Winter 2008

Created Wetlands

Wetlands and Global Climate Change

Wetlands provide many key ecosystem services that enhance both natural systems as well as contribute to human health and well being. Nearly all amphibians and as many as 50% of migratory birds regularly use wetlands during their life cycle, and 75% of commercial marine fisheries depend on wetlands indirectly through the use of estuaries as nurseries(NOAA et al. 2003). Wetlands also serve the general public by reducing flooding, decreasing erosion, recharging ground water, improving water quality, and augmenting or providing wastewater treatment (EPA 1992).

While specific characteristics such as vegetation type will vary from site to site, water saturation is the defining factor for wetlands. The Army Corps of Engineers (Corps) and Environmental Protection Agency (EPA) define a wetlands as "areas which are inundated or saturated by surface or ground water at a frequency and duration sufficient to support…a prevalence of vegetation typically adapted for life in saturated soil conditions" (EPA 1992).

Despite the myriad benefits provided by wetlands, less than 46% remain of the 215 million acres that existed in the United States before the arrival of Europeans; most were drained for agriculture or other development (NOAA et al. 2003). Climate change is likely to only further exacerbate this trend. The Intergovernmental Panel on Climate Change (IPCC) estimates that average seal-level rise over the next century will inundate many low-lying coastal wetland habitats (Burkett and Kusler 2000). Moreover, since wetlands occur in transition zones between aquatic and terrestrial environments, subtle changes in hydrology resulting from the United States becoming warmer and wetter will result in the disappearance of many wetlands (Burkett and Kusler 2000). In general, wetlands depend on precipitation for their water supply will be most vulnerable (Winter 2000).

Losing a significant amount of wetland area will not only be disastrous because humans will lose the ecosystem services wetlands provide. Wetlands play a crucial role in the global carbon cycle by sequestering carbon in the form of biomass, methane, dissolved organic matter and organic sediment (Burkett and Kusler 2000). The loss of wetlands will be accompanied by a release of stored carbon into the atmosphere and may exacerbate global warming and climate change (Burkett and Kusler 2000). An estimated 20-35% of global terrestrial carbon is stored in boreal peatlands, and an increase in temperature in the northern latitudes in which these ecosystems occur may mean that wetlands will shift from a net reservoir of carbon to a net source (Burkett and Kusler 2000).

In light of these trends, decision makers have placed a greater emphasis on preserving existing wetlands as well as increasing total wetland area. For example, the IPCC recommended the creation of wetlands as a buffer against sea level rise and flooding, and the United States government has recently supported a "no net loss" initiative (IPCC 2007, Burkett and Kusler 2000). While preserving existing wetlands is preferable, development still occurs on these ecosystems. This has led to the formation of mitigation sites, which are created or restored wetlands mandated by the Clean Water Act when natural wetlands are filled or drained for development (Stolt et al. 2000). Whatever the method of increasing wetland areas may be, the success of these initiatives will be crucial in light of global climate change because wetlands will prove to be important carbon sinks and serve as a strategy to mitigate greenhouse gas emissions (Burkett and Kusler 2000).

Wetland Mitigation: Restoration vs. Creation

Mitigation sites can either be restored or created. Restoring wetlands is essentially re-creating a wetland on a site that historically supported a wetland, whereas creating a wetland is constructing wetland areas where none previously existed (NOAA et al. 2003). Restored or created wetlands can have many objectives ranging from providing habitat to endangered species to enhancing existing wetlands. Created wetlands, which are the focus of this paper, are most often used for human benefit in the form of stormwater treatment, acid mine drainage treatment, and, in some cases, feedlot runoff treatment (PRFC, EPA 1988).

Site Selection for Created Wetlands

Creating wetlands is considerably more difficult than restoring them because of the inherent complexity of a wetland ecosystem. Wetlands naturally occur as a result of several features of the watershed such as topography (elevation, aspect, and slope), climate, precipitation patterns, soil types, groundwater, surface waters, floodplains, and vegetation communities (NOAA et al. 2003). Simply put, a site is more likely to behave like a wetland if it used to be one. This is not to say that wetland creation is impossible; however, the site selected for a creation project should have features that are found in natural wetlands if the project is likely to succeed.

Hydrology

Suitable hydrological conditions are arguably the most important key factor when selecting a site for the creation of a wetland. The hydrological regime is a function of the duration, flow, amount, and frequency of water on a site; therefore, care must be taken to ensure that the water level in the system and the duration of flooding are appropriate or can be engineered to become appropriate (NOAA et al. 2003) (EPA 1988).

Hydrology is typically the driving factor of other ecological elements of the system. For example, a site with suitable wetland hydrology (or the capacity to have suitable hydrology) will produce soils that can support appropriate hydrophytic vegetation (NOAA et al. 2003), as well as plant diversity, density, and health (Texas GLO).

