Constructed Wetland Use in Nonpoint Source Control

New BMP, September, 1997

Description

Constructed wetlands are excavated basins with irregular perimeters and undulating bottom contours into which wetland vegetation is purposely placed to enhance pollutant removal from stormwater runoff. Stormwater enters a constructed wetland through a forebay where the larger solids and course organic material settle out. The stormwater discharged from the forebay passes through emergent vegetation which acts to filter organic materials and soluble nutrients. The vegetation can also remove some dissolved nutrients. Constructed wetlands can also be designed to reduce peak stormwater flows.

The use of constructed wetlands can be looked at from two ways. First, a constructed wetland may be used primarily to maximize pollutant removal from stormwater runoff and also help to control stormwater flows. Or, it may be used primarily to control stormwater flows, with increased pollutant removal capabilities.

Secondary benefits of constructed wetland include preservation and restoration of the natural balance between surface waters and ground waters, increased wildlife habitats, and higher property values than if the same area was turned into a rectangular stormwater basin.

The following criteria dictate the feasibility of using a constructed wetland for stormwater treatment: 1) the type of wetland designed and its characteristics; 2) the hydrologic characteristics of the designed wetland; 3) the vegetation planted within the wetland (to utilize and lower nutrients and pollutants); 4) the type and volume of nutrients and pollutants entering the wetland prior to treatment; and 5) soil texture.

Note: **This BMP should never be used during the construction phase of any project or for sedimentation control.** Runoff from construction sites is typically very sediment-laden. Such runoff will choke the constructed wetland and may render it useless in a short amount of time. **Existing natural wetland systems should *never* be destroyed to construct another wetland habitat for stormwater treatment.**

Other Terms Used to Describe

Wetlands include fens, bogs, swamps and marshes.

Pollutants Controlled and Impacts

In addition to trapping sediment, nutrients and soluble pollutants may be taken up and assimilated into the plant tissues where they are held until harvesting or the annual fall die-back.

Application

Land Use

Numerous land uses can benefit from the use of created wetlands for the treatment of stormwater. Land uses include agriculture, transportation, recreational areas such as golf courses, and urban and urbanizing areas.

Soil/Topography/Climate

Soil at the site proposed for a created wetland must be suitable to allow for sufficient water retention, infiltration and wetland plant growth. For wetland vegetation, soils must be suitable, from the ground surface to below the static water level. It may be necessary to stockpile topsoil during construction and later overlay it along the wetland bottom and side slopes.

The topography of the site proposed for a created wetland must also be considered. Steep side slopes surrounding the wetland should be avoided since they will deter the growth of wetland vegetation, which in turn increases problems with harvesting and maintenance problems (which may raise potential safety concerns). Minimal excavation is preferred to reduce constructions costs and to produce a more natural looking wetland.

It is also important to know the location of the water table. This information will aid in designing areas that will have standing water.

Climate may be a factor if the wetland will receive large amounts of stormwater during the winter months. Shallow wetland zones may freeze solid in the northern temperate area, thereby decreasing the overall effectiveness of the wetland. The lack of vegetation during the winter will also lower the amount of nutrients and pollutants that can be assimilated into plant tissues. Without aquatic vegetation, the sediment may move through the wetland quickly unless the detention time is long enough for the particles to settle out. Therefore, if the wetland will receive large amounts of stormwater during freezing weather, it may be necessary to provide deep pools that will not freeze solid.

When to Apply

This BMP must not be placed into service until all other construction activities are complete and the wetland and contributing area are stabilized. Again, this prevents overloading the wetland with sediment from unstabilized areas. Wetlands should be considered permanent year-round practices.

Where to Apply

Apply in areas where nutrients and sediment are the primary pollutants of concern. Pre-treatment of toxic contaminants must be assured.

There are some locations where wetlands were historically drained for agricultural and other purposes and *may* no longer meet the scientific and legal definition of a wetland; these sites may provide an excellent opportunity for the re-establishment of wetland habitat for stormwater storage and treatment.

Relationship With Other BMPs

Depending on the quality of the stormwater to be treated by the wetland, it may be necessary to provide some pre-treatment to the water. This follows the "treatment train" concept presented in the Guidebook. It may be necessary to consider the constructed wetland as the last step in a system of BMPs. To provide pre-treatment, consider using Oil/Grit Separators or Catch Basins to remove oil and grease. The following BMPs can be used upstream of a wetland to remove sediment and other solids: Buffer/Filter Strips; Check Dams; Grassed Waterway; Sediment Basins; Extended Detention Basins and Wet Detention Basins. Refer to each BMP for its uses and limitations.

Specifications

Planning Considerations:

Determine if the site selected for the constructed wetland:

- meets the soil/topography/climate and other conditions above. Prior to seeding/planting a wetland, test the soil to determine if the soil will support wetland vegetation, or if a soil enhancement plan should be developed.

