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EPA

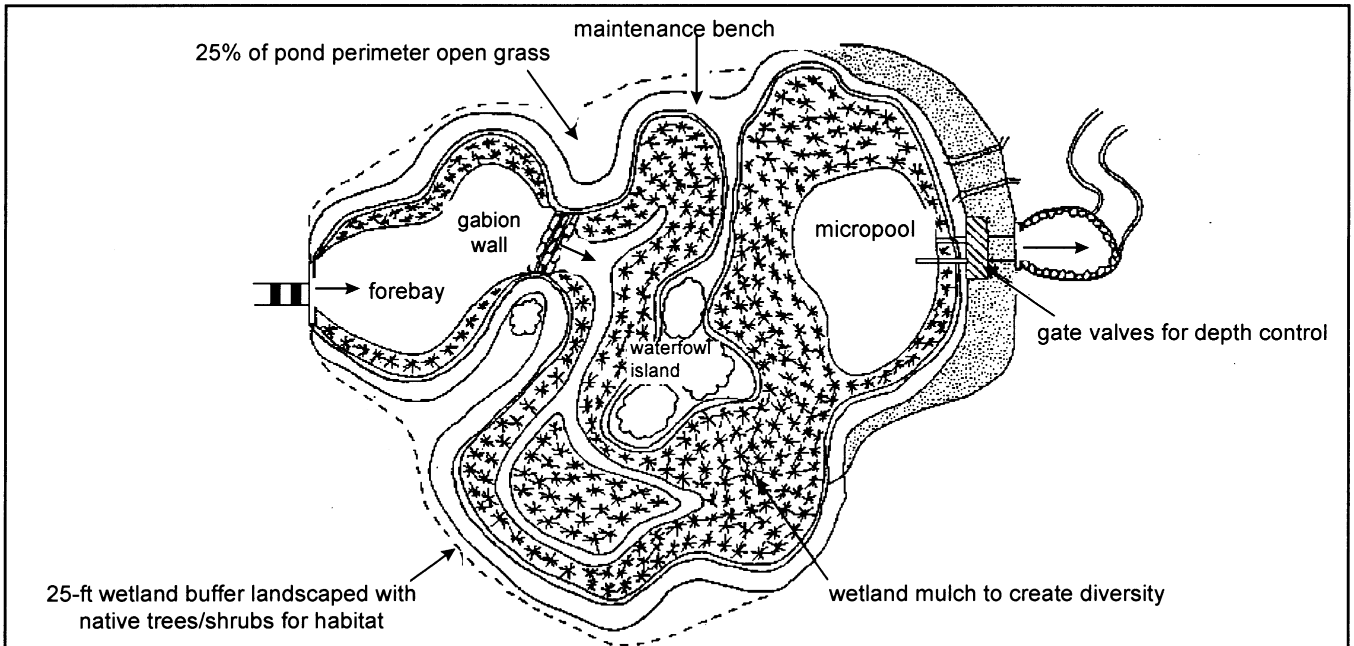
Storm Water Technology Fact Sheet
Storm Water Wetlands

DESCRIPTION

Wetlands are those areas that are typically inundated with surface or ground water and that support plants adapted to saturated soil conditions. A typical shallow marsh wetland is shown in Figure 1. Wetlands have been described as "nature's kidneys" because the physical, chemical, and biological processes that occur in wetlands break down some compounds (e.g., nitrogen-containing compounds, sulfate) and filter others (Hammer, 1989). The natural pollutant-removal capabilities of wetlands have brought them increased attention as storm water best management practices (BMPs).

Wetlands used for storm water treatment can be incidental, natural, or constructed. Incidental wetlands are those wetlands that were created as a result of previous development or human activity. The use of natural wetlands for storm water treatment is discouraged by many experts and/or public interest groups, and may not be an option in many areas. However, some states allow wetlands to be used as storm water BMPs, but only in very restricted circumstances. For example, the State of Florida allows the use of natural wetlands that have been severely degraded or wetlands that are intermittently connected to other waters (i.e., they are connected only when groundwater rises above ground level) (Livingston, 1994). Conversion of natural wetlands to storm water wetlands is done on a case-by-case basis and requires the appropriate state and federal permits (e.g., 401 water quality certification and 404 wetland permit).

Two types of constructed wetlands have been used



Source: MWCOG, 1992a.

