Design Features of Constructed Wetlands for Nonpoint Source Treatment

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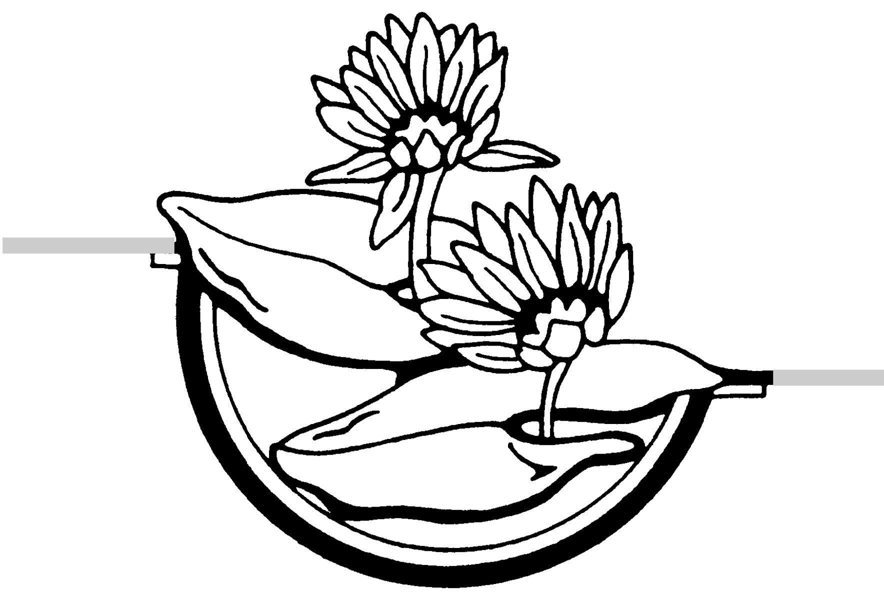

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What is a constructed wetland?

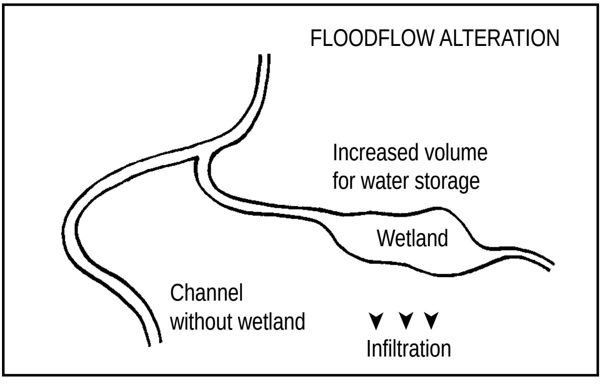
Wetlands have been constructed to treat a variety of liquid wastes including secondary wastewater treatment facility effluent, mine wastes, septic system effluent, stormwater, and nonpoint source (NPS) pollution. This may involve restoring previously drained wetlands or constructing new wetlands in appropriate areas. This brochure provides guidance on the use of **constructed wetlands** to treat nonpoint sources such as excess runoff, eroded soil, and nutrients.

A word of caution is necessary—**natural wetlands** should not be used to treat NPS pollution without first obtaining necessary permits and conducting a thorough environmental assessment to insure that the wetland can support the necessary treatment without becoming degraded. Likewise, using wetlands for treating toxic wastes is not recommended without extensive evaluation.

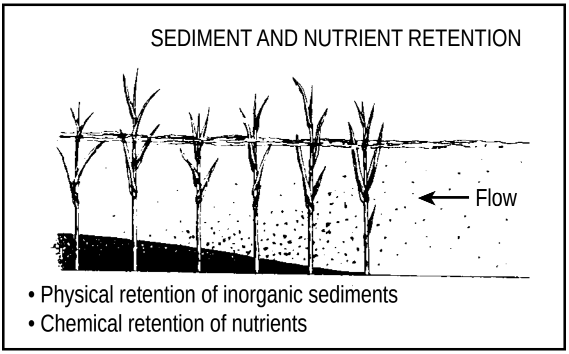
How do constructed wetlands work to reduce NPS pollution?

Constructed wetlands provide *storage capacity* for runoff water within their basins. In addition, organic soils found in mature wetland systems act like a sponge to retain water and allow infiltration into the groundwater. This decreases not only total runoff volume but also peak discharges which may otherwise cause flooding or erosion downstream.

As channelized flow enters a wetland, the velocity is reduced as the water spreads out over the wetland. Velocity is further reduced by the frictional resistance of aquatic vegetation. It is this *reduction in velocity* which is most responsible for sediment and nutrient retention in constructed wetlands. As the velocity of flowing water slows, it loses the energy needed to keep particles in suspension, and these particles and associated nutrients then settle out.



Nutrients such as phosphorus and nitrogen are trapped and retained in constructed wetlands by several mechanisms: burial in sediments, chemical breakdown (e.g., denitrification and ammonia volatilization), and through assimilation by aquatic plants and bacteria. The primary mechanism for phosphorus removal is adsorption to wetland soils and precipitation reactions with calcium, aluminum, and iron. In most cases, phosphorus retention by vegetation is only seasonal as it is taken up by growing plants and released with vegetation die-back in the fall.



How can you enhance the functioning of constructed wetlands?

There are a number of design features that can increase the efficiency of constructed wetlands to trap and retain NPS pollutants.

Loading Rate: Proper sizing of a constructed wetland in relation to its watershed is probably the most important factor affecting wetland performance. If the wetland is sized too small, water flow through the system can be too rapid for effective treatment. Too little water flowing through can result in stagnant water or temporary dry conditions. Primary plant productivity and decomposition rates are both higher in flowing water but high velocities discourage plant growth. Permanently flooded wetlands perform better than wetlands which dry out seasonally. Therefore, designing the hydraulic loading rate is critical. Ideally, for optimal performance, the size of the constructed wetland should be from 1% to 5% of the size of its drainage area. For example, a 25-acre watershed would require a 1-acre wetland. Designing hydraulic loading by analyzing existing channel discharge or watershed runoff coefficients is more precise than the 5% rule above.