- meets the legal definition of a wetland. An existing wetland cannot be destroyed to create another wetland for nonpoint source control. The area must also not contain any threatened or endangered plant or animal species, as these will be impacted upon construction. If any of these conditions exist, the site is not appropriate for a constructed wetland BMP. A qualified wetland scientist should perform the necessary wetland delineation and plant/animal survey prior to design.

- meets sizing requirements. The total surface area of the created wetland should be a minimum of 1% of the area draining into the wetland.

Determine the need the wetland will fulfill. This may include one or more of the following: hydrologic benefits, nutrient uptake, sediment trapping. The design of the constructed wetland will differ depending on its intended use. This BMP discusses four constructed wetland designs.

The construction of a wetland may require local, state and federal permits, depending on the specific circumstances. All relevant laws should be investigated prior to plans being developed to determine the legality of constructing a wetland for stormwater treatment and to ensure that necessary permits are obtained.

Again, it may be necessary to know the location of the water table.

It is essential to establish the emergent and upland plant communities as soon as possible following construction. This should be included in the construction sequence schedule.

Design Considerations:

Several examples of constructed wetland design are shown in Exhibits 1 through 4. Throughout this document the following plant community "zones" will be used to describe constructed wetlands.

These zones are shown in Exhibit 5.

Deep Marsh	18 to 72 inches in depth.
Low Marsh	6 to 18 inches in depth.
High Marsh	0 to 6 inches in depth.
Semi-wet	0 to 24 inches above the normal water level.

Wetland Configuration:
The wetland should be irregular in shape, with a length to width ratio of at least 2:1 preferably 4:1. Inlets and outlets must be placed far apart to avoid short circuiting (in other words, inlet water going directly into the outlet without receiving the treatment of the wetland). The length to width ratio can be increased by using high marsh areas or islands to cause incoming water to meander back and forth on its way through the system. With the proper design characteristics these wetlands can have a natural appearance and still provide all the desired functions for stormwater treatment.

All constructed wetlands should contain a *forebay* at the inlet and *micropool* at the outlet. The forebay at the inlet allows for sediment and other solids to settle out of the stormwater before entering the wetland. This forebay should be located in such a way that sediment can be removed with machinery as it fills up. The micropool at the outlet allows for the collection of all the water in the system at one common point. It also provides for cooling of the water before discharge.

In some cases the “Pocket Wetland” design shown in Exhibit 4 may not lend itself to the use of a properly designed forebay. A smaller “cattail” forebay may be useful at least to trap trash and oil.

The following are guidelines for the size ratios in percent of total surface area of each plant community: Deep Marsh (Forebay) 20%-45%, Low Marsh 25%-40%, High Marsh 30%-40%, Semi-wet (the size of this area depends on the topography surrounding the wetland; steep slopes will produce less semi-wet habitat and shallow slopes will produce more semi-wet habitat). A variety of different depths must be present within the wetland to meet the growing requirements of diverse emergent wetland plants.

Surface Area:
The total surface area of the created wetland should be a minimum of 1% of the area draining into the wetland. The pollutant removal capability of the wetland is increased as the surface area to volume ratio is increased. This ratio can be increased by a) increasing the overall area of the wetland , or b) creating a complex microtopography within the wetland of various pools, shoals and islands.

Volume:
The wetland should be able to contain a treatment volume capable of capturing the runoff generated by 90% of the runoff-producing storms in the region on an annual basis. The forebay should have a minimum treatment volume of 10% of the total wetland treatment volume. The micropool should also have a minimum treatment volume of 10% of the total treatment volume.

Water Depth:
The normal water depth in the forebay and micropool areas should be 3.0 to 6.0 feet. Be sure to allow sufficient capacity for 3 to 5 years of sediment accumulation in the forebay. The depth of the

standing water for the remaining surface area, where the wetland vegetation is installed, should vary between 6 to 18 inches. The depth/area allocation of the wetland should be designed to produce the desired plant communities at maturity.

If the wetland is also used for hydraulic detention, the temporary increase in water depth above the normal water level of the wetland should be no more than 3 feet and should not occur for more than 24 hours. Some wetland vegetation cannot survive inundation for extended periods of time. A wetland specialist can provide detailed information about specific species.

Side Slopes:
Side slopes leading into the wetland should be not more than 3:1 and not less than 10:1. Shallower slopes will promote better establishment and growth of wetland plant species, and will produce a more natural wetland appearance. Shallower slopes also allow for easier mowing and maintenance activities. It is recommended to include in the design a vegetated ten-foot wide shelf, one foot deep, leading to any deeper waters (forebay and micropool) to reduce the hazard potential.

