Constructed Wetlands Guidance Sheet

Description

Constructed wetlands are shallow marsh systems planted with emergent vegetation that are designed to treat stormwater runoff. Stormwater wetlands often incorporate small permanent pools and/or extended detention storage to achieve the full water quality treatment volume. While they are one of the best BMPs for pollutant removal, constructed wetlands can also mitigate peak rates and even reduce runoff volume to a certain degree. They also can provide considerable aesthetic and wildlife benefits. Constructed wetlands use a relatively large amount of space and require an adequate source of inflow to maintain the permanent water surface.

Constructed wetlands and multiple pond systems treat runoff through adsorption, plant uptake, filtration, volatilization, precipitation, and microbial decomposition. (1) Multiple pond systems in particular have shown potential to provide much higher levels of treatment (2). Constructed wetlands are designed to simulate the water quality improvement functions of natural wetlands to treat and contain surface water runoff pollutants and decrease loadings. Many of these systems are currently being designed to include vegetated buffers and deep water areas to provide wildlife habitat and aesthetic enhancements. Periodic maintenance is required for these systems. Long-term effectiveness will generally depend on proper operation and maintenance of the entire system.

Constructed wetlands differ from artificial wetlands created to comply with mitigation requirements in that they do not replicate all of the ecological functions of natural wetlands. Enhanced designs may include a forebay, complex microtopography, and pondscaping with multiple species of wetland trees, shrubs, and plants. (3)

Although natural wetlands can sometimes be used to treat storm water runoff that has been properly pretreated, storm water wetlands are fundamentally different from natural wetland systems. Stormwater wetlands typically have less biodiversity than natural wetlands in terms of both plant and animal life. Several design variations of the storm water wetland exist, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland. (4)

Variations

Shallow Marsh

In the shallow marsh design, most of the wetland volume is in the relatively shallow high marsh or low marsh depths. The only deep portions of the shallow wetland design are the forebay at the inlet to the wetland and the micropool at the outlet. One disadvantage to this design is that, since the pool is very shallow, a large amount of land is typically needed to store the water quality volume (i.e., the volume of runoff to be treated in the wetland).

Extended Detention Wetland

This design is the same as the shallow marsh, with additional storage above the surface of the marsh. Storm water is temporarily ponded above the surface in the extended detention zone for between 12 and 24 hours. This design can treat a greater volume of storm water in a smaller space than the shallow wetland design. In the extended detention wetland option, plants that can tolerate wet and dry periods should be specified in the extended detention zone.

Pond/Wetland System

The pond/wetland system combines the wet pond design with a shallow marsh. Storm water runoff flows through the wet pond and into the shallow marsh. Like the extended detention wetland, this design requires less surface area than the shallow marsh because some of the volume of the practice is in the relatively deep (i.e., 6–8 feet) pond.

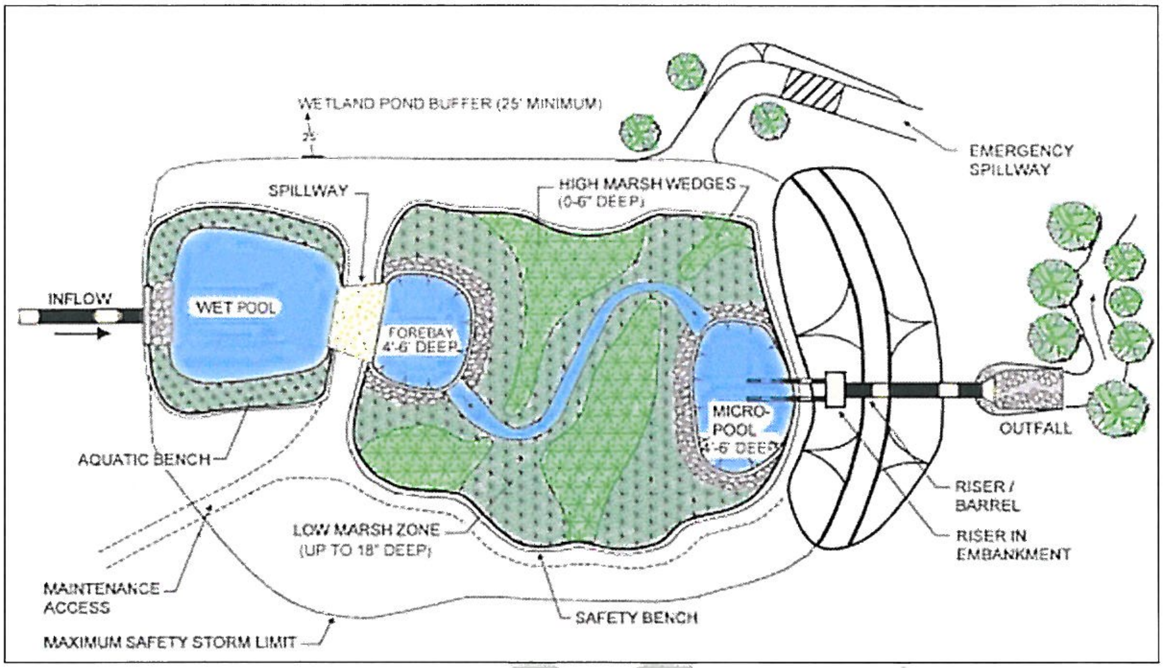

Figure X-X. Schematic of a typical constructed pond/wetland system.