Phosphorus removal efficiency declines with increasing phosphorus loading. With high loading rates, adsorption sites become saturated and there is insufficient capacity for biotic assimilation. There are cases where overloaded wetlands have become phosphorus sources to downstream lakes.

Hydraulic Retention Time: Hydraulic retention time refers to the length of time water remains in the constructed wetland. It is closely related to hydraulic loading rate. The longer water remains in the wetland the greater chance of sedimentation, adsorption, biotic processing and retention of nutrients. Proper sizing of the wetland is important but restricting the size of the wetland outlet is also effective. For wetlands with channel flow, the outlet cross sectional area should be less than 1/3 that of the inlet.

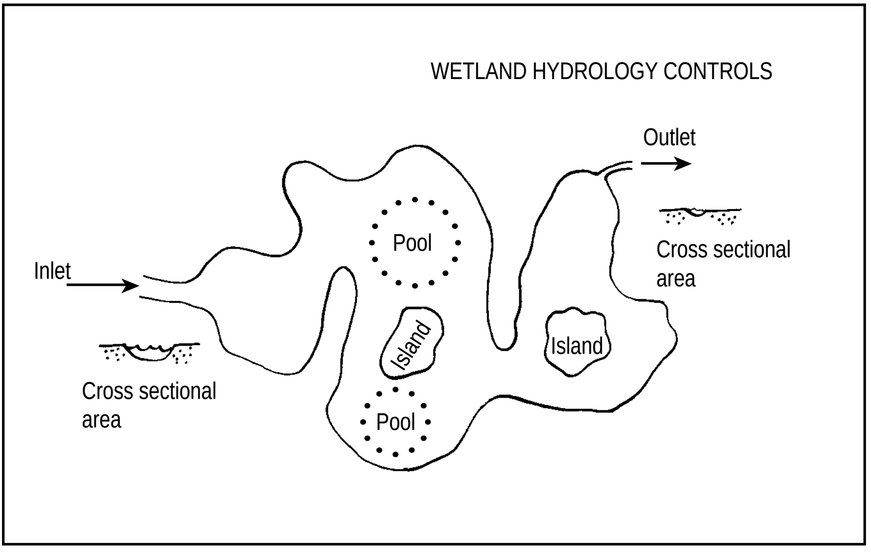
Water Velocity: Peak water velocities through the wetland should not exceed 1.5 feet/second. High velocities can wash out rooted vegetation and scour deposited sediments. Keep velocities low by regulating hydraulic loading, limiting the gradient (slope) through the wetland, restricting the outlet size, creating sinuous edges and planting persistent emergent vegetation. Ideally, flow velocities should be less than 0.6 feet/second.

Soils: Fine-textured clay soils and soils with high organic matter content have more adsorption sites for retaining nutrients. Available calcium, aluminum, and iron in the soil enhance precipitation reactions with phosphorus.

Water Depth: Water depths less than 40 inches result in greater resistance to flow and shallow depths favor aquatic vegetation. The preferred depth range for emergent plants is 0–1.0 feet of water; for rooted surface plants, 1.0–2.0 feet of water; and for rooted submersed plants, 1.5– 6.5 feet of water. Pools deeper than 40 inches should also be included in the wetland design to maximize sediment deposition and provide winter fish habitat.

Maximize Edge: Sinuous edges between the terrestrial and aquatic zones provide more resistance to flow and more edge habitat for plants and animals. Round wetlands have the least amount of edge per given surface area. Islands create additional edge plus they provide refuge from predation for nesting birds.

Minimize Edge Slope: The terrestrial-aquatic boundary should have a very gradual slope. This allows for the establishment of a continuum of emergent species and reduces the erosive effects of waves hitting a sharp shoreline boundary.



Persistent Emergent Vegetation: Persistent emergent vegetation has stems which persist even after the growing season. This provides year-round resistance to water flow. Persistent emergent plants include: cattail (*Typha spp.*), iris (*Iris pseudacorus* or *I. versicolor*), rush (*Juncus spp.*), cordgrass (*Spartina spp.*), reedgrass (*Calamagrostis spp.*), sawgrass (*Cladium jamaicense*), and switch-grass (*Panicum virgatum*). Woody plants such as alder (*Alnus spp.*), buttonbush (*Cephalanthus occidentalis*), black willow (*Salix nigra*), and others are useful edge species with persistent stems. Aquatic bed or submergent vegetation removes nutrients seasonally but does not offer significant frictional resistance to suspended sediments.

Pre-sedimentation Basin: Many constructed wetland designs incorporate a pre-sedimentation basin to trap sediments and large particulates before they enter the wetland. This can extend the life of the constructed wetland and ultimately enhance treatment efficiency.

Maintenance

Constructed wetland planning should not overlook the need for long-term maintenance. Additional vegetation planting may be required to speed plant coverage, replace damaged plants or to try more suitable varieties. Perimeter fencing may be required if livestock grazing is anticipated to be a problem. Maintenance may be needed to control the spread of undesired plant species such as purple loosestrife.

Inlets and outlets can become blocked with debris which will require periodic removal. Inlet and outlet structures should be inspected weekly and especially following big storm events. Most importantly, if the wetland functions well as a sediment and nutrient trap, it may eventually require dredging to remove accumulated materials. Thus, vehicular access to the site must be provided for maintenance vehicles and possibly dredging equipment.

Useful References

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