Examining hydrology is especially important if a wetland is constructed for wastewater management. Characteristics such as the source of water, velocity, flow rate, renewal rate, and frequency of inundation have a great influence on the chemical and physical properties of wetland substrates (EPA 1988). Aspects of the water cycle such as precipitation, infiltration, evapotranspiration, hydraulic loading rate, and water depth play a role in a wetland's ability to remove organics, nutrients and trace elements from the water (EPA 1988). Ground slope, water depth, and geometric shape also control the flow velocity which determines the detention time through a wetlands treatment system (EPA 1988).

Not surprisingly, hydrological conditions add many layers of complexity to site selection. It also constitutes a primary challenge in creation projects, since it is often necessary to bring water to a site where it does not naturally occur and manipulate the site to receive the water in a way that mimics a natural wetland (NOAA et al. 2003). Careful consideration into the hydrology of a site therefore is the first and most important step in creating a functional wetland.

Soils

Wetlands contain hydric soils which develop under anaerobic conditions resulting from long-term exposure to saturation, flooding, or ponding (Hunt et al. 1997). The presence of hydric soils is extremely important to ecosystem function since most of the chemical reactions typical to wetlands occur in the soil (Kentula 2002). As stated previously, hydric soils are a direct result of appropriate hydrology on the site. However, if they are not already present, management of water levels and water chemistry can encourage their development (EPA 1992).

Topography

Topography affects the cut and fill requirements, slope stability, access, and drainage and erosion potential (Texas GLO). It is an important consideration because grading and excavating often represent a significant cost factor (EPA 1988).

Vegetation

Plants play an important role in wetlands because by transferring oxygen to their root zone, they facilitate oxygen penetration deeper in the water table than is possible by diffusion alone and aid in many ecosystem processes (EPA 1988). Plants ubiquitous to many wetlands such as cattails are called hydrophytic since they have evolved to tolerate the unique and stressful conditions encountered in a wetland environment (Kentula 2002).

The most important feature to look for on a site when considering vegetation success is the presence of hydric soils. In addition, many wetland creationists recommend choosing a site near other wetlands, since the surrounding wetland plants may aid in the natural colonization of the site (Texas GLO). Isolated sites are also less desirable because they may be more vulnerable to invasion by non-native species (NOAA et al. 2003). During wetland creation, vegetation is either seeded directly, the existing seedbank is utilized, seedlings are transported, or established vegetation is transported from existing sites (EPA 1992).

Water Source and Quality

While hydrology is an crucial aspect of wetlands, water quality should not be ignored since inputs from surrounding landscape can affect a wetland's ability to process water and change the characteristics of a site (Kentula 2002). For example, when salts commonly used along highways enter a site, they can alter the composition and productivity of the plant community. The relative importance of surrounding water quality in site selection, however, depends on the objectives for creating the wetland.

Other General Factors

The actual size of land needed to complete the wetland creation objectives will be determined by needed flow control structures, access roads and utility rights of way, as well as buffer zones and other factors (Texas GLO). It is also extremely important to place site selection in the context of state regulations, water quality standards, water rights considerations, and adjacent land uses (Texas GLO).

It is also interesting to note that species such as beavers, muskrats, and geese may interfere with the eventual successful function of a wetland (Texas GLO). While it is probably not possible to avoid these species altogether, their relative abundance on the site should be taken into consideration.

Creation Costs

The majority of costs and energy required for wetland creation are associated with pre-application treatment, pumping and transmission to the site, distribution at the site, minor earthwork, and land costs (EPA 1988). Land costs are directly related to the amount of land required; depending on water quality and winter temperatures, wetlands average ½ to 1 sq. ft. per gallon of water treated per day if the major objective for establishing the wetland is wastewater treatment {NSI}. While the cost varies depending on the type of wetland created, one company estimates a range of $22,000 to $50,000 per acre for surface flow wetlands. {Natural Systems International}.

Created Wetland Design

Once a proper site has been selected, the next step is to design the wetland to meet a specific objective; in practice, the majority of created wetlands are constructed for wastewater treatment.

Created Wetland Design Leaders: the EPA and the TVA

Both the EPA and the Tennessee Valley Authority (TVA) are leaders in constructed wetland design and approach design from different angles. The TVA designs mainly for residential and small commercial systems; their design approach uses a hydraulic loading criterion (Sauter and Leonard 1997). The EPA often designs for large municipal wastewater treatment systems, and their model determines surface area by the organic loading of the system (Sauter and Leonard 1997). Despite the disparate design approaches, both government agencies have produced successful created wetlands (Sauter and Leonard 1997).