FIGURE 1 SHALLOW MARSH WETLAND

successfully for wastewater treatment: the subsurface flow (SF) constructed wetland and the free water surface (FWS) constructed wetland. In the FWS wetland, runoff flows through the soil-lined basin at shallow depths. The wetland consists of a shallow pool planted with emergent vegetation (vegetation which is rooted in the sediment but with leaves at or above the water surface).

In contrast to the FWS wetland, the SF wetland basin is lined with a pre-designed amount of rock or gravel, through which the runoff is conveyed. The water level in an SF wetland remains below the top of the rock or gravel bed. Studies have indicated that the SF wetland is well suited for the diurnal flow pattern of wastewater; however, the peak flows from storm water or combined sewer overflows (CSOs) may be several orders of magnitude higher than the baseflow. The cost for a gravel bed to contain the peak storm event would be very high, which may preclude the use of SF wetlands for storm water or CSO treatment. Therefore, the remainder of this fact sheet addresses the FWS constructed wetland or natural and incidental wetlands for use in storm water applications.

There are four basic designs of FWS constructed wetlands: shallow marsh, extended detention wetland, pond/wetland system, and pocket wetland. As shown in Figure 2, these wetlands store runoff in a shallow basin vegetated with wetland plants. The selection of one design over another will depend on various factors, including land availability, level and reliability of pollutant removal, and size of the contributing drainage area.

The shallow marsh design requires the most land and a sufficient baseflow to maintain water within the wetlands. The basic shallow marsh design can be modified to store extra water above the normal pool elevation. This wetland, known as an extended detention wetland, attenuates flows and relieves downstream flooding.

The pond/wetland system has two separate cells: a wet pond and a shallow marsh. The wet pond traps sediments and reduces runoff velocities prior to entry into the wetland. Less land is required for a pond/wetland system than for the shallow marsh system.

Still less land is required for a pocket wetland. Pocket wetlands should be designed with contributing drainage areas of 0.4 to 4 hectares (1 to 10 acres) and usually require excavation down to the water table for a reliable water source. Unreliable water sources and fluctuating water levels result in low plant diversity and poor wildlife habitat value (MWCOG, 1992b).

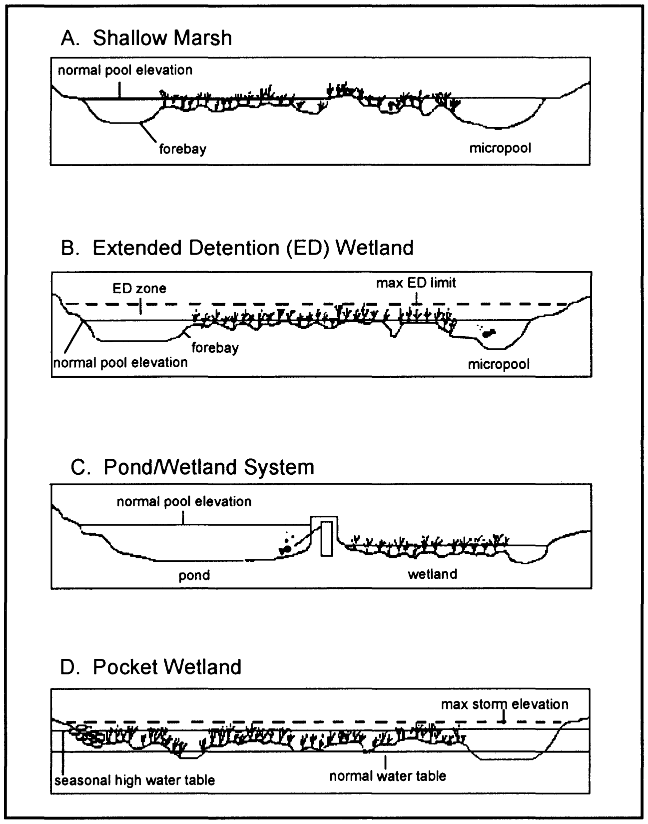


FIGURE 2 COMPARATIVE PROFILES OF FOUR STORM WATER WETLAND DESIGNS

Cross-sectional profiles of the four storm water wetlands not drawn to scale. In Panel A, most of the shallow marsh is shallow, supporting emergent wetland plants. In extended detention wetlands (Panel B), the runoff storage of the wetland is augmented by temporary, vertical extended detention storage. The pond/wetland system (Panel C) is composed of a deep and a shallow pool. Pocket wetlands (Panel D) are excavated to the groundwater table to keep water elevation more consistent.