Pocket Wetland

This design is very similar to the pocket pond. In this design, the bottom of the wetland intersects the ground water, which helps to maintain the permanent pool. Some evidence suggests that ground water flows may reduce the overall effectiveness of storm water management practices. (5) This option may be used when there is not significant drainage area to maintain a permanent pool.

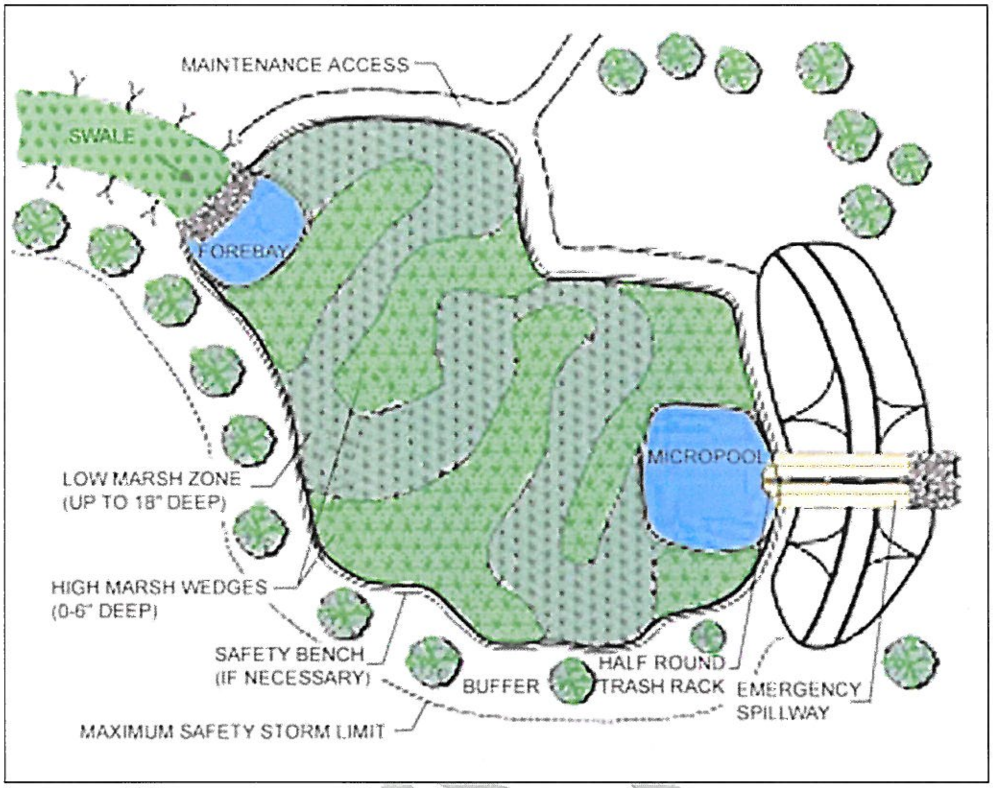

Figure X-X. Schematic of a typical pocket wetland system.

Gravel-Based Wetlands

In this design, runoff flows through a rock filter with wetland plants at the surface. Pollutants are removed through biological activity on the surface of the rocks, as well as by pollutant uptake of the plants. This practice is fundamentally different from other wetland designs because, while most wetland designs behave like wet ponds with differences in grading and landscaping, gravel-based wetlands are more similar to a filtering system. (4)

To promote greater nitrogen removal, rock beds may be used as a medium for growth of wetland plants. The rock should be one to three inches in diameter, placed up to the normal pool elevation, and open to flow-through from either direction.

Limitations

Some features of stormwater wetlands that may make the design challenging include the following:

- Each wetland consumes a relatively large amount of space, making it an impractical option on many sites.
- Improperly designed wetlands can become a breeding area for mosquitoes.
- Wetlands require careful design and planning to ensure that wetland plants are sustained after the practice is in place.
- Designers need to ensure that wetlands do not negatively impact natural wetlands or forest during the design phase. (4)

Design and Siting Criteria

Hydrology

Constructed wetlands must be able to receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability. Hydrologic calculations (or a water balance) should be performed to verify this. Shallow marshes can become dry at the surface but not for greater than one month, even in the most severe drought. A permanent water surface in the deeper areas of the wetland should be maintained during all but the driest periods. A relatively stable normal water surface elevation will reduce the stress on wetland vegetation. The wetland must have a drainage area of at least 10 acres (5 acres for "pocket" wetlands) or some means of sustaining constant inflow. Even with a large drainage area, a constant source of inflow can improve the biological health and effectiveness of a constructed wetland.