Outlets:
The wetland outlet will control the release rate from the wetland. The outlet must maintain the desired water level in the wetland and provide the desired release rate for a range of storm events. Wetlands which are designed for extended detention may need to use multiple outlets. Outlet design and flow routing through the wetland are complex procedures which should be done by licensed professional engineers. A detailed design method can be found in the "Stormwater Management Guidebook," published by the Michigan Department of Environmental Quality, Land and Water Management Division.

If an outlet pipe is used, it should be designed to draw water from one foot below the water surface. This will decrease clogging from floating vegetative material and will also draw cooler water from the bottom of the wetland.

The outlet should be designed so that trapped trash and debris can be easily removed.

An additional valved outlet should be provided to drain the wetland for maintenance.

A stabilized outlet structure must be used at the discharge of the forebay and at the outlet from the wetland. This will prevent erosion within the wetland and at the discharge point. See the <u>Stabilized Outlets</u> and <u>Riprap</u> BMPs for more detail regarding proper design.

An example outlet structure is shown in Exhibit 5 of this BMP and in the exhibits of the <u>Extended Detention Basin BMP</u>.

Emergency Spillway:
An emergency spillway must be provided to safely discharge from the wetland during storms which exceed design. A common design condition of an emergency spillway is the 50 to 100-year storm event. However, in wetland design the emergency spillway should be placed to limit the extended detention of stormwater to a maximum of 3 feet or the 50 to 100-year design storm, whichever is less.

Water Balance:
An adequate dry weather water balance for the wetland must be maintained throughout the year. This entails the measurement of the incoming base flow to the wetland as well as using soil borings to determine the elevation of the water table and soil permeability rates. This data can then be used to determine if the water inputs (runoff, precipitation, and groundwater) are greater than the water losses (discharge, infiltration, and evaporation). To maintain the water level during the dry season, it may be necessary to install a clay or plastic semi-permeable or impermeable liner. The need for a liner shall be determined by the examination of the preceding information. Some liners are discussed further in the Pond Sealing and Lining BMP (although this should not be treated as an exclusive source of information).

Vegetation:
A qualified wetland scientist should prepare the portion of the design that relates to vegetation (plant species) selection, installation, and harvesting procedures. The wetland should contain a high diversity and density of wetland plant species. The plant communities should be designed by creating a functional pondscape within and around the wetland. This planning will increase the wetland's ability to remove nutrients and pollutants and will provide habitat diversity within the created wetland.

Establishing the emergent and upland plant communities as soon as possible following construction will allow the wetland to begin stormwater treatment and will provide erosion control during the first growing season.

Periodic harvesting of the vegetation is essential in stimulating the growth of many plant species, thereby allowing them to remove more of the nutrients flowing into the wetland. Periodic harvesting also may remove accumulated nutrients and excess organic material and thereby extend the life of the constructed wetland.

Wildlife Enhancement:
Measures to further enhance habitat for wildlife are encouraged. Wildlife enhancement, however, is a secondary concern. For the purposes of this BMP, pollutant removal and hydraulic detention are the primary concern. Additional wildlife elements may be added to increase the use of the wetland by wetland-dependent animal species. This becomes even more important in areas which are predominantly urban and have lost much of their natural habitat. For example, maximizing vegetation density around the wetland will attract numerous waterfowl and other species while discouraging the entry of domestic animals that would prey on wildlife. Wildlife use should not be encouraged if toxic or harmful pollutants are expected to accumulate within the water, soil or plants.

Construction Considerations:
Wetlands contain areas of deep water and muck soils which may present a safety hazard for those persons working or playing in and around them. Depending on local regulations, wetland areas may need to be fenced during and after construction for increased safety. Special care should always be taken during the initial seeding/planting and at harvesting times to minimize potential problems.

Maintenance

A detailed maintenance plan must be developed which specifies short and long-term maintenance of the wetland. The complexity of the plan is dependent on the complexity of the design. For simple structures the plan may only need to specify how often to mow and inspect the banks, when to inspect inlet and outlet structures for signs of clogging and when to remove sediment. More complex structures with mechanical devices such as valves or pumps may require much more detail, including manufacturer's maintenance recommendations. It is a good idea to develop a checklist for maintenance items which includes the schedule for the maintenance or inspection and a date and signature for when it was completed.