Source: MWCOG, 1992b.

APPLICABILITY

Wetlands improve the quality of storm water runoff, and can also control runoff volume (e.g., extended detention wetland). Wetlands are one of the more reliable BMPs for removing pollutants and are adaptable to most locations in the U.S. Locations with existing wetlands used for storm water treatment include Alabama, California, Colorado, Florida, Illinois, Maine, Maryland, Michigan, Minnesota, Virginia, and Washington. Wetlands have been used to treat runoff from agricultural, commercial, industrial, and residential areas.

In the past, the natural ability of wetlands to remove pollutants from water has primarily been harnessed to treat wastewater. However, the utilization of wetlands to treat storm water has gained attention in recent years, and many storm water wetlands treatment systems are now operational. Ongoing evaluations are being conducted to determine the effectiveness of wetlands in pollutant removal and to determine the level of maintenance required to sustain their performance, while other studies are evaluating the potential for design modifications to improve wetland performance.

ADVANTAGES AND DISADVANTAGES

Environmental benefits associated with storm water wetlands include improvements in downstream water and habitat quality, enhancement of diverse vegetation and wildlife habitat in urban areas, and flood attenuation. Downstream water quality is improved by the partial removal of suspended solids, metals, nutrients, and organics from urban runoff. Habitat quality is also improved as reduced sediment loads are carried downstream and the erosion of stream banks associated with peak storm water flows is reduced. Wetlands can support a diverse wildlife population, including species such as sandpipers and herons, and can attenuate runoff and alleviate downstream flooding (particularly extended detention wetlands).

Storm water wetlands can cause adverse environmental impacts upstream of the wetland, within the wetland itself, and downstream of the wetland. Storm water wetlands located in a large watershed (larger than 40 hectares (100 acres)) may degrade upstream headwaters, which receive no effective hydrologic control (MWCOG, 1992b). The wetland designer can incorporate upstream modifications to relieve this negative impact.

Possible adverse effects within the wetland itself are the potential for blocking fish passage, potential habitation by undesirable species, and potential groundwater contamination. A wetland constructed in the stream channel may block fish access to part of the stream, thereby decreasing fish diversity in the stream.

Geese and mallards may become undesirable year-round residents of the wetland if structural complexity is not included in the wetland design (i.e., features that limit deep and open water areas and open grassy areas that are favored by these birds). These animals will increase the nutrient and coliform loadings to the wetland and may also become a nuisance to local residents. The takeover of vegetation by invasive nuisance plants is also a potential negative impact. Invasive species pose a threat to native species and may adversely affect the wetland's ability to treat storm water. Maintaining and/or planting upland buffer zones can help to reduce the introduction of nuisance plant species. Planting emergent vegetation may also reduce nuisance algal blooms (Carr, 1995).

The issue of groundwater contamination resulting from the migration of polluted sediments to the groundwater has been considered a potential negative environmental impact. However, studies indicate that there is little risk of groundwater contamination (MWCOG, 1992b).

A storm water wetland can act as a heat sink, especially during the summer, and can discharge warmer waters to downstream water bodies. The increased temperatures can affect sensitive fish species (such as trout and sculpins) and aquatic insects downstream. Therefore, it is not recommended to construct storm wetlands upstream of temperature-sensitive fish populations. Regardless of the sensitivity of downstream species, the designer should always take precautions to reduce the potential warming effects of wetlands construction.

Communities may be opposed to a wetland for fear of mosquitoes and other nuisances, or because of wetlands' appearance. However, wetlands can be designed attractively and features (e.g., fish and vegetation) can be adapted to control mosquitoes and other nuisances. The use of *Gambusia* fish for mosquito control has become a common practice in warmer climates, while colder climates use the black striped topminnow (*Notrophus fundulus*) (U.S. EPA, 1995). To minimize the protection from predators offered by taller plants, the use of low growing plants is recommended where pests are a concern (U.S. EPA, 1996).

Wetlands may remove pollutants less effectively during the non-growing season and in localities with lower temperatures. Decreases in some pollutant-removal efficiencies have been observed when wetlands are covered with ice and when they receive snow melt runoff.

Finally, because of the large land requirement for storm water wetlands systems (See **Design Criteria**), their use may be precluded in urban settings and established communities.

Several possible remedies to these impacts are discussed in the publication *Design of Storm Water Wetland Systems* (MWCOG, 1992).

