolgrass	<i>Scirpus cyperinus</i>	III and IV	Tall, brown seed heads in late summer. Makes a tall border.
Sedge	<i>Carex</i> spp.	III and IV	Many species available. Good initial colonizer.
Common rush	<i>Juncus</i> spp.	III and IV	Grows best at the water's edge. Near evergreen in the coastal plan and eastern piedmont.

Table 2. Stormwater Wetland Vegetation — Tier 2. Research indicates these plants survive often in stormwater wetlands and add color. They are listed in order of water tolerance, from the most water tolerant to the least.

Common Name	Scientific Name	Zone(s)	Comments
Water lotus (American lotus)	<i>Nelumbo lutea</i>	I, edge II	Protrudes from deep pools. Good for mountain wetlands. Some concern that this plant is too aggressive. Although this species is listed as native to North Carolina by the U. S. Department of Agriculture, some vegetation experts do not recommend its use.
Arrow arum	<i>Peltandra virginica</i>	III	Similar appearance to <i>Sagittaria</i>
Swamp milkweed	<i>Asclepias incarnata</i>	III and IV	Orange flowers in fall
Blue flag iris	<i>Iris virginica</i> or <i>versicolor</i>	III, IV edge	Showy blue (or other color) flowers in late spring. Grows at water's edge.
Cardinal flower	<i>Lobelia cardinalis</i>	IV	Red flowers in late summer
Hibiscus (rose mallow)	<i>Hibiscus moscheutos</i> and <i>H. grandiflorus</i>	IV	Showy white and red flowers in mid- to late summer
Swamp rose	<i>Rosa palustris</i>	IV	Off-white blooms in spring
Joe-pye weed	<i>Eupatorium purpureum</i>	IV and V	Purplish bloom in summer and fall

The denser the initial planting, the more quickly the vegetation will establish and the less likely invasive species of plants will dominate the stormwater wetland. For most of the species listed in Tables 1 and 2, the recommended planting density is one plant on 24-inch centers (or one plant per 4 square feet), if the stormwater wetland is to be colonized in one year. Planting herbaceous vegetation on 36-inch centers (one plant per 9 square feet) will tend to have the wetland fully colonized after two years. We do not recommend planting in densities of less than one plant per 9 square feet.

Several trees can survive in stormwater wetlands, including bald cypress (*Taxodium distichum*), river birch (*Betula nigra*), sycamore (*Platanus occidentalis*), and red maple (*Acer rubrum*). Clusters of trees should be avoided, however, due to their eventual harboring of mosquito larvae and pupae. A tree density of three to four trees per 10,000 square feet of wetland surface area is recommended. Because many trees will “volunteer” in a stormwater wetland (especially black willows, alders, and sweet gums), anyone responsible for wetland maintenance should be told which trees are desirable and which should be removed.

A large wetland may have a vegetated dam face. The dam face should be completely free of trees and shrubs, as discussed in *Stormwater Wetland and Wet Pond Maintenance* (AGW-588-7). The best vegetative cover for the dam face (and rear) is grass. If water is to flow over a grassed area at a velocity exceeding 4 feet per second, turf reinforcement matting will be needed.

A discussion of planting methods is found in *Stormwater Wetland Construction Guidance* (AG-588-13).

PROVIDING A GROWTH MEDIUM FOR WETLAND VEGETATION

As discussed earlier, it is important to avoid excessive seepage from the wetland. To prevent excessive exfiltration from wetlands, the in-situ soil is either tamped down or a clay supplement is added and tamped down into the stormwater wetland’s base soil. If this compacted soil is not amended, it is difficult for wetland plants to spread their roots through it. For that reason, we strongly recommend that a layer of topsoil be stored or brought in during construction and placed over the compacted soil in the bottom of the wetland. The suggested thickness of the topsoil layer is 3 to 6 inches, with a 4-inch minimum preferred (Figure 7).



Figure 7. Topsoil being replaced on the wetland fringe of a wet pond

Adding topsoil back to the wetland provides organic matter and an easy path for root growth during the initial stage of the stormwater wetland’s life. Recent research at N.C. State on small-scale wetlands revealed increased performance of nitrate treatment when poor soils were amended with organic matter (see Burchell et al. in the Resources section). The topsoil is especially important in the shallow water (III) and temporary inundation (IV) zones.