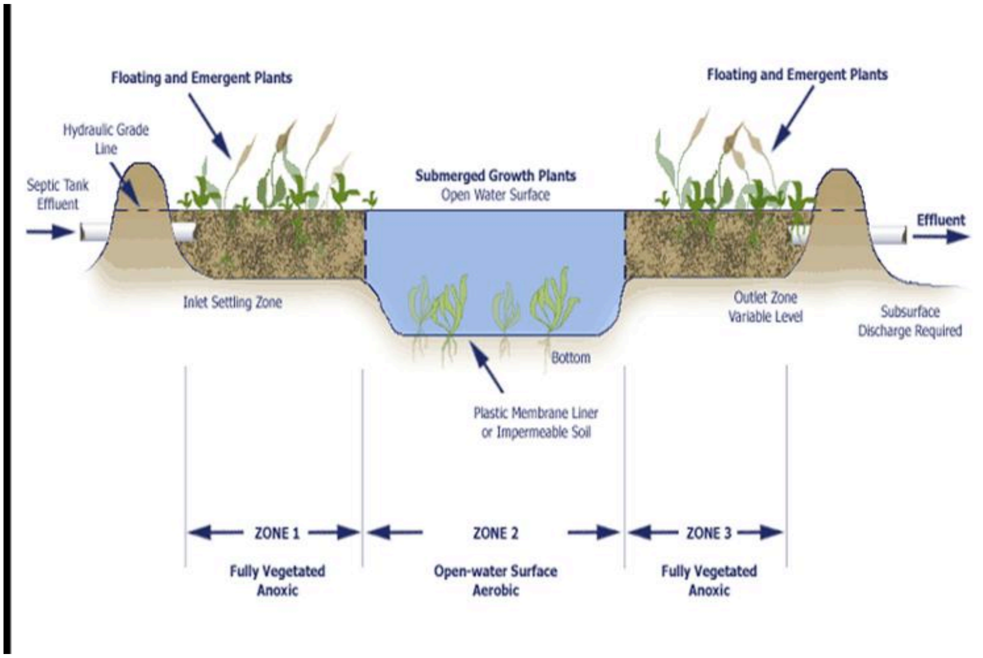
Discharge vs. Non-Discharge Systems

Created wetlands are designed to be either discharge systems, where effluent exits into other waters, or non-discharge systems, where wastewater is disposed of on site by evaporation, transpiration, or percolation (Sauter and Leonard 1997). This is an important distinction because discharge systems enter the "waters of the United States" and the Clean Water Act mandates that the Corps issue a permit before their construction.

Surface Flow (SF) Systems vs. Free Water Surface (FWS) Systems

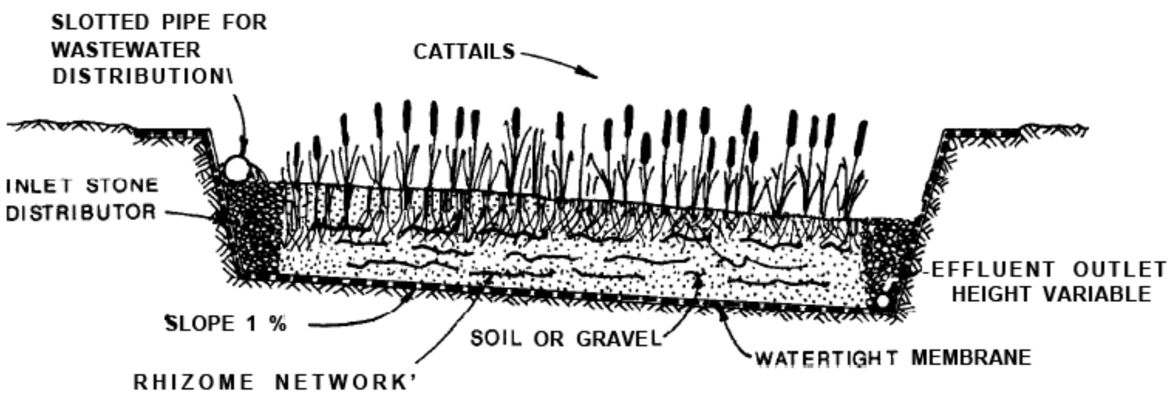
Created wetlands fall into two major designs; Surface Flow (SF) systems and Free Water Surface (FWS) systems. Both systems are successfully implemented throughout the United States, Europe, and parts of Asia (Sauter and Leonard 1997). Both systems also rely on the same microbiological reactions for wastewater treatment. The primary difference between the two lies in the hydraulics of the system, which is determined by the media (soil or rock) through which the water passes (EPA 1988).