DESIGN CRITERIA

Local, state and federal permit requirements should be determined prior to wetland design. Required permits and certifications may include 401 water quality certifications, 402 storm water National Pollutant Discharge Elimination System (NPDES) permits, 404 wetland permits, dam safety permits, sediment and erosion control plans, waterway disturbance permits, forest-clearing permits, local grading permits, and land use approvals.

A site appropriate for a wetland must have an adequate water flow and appropriate underlying soils. The baseflow from the drainage area or groundwater must be sufficient to maintain a shallow pool in the wetland and support the wetlands' vegetation, including species susceptible to damage during dry periods. Underlying soils that are type B , C, or R (zone of accumulation, partially altered parent material and unaltered parent material, respectively) will have only small infiltration losses. Sites with type A soils (soils rich in organic matter) may have high infiltration rates. These sites may require geotextile liners or a 15 centimeter (6 inch) layer of clay. After any necessary excavation and grading of the wetland, at least 10 centimeters (4 inches) of soil should be applied to the site. This material, which may be the previously-excavated soil or sand and other suitable material, is needed to provide a substrate in which the vegetation can become established and to which it can become anchored. The substrate should be soft so that plants can be inserted easily.

The Metropolitan Washington Council of Governments (MWCOG, 1992b) has recommended basic sizing criteria for wetland design. The volume of the wetland is determined as the quantity of runoff generated by 90 percent of the runoff-producing storms. This volume will vary throughout the U.S. due to different rainstorm patterns. In the Mid-Atlantic Region, for example, a 1.25-inch storm is used as the sizing criterion.

Watershed imperviousness will also impact the runoff volume generated from a storm. The following equations are used to determine the treatment volume (Vt):

(1) $Rv = 0.05 + 0.009 (I)$

where:

Rv = storm runoff coefficient

I = % (as decimal) site imperviousness

(2) $Vt = [(1.25)(Rv)(A)/12](43{,}560)$

where:

Vt = treatment volume (cubic feet)

A = contributing area (acres)

Sizing criteria for wetlands vary, with some states having their own methods. For example, shallow wetland basins constructed in Maryland are designed to maximize basin surface area. The surface area should be a minimum of 3 percent of the area of the watershed draining to it. Maryland recommends designing for extended detention, using 24-hour detention of the 1-year storm for design purposes. In contrast, the Washington State Department of Ecology sizes wetlands using the runoff generated from the 6-month, 24-hour rainfall event. The minimum surface area established by MWCOG for shallow marshes is 2 percent of the wetland area. The remaining three wetland designs should have wetland to watershed ratios greater than 1 percent.

TABLE 1 GUIDELINES FOR ALLOCATING WETLAND SURFACE AREA AND TREATMENT VOLUME

Target Allocations	Shallow Marsh	Extended Detention Wetland	Pond/Wetland	Pocket Wetland
Percent of Wetland Surface Area				
Forebay	5	5	0	0
Micropool	5	5	5	0
Deepwater	5	0	40	5
Low Marsh	40	40	25	50
High Marsh	40	40	25	40
Semi-Wet	5	10	5	5
Percent of Treatment Volume				
Forebay	10	10	0	0
Micropool	10	10	10	0
Deepwater	10	0	60	20
Low Marsh	45	20	20	55
High Marsh	25	10	10	25
Semi-Wet	0	50	0	0

Depth:
Deepwater - 0.5 - 2 meters (1.5 to 6 feet) below normal pool level
Low Marsh - 0.17- 0.5 meters (0.5 to 1.5 feet) below normal pool level
High Marsh -0.5 feet below normal pool level
Semi-Wet - 0 to 2 feet above normal pool level (includes Extended Detention)

Source: Modified from MWCOG, 1992b.

MWCOG has also established criteria for water balance, maximum flow path, allocation of treatment volume, minimum surface area, allocation of the surface area, and extended detention. As previously discussed, during dry weather, flow must be adequate to provide a baseflow and to maintain the vegetation. The flow path should be maximized to increase the runoff's contact time with plants and sediments. The recommended minimum length to width ratio of the wetland is 2:1. If a ratio of less than 2:1 is necessary, the use of baffles, islands, and peninsulas can minimize short circuiting (allowing runoff to escape treatment) by ensuring a long distance from inlet to outlet.

