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Site Selection for Hydrologic Modifications to Restored or Created Freshwater Wetlands

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Introduction

Wetland mitigation replacement regulations in the United Statesfrequently prefer in-kind replacement. The replacement wetland should be the same type and have similar functions as the wetland being destroyed. While a wetland planning project may be designed to create a particular type of wetland, the type which results depends on the amount of water which flows into the wetland basin, how much water is retained and for how long, and the configuration of the basin. If the designers have not thoroughly evaluated the watershed, including the site's soils, the expected surface water runoff and groundwater flows, the resulting wetland may not be what was expected (Kentula et al., 1992). Some examples of wetland designs in Oregon are listed in Kentula et al. (1992) and include situations that fall short of being hydrologically self-sustaining. Two such examples are a riverine wetland that needs to be supplied by well water during dry periods of low flow, and another wetland that must be connected to a boat basin by a pipe.

Wetlands can occupy a variety of positions in the landscape, from areas of steep slopes to areas with minimal slopes; topographic depressions or drainage divides (Bedford, 1996). Riverine wetlands may be found in the floodplains of streams and rivers; prairie potholes are found in topographic depressions of glaciated areas where drainage systems have not developed; playas are found in isolated basins in the arid southwestern United States. Wetlands may occur on hillsides below a break in the slope where the surface water may not drain as quickly; in areas where the groundwater table intersects the surface due to topography, or in areas where the subsurface strata produce different hydrologic properties.

Wetlands are fed by water from three sources: precipitation, surface water runoff and groundwater discharge (Bedford, 1996). The amount of water the wetland receives from each of these depends on the climate of the region, the size of the watershed and its vegetation characteristics, and the position of the wetland in respect to the surface topography and the groundwater table. Many, but not all, wetlands receive water from all three sources. While all wetlands are fed by precipitation, those in arid climates are less dependent on precipitation than on surface water runoff or ground water discharge. Those wetlands that are primarily dependent on surface water runoff require a large watershed to supply adequate water. In the midwestern United States, depressional wetlands that have standing water typically have a watershed area of at least seventeen acres (Galatowitsch and van der Valk, 1994). Surface water dependent wetlands may accumulate water above an impermeable layer in the soil (typically clay) that creates a perched water table (Galatowitsch, 1997). Other wetlands are recharge wetlands, that is, the water that accumulates moves slowly downward through the soil till it reaches the water table. Riverine wetlands adjacent to a stream are dependent on the stream for water during peak flows. Groundwater dependent wetlands (discharge wetlands) occur at places where the water table intersects the surface such as on the side of a hill or streambank, or at the bottom of a depression (Bedford, 1996). The ground water may also discharge in flat topographical areas if changes in subsurface hydrologic properties, such as hydraulic conductivity, force the water to move upwards.

Wetland replacement designs are often limited by economic factors. Many wetland mitigation replacement plans try to use the minimum amount of land necessary, given the requirements of regulatory agencies. If a minimum basin slope of 5:1 (20 percent or 9 degrees) is allowed, the resulting seasonally flooded wetland will have steep sides with the majority of the area covered with standing water. A fringe of wetland vegetation will grow only around the base of the slope. Natural wetlands typically have slopes from 10:1 to 20:1 (5 percent or 2 degrees) (Kentula et al., 1992) and contain much more vegetation throughout (i.e. sedge meadows or scrub/shrub wetlands). A design for a self-sustaining wetland of the desired type requires a site with the appropriate hydrology. The techniques for locating and evaluating a potential site will depend on whether the goal is to restore a wetland which has been altered or to create a wetland in a new location. Restoration is often a simpler process because the site history may be known, but restoration is not guaranteed to succeed. Creation requires more intense monitoring and testing of the hydrology and the soils on the potential site. This paper is intended to provide an overview of the site selection process for restoration and creation of inland freshwater wetlands. Data that may be useful in identifying potential sites include initial map reviews, topographic and hydrologic considerations.

Off-Site Review Methods

Initial investigations for potential sites include reviewing maps, aerial photographs and regulatory office records. Topographic maps from the U.S. Geological Survey give initial information about the topography on a regional scale (1:24,000) which is useful for determining watershed drainage areas. If topographic maps are available at a larger scale (i.e. 1:2,400) from private surveying or aerial photography sources, then better information can be obtained on individual basins, slopes and cultural features that may be impacted. A check of historical aerial photographs (aerials) will give information on areas that have been drained by tiling or ditches. Aerials are available in black-and-white, color and infrared (Brodie, 1989). Aerial photographs can be obtained from the Natural Resource Conservation Service (NRCS) and the Agricultural Stabilization and Conservation Service (ASCS) (Wenzel, 1992). The selection of a site that has been previously filled or drained provides an opportunity to restore the hydrology by reversing the alterations, that is, by removing the tile, plugging the ditch or excavating the fill material. Information on ditches and tiling can often be obtained by a local watershed management organization, drainage district or the county water conservation district. Local tile installation firms may provide information on tile lines that have been installed (Galatowitsch, 1997). Location of an existing wetland on National Wetland Inventory maps may provide an opportunity. Enlarging an existing wetland or creating an adjacent one may have a higher probability of success since appropriate hydrology and soils are nearby. State agencies may have additional information on geographical information system (GIS) databases (USDA).