The maintenance plan should include the following at a minimum:

- Specify what individual or agency is responsible for which maintenance items. If several agencies are involved each must agree to do their portion of the maintenance.
- Inspect the wetland twice a year and after major storm events. Initially, determine if it is working according to design, look for signs of eroding banks or excessive sediment deposits and insure that plant growth is occurring as expected. Routine inspections should include looking for clogged outlets, dike erosion and nuisance animals. Be sure to specify what measures to take to correct any defects.
- Determine what the maximum sediment accumulation in the forebay and micropool can be from the design. Sediment accumulation should not reduce the treatment volume to less than 10% of the total wetland treatment volume. Specify how to measure the sediment accumulation, how to remove excess sediment and where to dispose of it.
- Remove floatables and trash as necessary.
- Inspect structures such as riprap or concrete for signs of damage. Inspect and test any mechanical structures such as gates, valves or pumps.
- Mow the banks and access roads at least twice per year to prevent the growth of woody vegetation.
- Harvesting (the periodic annual or semiannual cutting and removal of wetland vegetation) is necessary to maintain the capability of the wetland to remove soluble nutrients and pollutants. Harvesting the vegetation promotes plant growth and thereby the uptake of soluble nutrients and pollutants from stormwater. A written harvesting procedure should be prepared by a qualified wetland scientist. The plan should include how to dispose of harvested material.
- Harvesting vegetation within a natural wetland is often difficult due to the topography and thick organic soils present. However, a constructed wetland can be designed in a manner that decreases harvesting and maintenance practices and associated costs.