A suggestion for allocating treatment volumes is shown in Table 1. The wetland surface area is allocated to four different depth zones: deepwater (0.5 to 2 meters, or 1.5 to 6 feet, below normal pool), low marsh (0.17 to 0.5 meters, or 0.5 to 1.5 feet, below normal pool), high marsh (up to 0.17 meters, or 0.5 feet, below normal pool), and semi-wet areas (above normal pool). The allocation to the various depth zones will create a complex internal topography that will maximize plant diversity and increase pollutant removal. The State of Maryland requires that 50 percent of the shallow marsh be less than 0.17 meters (0.5 feet) deep, that 25 percent range from 0.17 to 0.33 meters (0.5 feet to 1 foot) deep, and that the remaining 25 percent range from 0.67 to 1 meter (2 to 3 feet) deep.

Extending detention within the wetland increases the time for sedimentation and other pollutant-removal processes to occur and also provides for attenuation of flows. Up to 50 percent extra treatment volume can be added into the wetland system for extended detention. However, to prevent large fluctuations in the water level that could potentially harm the vegetation, Extended Detention elevation should be limited to 11 meters (33 feet) above the normal pool elevation. The Extended Detention volume should be detained between 12 and 24 hours.

Sediment forebays are recommended to decrease the velocity and sediment loading to the wetland. The forebays provide the additional benefits of creating sheet flow, extending the flow path, and preventing short circuiting. The forebay should contain at least 10 percent of the wetland's treatment volume and should be 2 to 3 meters (4 to 6 feet) deep. The State of Maryland recommends a depth of at least 1 meter (3 feet). The forebay is typically separated from the wetland by gabions or by an earthen berm (MWCOG, 1992b).

Flow from the wetland should be conveyed through an outlet structure that is located within the deeper areas of the wetland. Discharging from the deeper areas using a reverse slope pipe prevents the outlet from becoming clogged. A micropool just prior to the outlet will also prevent outlet clogging. The micropool should contain approximately 10 percent of the treatment volume and be 2 to 3 meters (4 to 6 feet) deep. An adjustable gate-controlled drain capable of dewatering the wetland within 24 hours should be located within the micropool. A typical drain may be constructed with an upward-facing inverted elbow with its opening above the accumulated sediment. The dewatering feature eases planting and follow-up maintenance (MWCOG, 1992b).

Vegetation can be established by any of five methods: mulching; allowing volunteer vegetation to become established; planting nursery vegetation; planting underground dormant parts of a plant; and seeding. Donor soils from existing wetlands can be used to establish vegetation within a wetland. This technique, known as mulching, has the advantage of quickly establishing a diverse wetland community. However, with mulching, the types of species that grow within the wetland are unpredictable.

Allowing species transmitted by wind and waterfowl to voluntarily become established in the wetland is also unpredictable. Volunteer species are usually well established within 3 to 5 years. Wetlands established with volunteers are usually characterized by low plant diversity with monotypic stands of exotic or invasive species. A higher-diversity wetland can be established when nursery plants or dormant rhizomes are planted. Vegetation from a nursery should be planted during the growing season - not during late summer or fall - to allow vegetation time to store food reserves for their dormant period. Separate underground parts of vegetation are planted during the plants' dormant period, usually October through April, but the months will vary with local climate. Another planting technique, the spreading of seeds, has not been very successful and therefore is not widely practiced as a principal planting technique.

Appropriate plant types vary with locations and climate. The wetland designer should select five to seven plants native to the area and design the depth zones in the wetland to be appropriate for the type of plant and its associated maximum water depth. Approximately half of the wetland should be planted. Of the five to seven species selected, three should be aggressive plants or those that become established quickly. Examples of aggressive species used in the Mid-Atlantic Region include softstem bulrush (*Scirpus validus*) and common three-square (*Scirpus americanus*). Aggressive plants as well as other native wetland plants are available from numerous nurseries. Most vendors require an advance order of 3 to 6 months.

After excavation and grading the wetland should be kept flooded until planting. Six to nine months after being flooded and two weeks before planting, the wetland is typically drained and surveyed to ensure that depth zones are appropriate for plant growth. Revisions may be necessary to account for any changes in depth. Next, the site is staked to ensure that the planting crew spaces the plants within the correct planting zone. Species are planted in separate zones to avoid competition. The State of Maryland recommends planting two aggressive or primary species in four specific areas and planting an additional 40 clumps (one or more individuals of a single species) per acre of each primary species over the rest of the wetland. Three secondary species are planted close to the edge of the wetland at an application rate of 10 clumps of 5 individual plants per acre of wetland, for a total of 50 individuals of each secondary species per acre of wetland. At least 48 hours prior to planting, the wetland should be drained; within 24 hours after planting, it should be re-flooded.