County soil survey maps can be checked for possible restoration sites by looking for soils that are listed as hydric. Wetland (hydric) soils become anaerobic within a few days and develop characteristics such as mottles and gray coloration. These include Aquic suborders, Aquic subgroups, Albolls suborder, Salorthids great groups, Pell great groups of Vertisols, Pachic subgroups, or cumulic subgroups (Wetland Training Institute, 1991). In general, these soils are defined as somewhat poorly drained, moderately poorly drained, or very poorly drained. Even if the site has been filled or drained, the county soil survey will describe the hydrologic characteristics of the original soil. Soil surveys often have information on groundwater levels and the degree of seasonal fluctuations as well as specific conductance and hydrologic conductivity for the mapped soil units. One should be aware, however, that the soil maps do not show every unit individually due to limitations of scale. If a soil unit is less than three acres in size, descriptions may list it as being included in another mapped unit.

Groundwater Regime

The groundwater hydrologic regime is not static. Groundwater levels fluctuate yearly, seasonally, and with individual precipitation events. The water table, or the free water surface, rises in the spring with recharge from increased precipitation and infiltration (Mausbach and Richardson, 1994). Groundwater flows down gradient to areas of lower water pressure . If the water table intersects the ground surface, water is discharged. This area may be a stream bank, lake shore or wetland basin. Wetlands can act as both recharge areas and discharge areas, depending on the season and amount of precipitation. In the spring, the groundwater is recharged from rainfall or snowmelt and the water table rises. If the hydraulic head (water pressure) at depth is greater than the hydraulic head at the surface, and the water will rise and discharge into the wetland (National Resources Conservation Service, 1993). The wetland will have saturated soils and may have standing water in the center. In the summer and fall, the water table falls with increasing evaporation, plant transpiration, and discharge into streams. If the water table falls one foot or more below the ground surface, the wetland will dry up. A wetland may become a recharge area during precipitation events if the water table is below the surface. If the groundwater does not intersect the surface at any time during the year, the wetland will be a recharge wetland only and be totally dependent on surface water for its hydrology. These wetlands are seasonally and ephemerally flooded, even without alteration (Galatowitsch, 1997).

Drainage Area

In choosing a site for a restoration project, or in designing a new wetland, evaluation of the drainage areas that affect the basin is necessary, including the human-made drainage ditches and tiling. Information on ditches and tiling are important because they may be draining a larger area than the immediate watershed. Basins in adjoining watersheds may be connected by tiling which is not obvious from site inspection (Galatowitsch and van der Valk, 1994). These basins may need to be drained by the existing tile system to prevent unwanted flooding of neighboring properties. In this case, the existing tile should be replaced with impervious tile or be re-routed rather than be completely removed. A wetland needs several times its area in upland to provide surface runoff and shallow groundwater. If the watershed/wetland ratio is not large enough, the supply of surface runoff and shallow groundwater may not be enough to sustain the wetland. The size of the watershed needed is dependent on the climatic regime of the area. In the prairie pothole region of the midwestern United States, where annual precipitation averages thirty inches per year, a ratio of at least 2.5:1 is needed to provide a seasonal wetland with standing water for some part of the year (Galatowitsch and van der Valk, 1994), with a minimum watershed of four acres. A for a semi-permanent wetland, a ratio of 4:1 to 10:1 is needed, with a minimum watershed of seventeen acres. In more humid regions, less upland watershed may needed; in the more arid regions, a larger watershed will be needed. If the purpose of the new wetland is to reduce flood-flows, the wetland should cover 0.5% of a watershed.

The watershed and wetland basin areas can be measured by delineating the drainage divides on a topographic map. To do this, locate the proposed wetland boundary. Trace a line away from the wetland uphill (perpendicular to the topographic contours) until the top of the hill is reached. Perpendicular lines and hilltop points can be drawn at several places around the wetland. Draw a line along the top of the hills connecting the dots until the wetland is surrounded. This area is the watershed. The area can be measured using planimeters, digitizers, or by using a grid overlay and counting the squares.

Drained Wetlands

If a site was drained by underground tile, chances are good that hydrology can be restored by removing the tile and installing a tile block, or by replacing a section with non-perforated tile. The amount of tile to be removed depends on the soils present. Ditched wetlands may be restored if the ditch is shallow and has not penetrated the confining soil layers. A dike across a ditch may be constructed from several materials. The most common method is an earthen dike. Straight-drop structures (weirs) of concrete, timber and corrugated steel have also been used but are more costly (Wenzel, 1992). Weirs can serve as both dikes and as emergency spillways and are usually very stable.

The water level in the resulting wetland may not match that of the original wetland if the surrounding land use has changed significantly over the years (Galatowitsch and van der Valk, 1994), or if more recent drainage projects have changed the size of the watershed. In most parts of the country, groundwater levels have dropped as well, with increasing demand for public and industrial uses. Ongoing public improvements have changed drainage patterns and the size of effective watershed basins. The water budgets of some restored wetlands may increase while others will decrease.