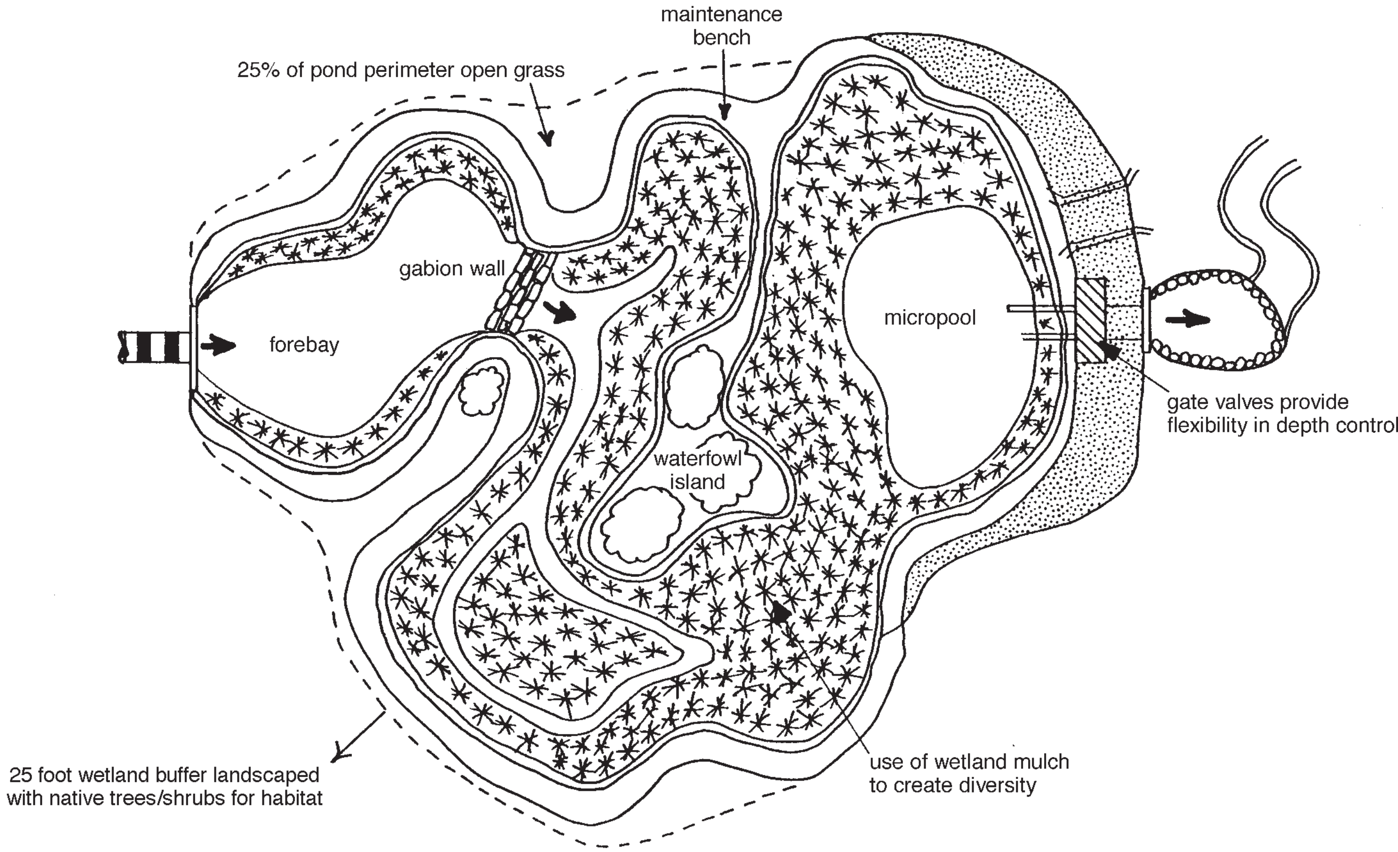
Exhibits

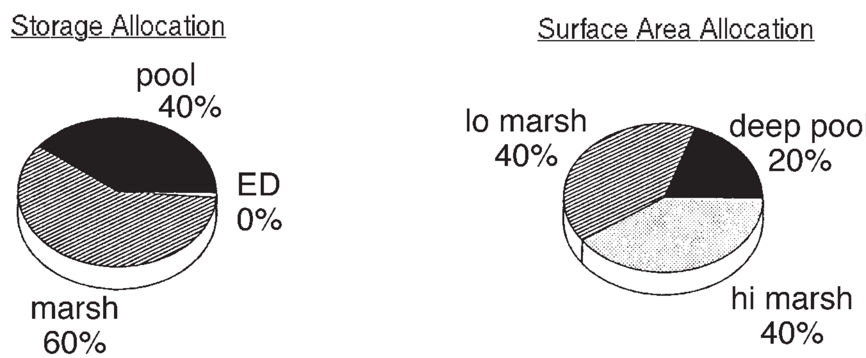
All five exhibits were taken from "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

Exhibit 1: The Shallow Marsh System
Exhibit 2: The Pond Wetland System
Exhibit 3: The Extended Detention Wetland
Exhibit 4: The Pocket Stormwater Wetland
Exhibit 5: Extended Detention Wetland Outlet Structure