The wetland design should include a buffer to separate the wetland from surrounding land. Buffers may alleviate some potential wetland nuisances, such as accumulated floatables or odors. MWCOG recommends a buffer of 8 meters (25 feet) from the maximum water surface elevation, plus an additional 8 meters (25 feet) when wildlife habitat is of concern. Leaving trees undisturbed in the buffer zone will minimize the disruption to wildlife and reduce the chance for invasion of nuisance vegetation such as cattails and primrose willow. If tree removal is necessary, the buffer area should be reforested. Reforestation also discourages the settlement of geese, which prefer open areas.

PERFORMANCE

Wetlands remove pollutants from storm water through physical, chemical, and biological processes. Chemical and physical assimilation mechanisms include sedimentation, adsorption, filtration, and volatilization.

Sedimentation is the primary removal mechanism for pollutants such as suspended solids, particulate nitrogen, and heavy metals. Particulate settling is influenced by the velocity of the runoff through the wetland, the particle size, and turbulence. Sedimentation can be maximized by creating sheet flow conditions, slowing the velocities through the wetland, and providing morphology and vegetation conducive to settling. The vegetation and its root system will also decrease the resuspension of settled particles.

Some pollutants, including metals, phosphorus, and some hydrocarbons, are removed by adsorption- the process whereby pollutants attach to surfaces of suspended or settled sediments and vegetation. For this removal process to occur, adequate contact time between the surface and pollutant must be provided in the design of the system.

Wetland plants filter trash, debris, and other floatables. Particulates (e.g., settleable solids and colloidal solids) are also filtered mechanically as water passes through root masses. Filtration can be enhanced by slow velocities, sheet flow, and sufficient quantities of vegetation. By increasing detention and contact time and providing a surface for microbial growth, wetland plants also increase the pollutant removal achieved through sedimentation, adsorption, and microbial activity.

Volatilization plays a minor role in pollutant removal from wetlands. Pollutants such as oils and hydrocarbons can be removed from the wetland via evaporation or by aerosol formation under windy conditions.

Biological processes that occur in wetlands result in pollutant uptake by wetland plants and algae. Emergent wetland plants absorb settled nutrients and metals through their roots, creating new sites in the sediment for pollutant adsorption. During the fall the plants' above-ground parts typically die back and the plants may potentially release the nutrients and metals back into the water column (MWCOG, 1992b). Recent studies, however, indicate that most pollutants are stored in the roots of aquatic plants, rather than the stems and leaves (CWP, 1995). Additional studies are required to determine the extent of pollutant release during the fall die-back.

Microbial activity helps to remove nitrogen and organic matter from wetlands. Nitrogen is removed by nitrifying and denitrifying bacteria; aerobic bacteria are responsible for the decomposition of the organic matter. Microbial processes require oxygen and can deplete oxygen levels in the top layer of wetland sediments. The low oxygen levels and the decomposed organic matter help immobilize metals.

Soluble forms of phosphorus, as well as ammonia, are partially removed by planktonic or benthic algae. The algae consume the nutrients and convert them into biomass, which settles to the bottom of the wetland.

The removal effectiveness of shallow marsh and pond/wetland systems has been fairly well documented, while the amount of removal efficiency data for Extended Detention wetlands and pocket wetlands is limited. Average long-term pollutant removal rates for constructed wetlands, as a whole, are presented in Table 2 (CWP, 1997).

TABLE 2 PERFORMANCE OF STORM WATER WETLANDS

Pollutant	Removal Rate
Total Suspended Solids	67%
Total Phosphorus	49%
Total Nitrogen	28%
Organic Carbon	34%
Petroleum Hydrocarbons	87%
Cadmium	36%
Copper	41%
Lead	62%
Zinc	45%
Bacteria	77%

Source: CWP, 1997.

As shown, petroleum hydrocarbons (87%), total suspended solids (TSS) (67%), lead (62%), and bacteria (77%) have the highest removal rates. Lower removal rates have been documented for nutrients, organic carbon, and other heavy metals. The removal rates will vary with the loadings to the wetland, retention time in the BMP, and other factors such as BMP geometry, site characteristics, and monitoring methodology (CWP, 1997). Excessive pollutant loadings (e.g., suspended solids) may exceed the wetlands' removal capabilities.