BYPASS OR NOT?

Sometimes when a stormwater wetland is a retrofit, not enough land is available to properly size it. In these situations, the wetland may need to have runoff bypass it rather than flow directly through it. When a substantially undersized wetland does not have a bypass, too much flow can enter the wetland, risking a “blow-out” of vegetation. A good rule of thumb is this: If the available area for a stormwater wetland is at least 67 percent of the required design surface area, the wetland should be constructed in the ephemeral channel *without* a bypass. If the available space is less than 67 percent of what is needed for a full-sized stormwater wetland, a bypass should be constructed.

OUTLET CONFIGURATION

A stormwater wetland outlet has three functions: (1) detain the water quality volume for treatment inside the wetland, (2) safely pass large events that exceed the water quality storm, and (3) allow for maintenance by lowering the pool elevation inside the wetland. *Designing Stormwater Wetlands for Small Watersheds* (AG-588-2) explains how to achieve each function. Since its publication, we have discovered

many design nuances that affect the outlet structure.

Stormwater wetlands must retain stormwater for a minimum of 48 hours. To achieve this, a drawdown hole, or orifice is used to slowly release the temporarily captured runoff. For stormwater wetlands serving watersheds of 50 acres or less, the typical orifice is quite small, with a diameter often measuring less than 2 inches, leaving it prone to clog (see AGW-588-7 for more information). Take these preventive design measures to limit the potential for clogging (Figure 8):

1. Include a trash rack around the orifice as part of all designs.
2. Draw water from lower portions of the deep pool by submerging the orifice inlet. This keeps floating debris from clogging the orifice.
3. Incorporate elements of a *flashboard riser*, a technology borrowed from controlled drainage systems in eastern North Carolina.

OFF-LINE VERSUS IN-LINE STORMWATER WETLANDS

Due to the regulatory difficulties of constructing stormwater wetlands in streams, many stormwater wetlands are constructed *off-line*. That is, water is diverted from the stream to the wetland and then released from the outlet of the wetland back to the stream. Sometimes off-line wetlands are the only possible practice from a retrofit perspective. Researchers have observed that off-line wetlands tend to be more difficult to design, and they perform more poorly than wetlands constructed in-line with an ephemeral stream.

Off-line wetlands tend to be sited in floodplains, which creates a challenge when flooding occurs. If the stream floods, it can force water to pond in the wetland for long periods of time. This is particularly true when the wetland is installed near a major river (such as the Cape Fear, Neuse, or Yadkin). When one of these rivers floods, floodwaters could inundate the stormwater wetland for weeks, killing most of the wetland vegetation.

Conversely, during dry periods when only small storms fall on a watershed, it is highly possible that too little (or no) water will enter the off-line stormwater wetland. Flow into off-line wetlands is often triggered by storms exceeding 0.50 inches. If a stormwater wetland is built in-line with a channel, any storm that produces runoff will provide water to the wetland.



Figure 8. Downturned pipe on an orifice (A) and a trash rack in place around an orifice (B)

A flashboard riser is an effective outlet (Figure 9, page 10) that has been adopted into several stormwater wetland designs in the past eight years. It is flexible. Very few pre-cast concrete structures have the appropriate flexibility. The riser functions by placing tongue and groove boards (Figure 10, page 10) on-end to form an adjustable weir. The orifice is simply drilled through one of the boards, to which a trash rack or downturn pipe (or both) can be attached.

The flashboard riser is traditionally a corrugated aluminum pipe cut in half with sleeves (channels) at either end into which the wooden boards are placed. This allows for adjustable water elevations. The type of lumber used should be an environmentally friendly marine grade. Some variations of flashboard structures employ materials other than wood (Figure 11, page 10). These materials are usually more expensive, but they may be easier to use or have a longer life. No matter the outlet type, install anti-seep collars to prevent piping.



Figure 9. An outlet employing the traditional flashboard riser



Figure 10. Small flashboard riser boards are stacked tongue-in-groove.

A schematic of a flashboard riser is found on the BAE Stormwater Engineering Group Web site: <http://www.bae.ncsu.edu/stormwater/specs.htm>.