Exhibit 1

The Shallow Marsh System



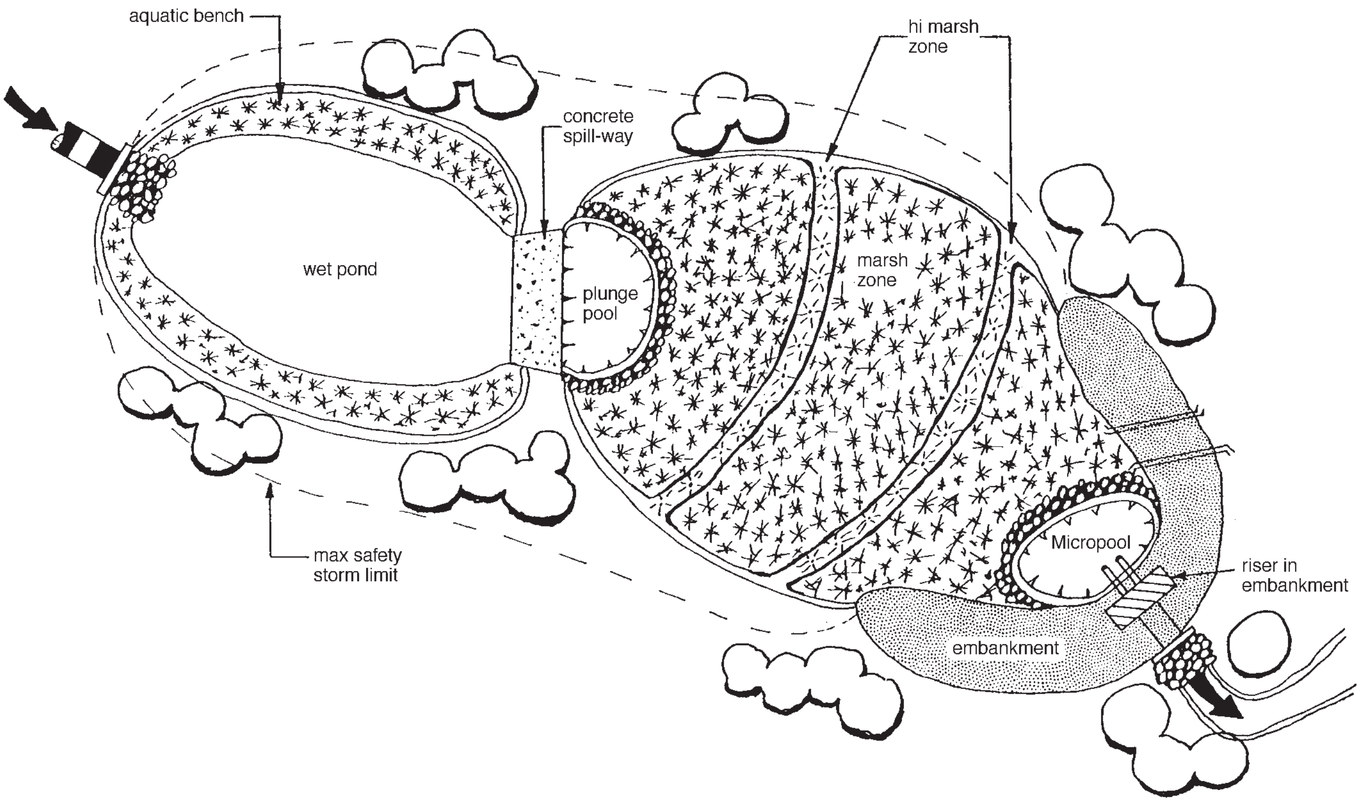


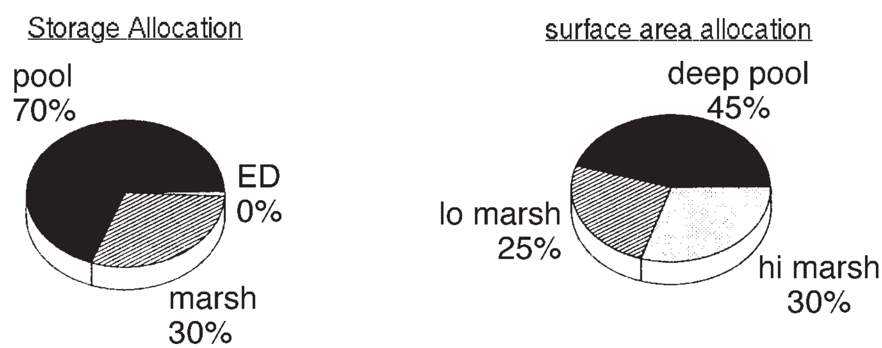
The majoriy of the shallow marsh system is zero to eighteen inches deep, which creates favorable conditions for the growth of emergent wetland plants. A deeper forebay is located at the major inlet, and a deep micropool is situated near the outlet.