In general, wetlands remove pollutants about as effectively as do conventional pond systems. Constructed storm water wetlands are more effective than natural wetlands, probably because of their intricate design and continued monitoring and maintenance (MWCOG, 1992). The wetlands' effectiveness seems to improve after the first few years of use as the vegetation becomes established and organic matter accumulates.

OPERATION AND MAINTENANCE

Well-designed and maintained wetlands can function as designed for 20 years or longer. However, wetland maintenance must actually begin during the construction phase. During construction and excavation, many constructed wetlands lose organic matter in the soils. The organic matter provides exchange sites for pollutants, and, therefore, plays an important role in pollutant removal. Replacing or adding organic matter after construction improves performance.

After the wetland has been constructed, its vegetation must be maintained on a regular basis. Maintenance requirements for constructed wetlands are particularly high while vegetation is being established (usually the first three years) (U.S. EPA, 1996). Monitoring during these first years is crucial to the future success of the wetland as a storm water BMP. Inspections should be conducted at least twice per year for the first three years and annually thereafter. Maintenance requirements may also include replacement planting, sediment removal, and possibly plant harvesting. Wetland design should include access to facilitate these maintenance activities.

Vegetative cover on embankments and spillways should be dense and healthy. Replacement planting may be required during the first several years if the original plants do not flourish. First year wetland vegetation growth at the water's edge and on the side slopes of the wetland can be protected from birds by surrounding the open water area of the wetland with wire to limit access to the vegetation. The embankment and maintenance bench should be mowed twice each year. Other areas surrounding the wetland should not require mowing. Mowing and fertilizing help promote vigorous growth of plant roots that resist erosion. Mowing also prevents the growth of unwanted woody vegetation. Additional routine maintenance that can be conducted on the same schedule should include removal of accumulated trash from trash racks, outlet structures, and valves, as well as debris on plants that could inhibit growth.

Constructed wetlands should be inspected after major storms during the first year of establishment. The inspector should assess bank stability, erosion damage, flow channelization, and sediment accumulation within the wetland. The inspector shall also take note of species distribution/survival, damage to embankments and spillways from burrowing animals, water elevations, and outlet condition. Water elevations can be raised or lowered by adjusting the outlet's gate valve if plants are not receiving an appropriate water supply.

Accumulated sediments will gradually decrease wetland storage and performance. There are two options to mitigate the effects of accumulated sediments: either the sediments should be removed as necessary or the water level in the wetland should be raised (i.e., the outlet should be adjusted to increase discharge elevation).

The construction of a sediment forebay will decrease the accumulation of sediments within the wetland and increase the wetland's longevity. The forebay will likely require sediment to be cleaned out every three to five years. The forebay design should allow drainage so that a skid loader or backhoe can be used to remove the accumulated deposits (MWCOG, 1992). Accumulation of organic matter can be reduced by plant harvesting or seasonal drawdown to allow organic material to oxidize (U.S. EPA, 1996).

A number of studies have been performed to determine the toxicity of pond sediments and whether they can be landfilled or land applied without having to meet hazardous waste requirements. Many studies to date have found sediments are not hazardous. However, one study showed that toxic levels of zinc had accumulated in sediment from the pretreatment pond (SFWMD, 1995). If toxic levels of metals have not accumulated in the sediment, then on-site land application of the sediments away from the shoreline will probably be the most cost-effective disposal method (no transportation costs or disposal fees are incurred). Wetlands that receive flow from a drainage area containing commercial or industrial land use and/or activities associated with hazardous waste may contain toxic levels of heavy metals in the sediments. Testing may be required for these sediments prior to land application or disposal.

COSTS

Costs incurred for storm water wetlands include those for permitting, design, construction and maintenance. Permitting costs vary depending on state and local regulations, but permitting, design, and contingency costs are estimated at 25 percent of the construction cost. Construction costs for an emergent wetland with a sediment forebay range from $65,000 to $137,500 per hectare ($26,000 to $55,000 per acre) of wetland. This includes costs for clearing and grubbing, erosion and sediment control, excavating, grading, staking, and planting. The cost for constructing the wetland depends largely upon the amount of excavation required at a site and plant selection. The cost for forested wetlands could be double that of an emergent wetland. Maintenance costs for wetlands are estimated at 2 percent per year of the construction costs (CWP, 1998).

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