The system should be designed to bleed down one-half the applicable treatment volume specified above between 60 and 72 hours following a storm event. A methodology for sizing a structure to meet the recovery time criteria is given in Appendix X. (7)

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 should be determined by the examination of the preceding information. (8)

Hydrology is the most important variable in wetland design. If the proper hydrologic conditions are developed, chemical and biological conditions will respond accordingly. The hydrologic condition, in turn, depend on climate, seasonal patterns of streamflow and runoff, tides (for coastal wetlands), and possible groundwater influences. Improper hydrology leads to the failure of many created wetlands (9). Improper hydrologic conditions will not always correct themselves as will the more forgiving biological components of the system. Ultimately, hydrologic conditions determine wetland function. (10)

Soil

If possible, avoid soil sources that contain a seed bank of unwanted species. Carefully consider the soil's permeability and the implications for ground water protection. Highly permeable soils may allow infiltration and possible contamination of groundwater and could prevent the development of hydrological conditions suitable to support wetland vegetation. An impermeable barrier may be necessary. Dredged material may be useful to help create a base substrate layer; however you it should be tested for contaminants or unwanter materials. Matching a local dredging project's disposal need with a beneficial use solution such as creating a constructed treatment wetland is likely to be more practical, cost-effective, and environmentally advantageous when made as part of a broad, watershed-level planning effort.

Underlying soils must be identified and tested with regard to suitability. Generally, hydrologic soil groups "C" and "D" are suitable without modification. "A" and "B" soils may require a clay or synthetic liner. Soil permeability must be tested in the proposed wetland location to ensure that excessive infiltration will not cause drying. It may be necessary to install a highly- compacted subsoil or an impermeable liner to minimize infiltration.

Organic soils generally have high water holding capacities and serve as a sink for pollutants, so organic soils are desirable for constructed wetlands. These soils are also useful for facilitation of plant growth and propagation and hinder the invasive or nuisance species growth.

Sizing and Configuration

Generally, the total surface area required for a constructed wetland is generally 2-3 percent of its drainage area. The wetland should be sized to treat the water quality volume and, if necessary, to mitigate the peak rates for larger events.

- The surface area of the entire stormwater wetland shall be at least 2-3 percent of the contributing drainage area (1.5% for shallow marsh design).
- A minimum of 35% of the total surface area can have a depth of six inches or less, and at least 65% of the total surface area shall be shallower than 18 inches.
- At least 25% of the WQv shall be in deepwater zones with a depth greater than four feet.
- If extended detention is used in a stormwater wetland, provide a minimum of 50% of the WQv in permanent pool; the maximum water surface elevation of WQv-ED shall not extend more than three feet above the permanent pool.
- A forebay shall be located at the inlet, and a four to six foot deep micropool that stores approximately 10% of the WQv shall be located at the outlet to protect the low flow pipe from clogging and prevent sediment resuspension. (11)

Effective wetland design displays "complex microtopography." In other words, wetlands should have zones of both very shallow (<6 inches) and moderately shallow (<18 inches) wetlands incorporated, using underwater earth berms to create the zones. This design will provide a longer flow path through the wetland to encourage settling, and it provides two depth zones to encourage plant diversity.

Wetlands need sufficient drainage area to maintain the permanent pool. In humid regions, this is typically about 25 acres, but a greater area may be needed in regions with less rainfall.

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.

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. (8)

General

Constructed wetlands should be designed with a length to width ratio of at least 2:1 wherever possible. If the length to width ratio is lower, the flow pathway through the wetland should be maximized. Constructed wetlands should not be constructed within 10 feet of the property line or within 50 feet of a private well or septic system. Constructed wetlands should be designed so that the 10-year water surface elevation does not exceed the normal water surface elevation by more than 3 feet. Slopes in and around Constructed wetlands should be 4:1 to 5:1 (H:V) wherever possible.