Source: "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

Exhibit 2

The Pond/Wetland System



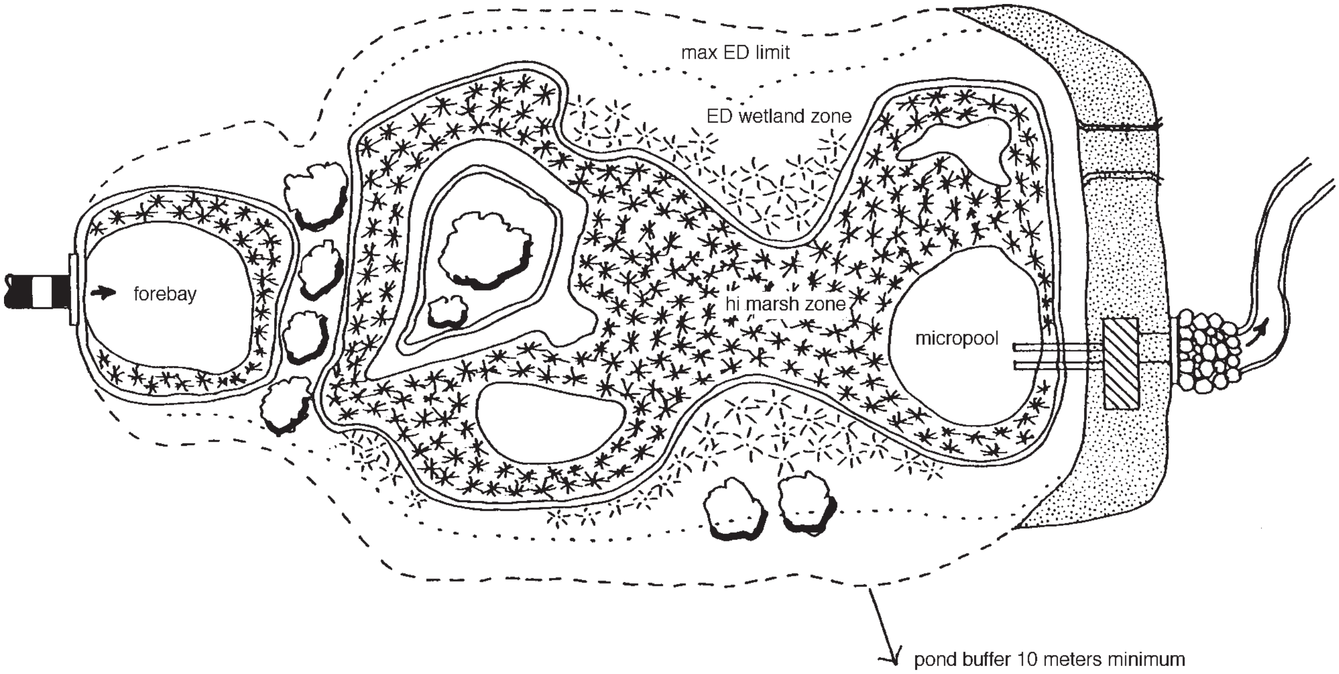


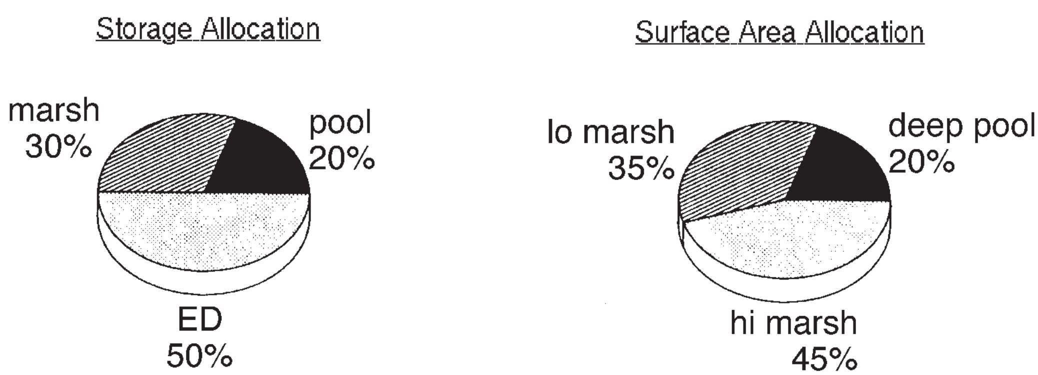
The pond/wetland system consists of two separate cells — a deep pond leading to a shallow wetland. The pond removes pollutants, and reduces the space required for the system.