A wetland manager can adjust the water level by adding or removing boards from the riser, or even by replacing a 2- by 6-inch board with a 2-by-4. The adjustable outlet allows a designer to compensate for potentially small (but important) grading mistakes inside the wetland. This is particularly important for the shallow water zone, which should be 2 to 4 inches deep. Being a couple of inches higher or lower than the target elevation can significantly affect the survival of desired vegetation.

When the wetland needs to be drained for maintenance purposes (for example, to plant the deep pools), a corresponding number of boards can be removed. The flashboards must be able to empty water from every wetland zone but Zone I, the deep pool zone. High flows can overtop the highest board, which acts as a weir. In short, a flashboard riser is able to meet all three functions of an outlet.

Finally, the adjustable water level concept is particularly useful during plant establishment. Research shows that less fluctuation in the water level during the initial growing season allows for a higher plant survival rate. The maximum fluctuation should be kept at 4 to 6 inches during the initial growing season, even if the outlet is designed to retain 12 inches of water during a water-quality event.



Figure 11. Adjustable outlet structures are modifications of the flashboard riser.

WETLAND DESIGN IN TROUT WATERS

Stormwater BMPs for Trout Waters (AGW-588-10), details several design guidelines associated with mountain stormwater wetlands:

Select vegetation that does not float on the water. Plants that float, such as spatterdock and fragrant water lilies, trap heat on the water's surface. The only deep pool plant that is effective in the mountains is the American lotus because it does not float. Draw water from the bottom of the deep pool adjacent to the outlet structure. This releases the coldest water in the wetland to a receiving stream, usually a trout-sensitive water.

SUMMARY

Stormwater wetlands have become one of the more common stormwater treatment practices in North Carolina because they can reduce pollutant loads. Since initial design standards were released in the late 1990s, new design guidelines have been developed that impact internal topography, wetland plant selection and establishment, and outlet configuration.

RESOURCES

RELATED FACT SHEETS in the Urban Waterways series (AG-588), North Carolina Cooperative Extension Service, N.C. State University:

Hunt, W. F. and B. A. Doll. 2000. *Designing Stormwater Wetlands for Small Watersheds* (AG-588-2). Online: <http://www.bae.ncsu.edu/stormwater/PublicationFiles/SWwetlands2000.pdf>

Hunt, W. F., C. S. Apperson, W. G. Lord, and S. G. Kennedy. 2005. *Mosquito Control for Stormwater Facilities* (AGW-588-4). Online: <http://www.bae.ncsu.edu/stormwater/PublicationFiles/Mosquitoes2005.pdf>

Hunt, W. F. and W.G. Lord. 2006. *Stormwater Wetland and Wet Pond Maintenance* (AGW-588-7). Online: <http://www.bae.ncsu.edu/stormwater/PublicationFiles/WetlandMaintenance2006.pdf>

Jones, M. P. and W. F. Hunt. 2007. *Stormwater BMPs for Trout Waters* (AGW-588-10). Online: <http://www.bae.ncsu.edu/stormwater/PublicationFiles/BMPsColdTemps2007.pdf>

Burchell, M. R., W. F. Hunt, J. D. Wright, and K. L. Bass. 2007. *Stormwater Wetland Construction Guidance* (AG-588-13). Available in May 2008.

RELATED WEB SITES

BAE Stormwater Team Web site:

<http://www.bae.ncsu.edu/stormwater>
N.C. State University's clearinghouse for stormwater BMP guidance, including design, construction, and maintenance of stormwater wetlands, bioretention, permeable pavements, water harvesting, and level spreaders.

USDA-NRCS Wetland Plant Database:

<http://plants.usda.gov>
National list of plants able to live (and not) in wetlands. Contains pictures, states whether a species is native, and provides other wetland plant details.

State Climate Office of North Carolina:

<http://www.nc-climate.ncsu.edu>
Provides climate data, such as rainfall and evapotranspiration amounts, for cities across North Carolina.

OTHER RESOURCES

Burchell, M. R., R. W. Skaggs, C. R. Lee, S. Broome, G. M. Chescheir, and J. Osborne. 2007. Substrate organic matter to improve nitrate removal in surface-flow constructed wetlands. *Journal of Environmental Quality* 36:194-207.

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