FWS are utilized for many larger systems (including acid mine drainage) and, as the name suggests, have visible standing water. It typically consists of basins or channels containing a subsurface barrier to prevent seepage (either clay or an impervious geotechnical material), soil or an equivalent medium to support vegetation, and relatively shallow water depth flowing over the soil surface (EPA 1988). They are less likely than SF systems to short-circuit because of the combination of long, narrow channels and shallow water depth, low flow velocity, and presence of plant stalks and litter to regulate water flow (EPA 1988).



**The above picture is a cross-section of a typical FSW system*.

SF system is a constructed wetland with a trench or bed underlain with an impermeable layer of clay or synthetic liner to prevent seepage. Essentially, these systems are horizontal trickling filters because water flows laterally through sand or gravel. SF systems are also known as the "root-zone method" or the "rock-reed-filter" method (EPA 1988).



**Above is a picture of a typical SF system.*

FWS are preferred over SF in some cases because they are cost less and because they can increase wildlife habitat. However, the SF system is often preferred for smaller applications because FWS often has problems with mosquitoes and other vectors and pests, odor, and there is an increased possibility that people will come into direct contact with waste (Sauter and Leonard 1997).

Created Wetlands and Wastewater Treatment

When the primary objective for constructing a created wetland is wastewater treatment, they can be a viable and cost-effective option when traditional on-site wastewater treatment methods are unfavorable (Sauter and Leonard 1997). This is because artificial wetlands mimic a natural wetland's ability to remove and transform a variety of nutrients such as ammonia, nitrogen, and phosphorus (Texas GLO). However, created wetlands can only be used for secondary wastewater treatment to reduce organics and nitrogen compounds; primary treatment (ie, removal of solids) usually occurs before effluent enters the site (Sauter and Leonard 1997).

In most cases, created wetlands are preferred over natural for treating wastewater. This is usually resulting from the fact that many natural wetlands have landform constraints. Examples of constraints include; channelized wetlands cause flows to leave the site rather than infiltrate it; some wetlands are too shallow to maintain necessary water levels; some wetlands have poorly defined boundaries and flow paths and make it difficult to control where the wastewater goes (Texas GLO). Created wetlands can also operate in cold climates where natural wetlands may not occur in significant amounts to allow for wastewater treatment (EPA 1988). Essentially, created wetlands allow for a controlled environment in which to treat wastewater effectively, naturally, and cost-effectively.

As compared to traditional methods of wastewater management, created wetlands can be as effective yet require less capital and operating costs (EPA 1988). They are not suitable for every situation, however; created wetlands that discharge to surface water require 4 to 10 times more land than conventional treatment facilities (EPA 1988). As discussed previously, they also can provide breeding grounds for vectors and other insects, and may generate odors. These factors mean that highly urban areas, where land is limiting and people are likely to come into contact with the wetland, are not suitable for this method of wastewater treatment.

The Success of Created Wetlands

Once a created wetland is completed, it cannot be simply left to its own devices. Long-term monitoring is essential to determine if a wetland is functioning properly. It can often be difficult to say if a created wetland project is successful or not since there can be many criteria by which to judge it; for example, is it a successful project if it has the proper vegetation or hydrology, or if fulfills its objective of treating wastewater? For most projects, a created wetland is compared to reference sites, which are sites that represent the least disturbed wetlands of the target type in the area (NOAA et al. 2003). A close resemblance to these reference sites is the best indicator of success.

The majority of created wetland mitigation site are located in estuarine areas along the coast of the Eastern United States; these are more likely to succeed than freshwater systems because they are less complex (Stolt et al. 2000). The EPA has evaluated a limited number of freshwater wetland compensatory mitigation sites and indicated that they provided certain wetland functions such as flood abatement and sediment trapping (Conifer et al. 1992). If the objective is to provide wastewater treatment, perhaps this could be an indication of success; however, it is less promising if the objective is to replace natural wetlands that were drained for development.

Unfortunately, many studies have indicated that created wetlands efforts have not been very successful; in most cases, they do not look or function like the natural systems they are supposed to replace (Campbell et al. 2002). Out of 40 mitigation creation and restoration projects in south Florida, 60% were judged to be incompletes or failures (Zedler and Callaway 1999). In Washington state, permitting created wetlands for mitigation resulted in a net wetland loss of 33% (Stolt et al. 2000). Key wetland characteristics such as hydric soil indicators, hydrology, and plant communities were lacking in created sites as compared to their reference sites (Hoeltje and Cole 2007).

A monitoring period of a decade is standard for many of the projects since they are a relatively recent development. This is inadequate for assessing present success or failure, much less future site conditions (Campbell et al. 2002). In light of the importance of wetland ecosystem services and the role they play in sequestering carbon, wetlands construction need to be better monitored as global climate change progresses. The lackluster performance of many created wetland mitigation projects indicates that wetland restoration should be preferred over creation (Bruland and Richardson 2006). However, despite the advances made in creating wetlands, preserving existing wetlands is the best strategy in light of global climate change.

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