Source: "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

Exhibit 3

The Extended Detention Wetland



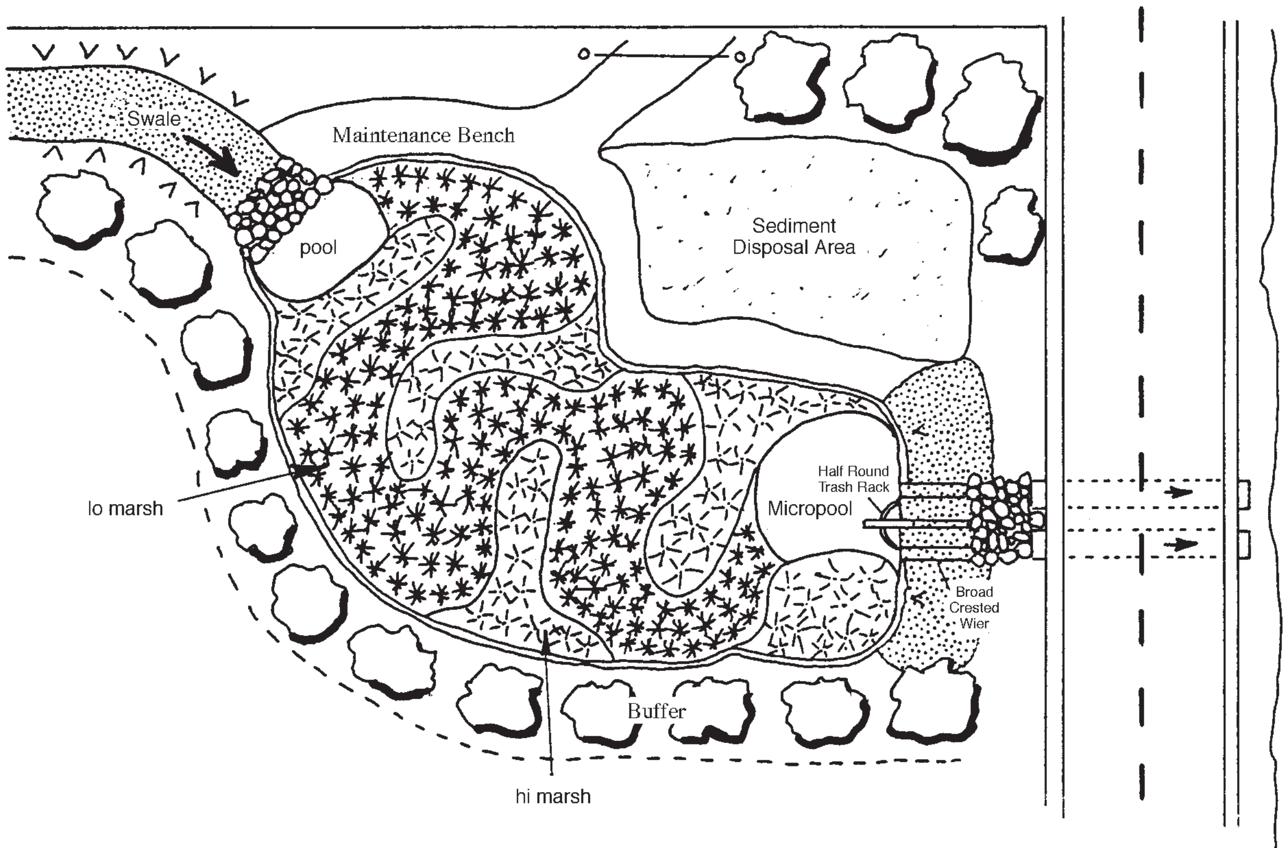


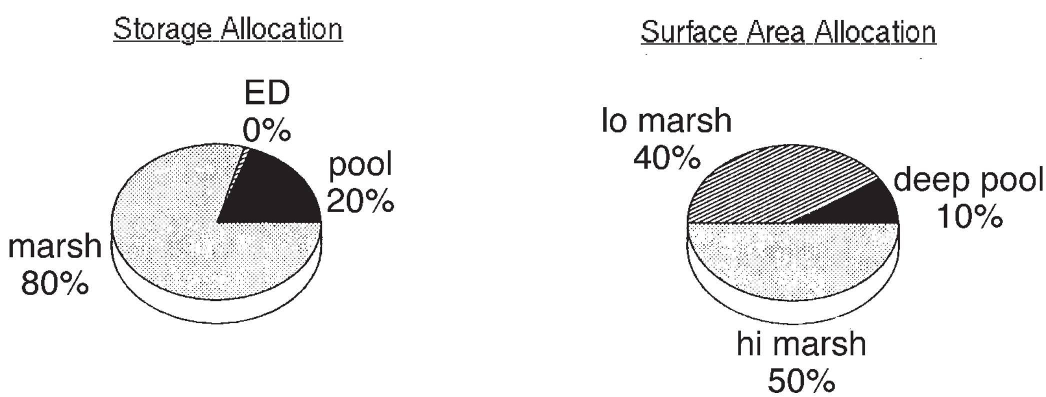
The water level within an ED wetland can increase by as much as three feet after a storm event, and then returns to normal levels within 24 hours. As much as 50% of the total treatment volume can be provided as ED storage, which helps to protect downstream channels from erosion, and reduce the wetland's space requirement.

Source: "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

Exhibit 4

The Pocket Stormwater Wetland



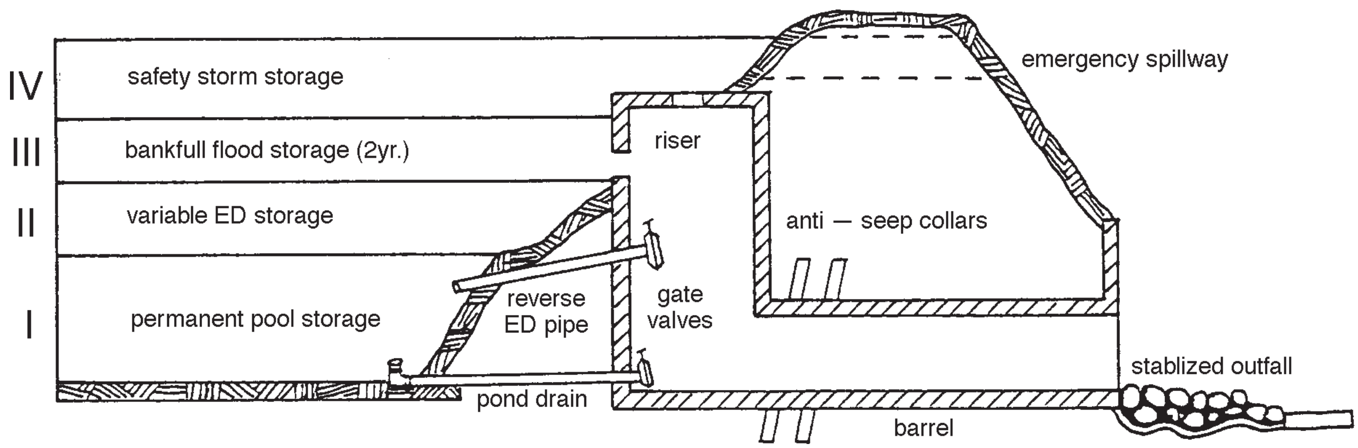


Pocket wetlands seldom are more than a tenth of an acre in size, and serve development sites of ten acres or less. Due to their size and unreliable water supply, pocket wetlands do not possess all of the benefits of other wetland designs. Most pocket wetlands have no sediment forebay. Despite many drawbacks, pocket wetlands may be an attractive BMP alternative for smaller development situations.

Source: "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.

Exhibit 5

Extended Detention Wetland Outlet Structure



The micropool of an ED wetland system is 4 to 6 feet deep, and helps protect the orifice of the reverse slope pipe extending from the riser. The pipe withdraws water within one foot of the normal pool, and is equipped with a gate valve to adjust detention times. The pond drain pipe is also equipped with a gate valve, and is used to drain the entire wetland for planting or sediment cleanout.

Source: "Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region." Anacostia Restoration Team, Department of Environmental Programs, Metropolitan Council of Governments.