Forebay/Inflow

Constructed wetlands should have a forebay at all major inflow points to capture coarse sediment, prevent excessive sediment accumulation in the remainder of the Constructed wetlands, and minimize erosion by inflow. The forebays should contain 10 to 15 percent of the total permanent pool volume and should be 4 to 6 feet deep (at least as deep as other open water areas). They should be physically separated from the rest of the wetland by a berm, gabion wall, etc. Flows exiting the forebay should be nonerosive to the newly constructed wetlands. Vegetation within forebays can increase sedimentation and reduce resuspension/erosion. The forebay bottom can be hardened to facilitate sediment removal. Forebays should be installed with permanent vertical markers that indicate sediment depth. Inflow channels should be fully stabilized. Inflow pipes can discharge to the surface or be partially submerged. Constructed wetlands should be protected from the erosive force of the inflow.

Outlet

Outlet control devices should be in open water areas 4 to 6 feet deep comprising about 5 percent of the total surface area to prevent clogging and allow the Constructed wetlands to be drained for maintenance. Outlet devices are generally multistage structures with pipes, orifices, or weirs for flow control. Orifices should be at least 2.5 inches in diameter and should be protected from clogging. Outlet devices should be installed in the embankment for accessibility. It is recommended that outlet devices enable the normal water surface to be varied. This allows the water level to be adjusted (if necessary) seasonally, as the constructed wetlands accumulates sediment over time, if desired grades are not achieved, or for mosquito control. The outlet pipe should generally be fitted with an antiseep collar. Online facilities should have an emergency spillway that can safely pass the 100-year storm with 1 foot of freeboard. All outflows should be conveyed downstream in a safe and stable manner.

Safety Benches

All areas that are deeper than 4 feet should have two safety benches, each 4 to 6 feet wide. One should be situated about 1 to 1.5 feet above the normal water elevation and the other 2 to 2.5 feet below the water surface.

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. (8)

Vegetation and Open Water Zones

About half of the emergent vegetation zone should be high marsh (up to 6" deep) and half should be low marsh (6" to 18" deep). Varying depths throughout the Constructed wetlands can improve plant diversity and health. The open water zone (approx. 35 to 40% of the total surface area) should be between 18 inches and 6 feet deep. Allowing a limited 5-foot deep area can prevent short-circuiting by encouraging mixing, enhance aeration of water, prevent resuspension, minimize thermal impacts, and limit mosquito growth. Alternating areas of emergent vegetation zone (up to 18 inches deep) and open water zone can also minimize short-circuiting and hinder mosquito propagation.
If a minimum coverage of 50% is not achieved in the planted wetland zones after the second growing season, a reinforcement planting is required. (11)

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. (8)

Vegetation selection needs to accommodate the hydraulic operations of the wetland system and still support habitat objectives. In general, use a diversity of native, locally obtained species. You should obtain seeds from a local seed bank or seedlings from a local nursery, whenever possible. Native plants from existing wetlands may be harvested provided that removal of the plants does not result in damage to the existing wetland or violate any applicable Local, State, or Federal regulations. Species should be chosen both for water quality and wildlife habitat functions, if that is the intent of the project. The use of weedy, invasive, or non-native species should be avoided. Also consider the plants' abilities to adapt to various water depths and soil and light conditions at the site. (12)

To develop a wetland that will ultimately be low maintenance, natural successional processes need to be allowed to proceed. This may mean some initial period of invasion by undesirable species, but if proper hydrologic conditions are imposed, these invasions will be temporary. The best strategy is to introduce, by seeding and planting, as many choices as possible to allow natural processes to sort out the species and communities in a timely fashion (a self-design wetland). (10)

Maintenance

Permanent access must be provided to the forebay, outlet, and embankment areas. It should be at least 9 feet wide, have a maximum slope of 15%, and be stabilized for vehicles. (13)

Table X-X. Regular maintenance activities for wetlands (Source: Adapted from WMI, 1997, and CWP, 1998)

Activity	Schedule
• Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants after the second growing season.	One-time
• Inspect for invasive vegetation and remove where possible.	Semi-annual inspection
• Inspect for damage to the embankment and inlet/outlet structures. Repair as necessary. • Note signs of hydrocarbon build-up, and deal with appropriately.	Annual inspection

• Monitor for sediment accumulation in the facility and forebay. • Examine to ensure that inlet and outlet devices are free of debris and are operational.	
• Repair undercut or eroded areas.	As needed maintenance
• Clean and remove debris from inlet and outlet structures. • Mow side slopes.	Frequent (3–4 times/year) maintenance
• Supplement wetland plants if a significant portion have not established (at least 50% of the surface area). • Harvest wetland plants that have been "choked out" by sediment build-up.	Annual maintenance (if needed)
• Remove sediment from the forebay.	5- to 7-year maintenance
• Monitor sediment accumulations, and remove sediment when the pool volume has become reduced significantly, plants are "choked" with sediment, or the wetland becomes eutrophic.	20- to 50-year maintenance

References

(1) Livingston et al., 1992

(2) Schueler, 1992

(3) SFWMD BMP Manual

(4) EPA BMP

(5) Schueler, 1997b

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