Wetlands that have been indirectly drained include stream and riverine wetlands. These include oxbow lakes, headwater areas and low-velocity channels. The streams and rivers associated with these wetlands have been modified by activities such as channelization, bank stabilization, pumping, dam building, dredging and watershed development (National Research Council, 1992). Some small-scale wetland restorations have been attempted as part of local greenway and stream restoration projects such as the Urban Streams program in California (National Research Council, 1992). The unstable regimes of the hydrologic and sediment components typical of streams complicate efforts. Oxbow lakes form when streams change course, abandon the old channel and cut a new one. A wetland could be restored by cutting a ditch or channel to reconnect the water supply of the stream to the wetland. Problems will occur over time as the stream deposits sediment in the channel or re-abandons the wetland channel. Long-term maintenance would be needed to prevent natural hydrologic change. In other streams where channelization and dams were installed, the original meandering pattern of the stream would need to be restored to make restoration feasible.

Filled Wetlands

Often wetlands were altered by filling the basin and raising the surface above the effective water table. These wetlands may be possibly restored by excavating the fill material (National Research Council, 1992). The original soil surface can be determined by taking soil borings or digging soil pits to determine the soil profile. The difficulty with this method is determining the original topsoil elevation and excavating the fill material to within a few inches of the original surface with heavy equipment. As much of the original topsoil should left as possible. The original topsoil contains organic material and inorganic nutrients. The need to apply soil amendments is reduced (Harris et al., 1989). It may be possible to re-establish the existing seed bank if the alterations were recent, within twenty years. Hydrologic considerations are similar to those of drained wetlands. The restored wetland may not resemble the original wetland if surrounding landuse patterns have changed.

Created Wetlands

Because of increasing development in areas suitable for wetland restoration, it is becoming necessary to explore upland areas where wetlands could be created. In California, Pacific coast shorelines have been so completely developed that the most viable areas for restoration are in the Central Valley, far from regions where most wetlands were lost (Bedford,1996). Wetlands designed in upland areas have the smallest probability of success. The surface topography may be significantly higher than the water table, the soils do not resemble hydric soils, and the seed bank is lacking.

Wetlands may be created by building dams, excavating a basin, or enlarging a floodplain. If a watershed evaluation similar to the type done for drained wetlands reveals that the upland area can supply adequate runoff and shallow groundwater to the proposed basin, a dam could effectively retain water. Dams are placed in a gently sloping valley or swale where shallow ponded water would cover a large area. To provide maximum area for wetland plants, the sides of the basin should have a gradual slope. Dams are constructed in a similar fashion as a dike across a drainage ditch. Care should be taken not to build the dam too high and flood areas not intended. Hydrologic data should be taken downstream regarding potential impacts such as reduced flow in the drainage way and an unexpected discharge if the dam should fail. Wetlands in drainage ways are susceptible to sedimentation, flooding and erosion. If the new wetland is sited adjacent to a stream, it should be located in the lowest energy segment of stream channels of streams that do not experience heavy seasonal flow (Admiraal et al., 1997).

The wetland basin should be located as low in the topographic setting as possible to maximize the watershed area and groundwater discharge. However, the basin should not be located in the valley of a "losing" stream (Hammer, 1992). A losing stream always recharges the groundwater aquifer and the wetland will not retain water. If a wetland is intended to hold water permanently or for extended periods of time, the soil profile should contain an impermeable layer such as clay, or the bedrock should be close to the surface. It may be necessary to seal the bottom of the basin with impermeable material such as bentonite, clay or a flexible membrane if no impervious layer exists (USDA 1992).

Detailed information about the groundwater regime will assist in designing the basin. Data on the seasonal fluctuations of the water table will aid in determining the depth of excavation needed to intersect the groundwater. Information should be collected for a minimum of three years to avoid data biased by overly wet or dry years. If information is available from additional sources, it can be beneficial in determining the average high and low water table levels during the year (Arcieri, 1996). The U.S. Geological Survey has a network of groundwater monitoring wells and stream gaging stations that can provide a long term reference data base on groundwater levels. The reference wells should be located in the same climatic region and in similar hydrogeologic settings such as glacial outwash, till, alluvium or stream terrace. Other information includes perched water tables, existing and potential groundwater use, and nearby wells (Brodie, 1989).

Data collected from piezometers is more useful than that collected from shallow wells. Shallow wells, which are slotted for the entire length of the pipe, give information only on the water table level. Piezometers give information about the hydraulic head (water pressure) of the groundwater. If the piezometers are grouped and installed at different depths, they can also give information about the vertical pressure (U.S. Army, 1993). Piezometers can be placed in a grid throughout the proposed basin, and a pressure gradient can be mapped. Piezometers can be made from one inch PVC pipes slotted at the base for six to twelve inches. Depths of the slotted pipe range from two to eight feet, depending on the water table. Piezometer information will indicate if the basin is a recharge or discharge area, and if the shallow groundwater is perched above an impermeable layer. Additional information on specific yield and hydraulic conductivity of the soils will help in determining how quickly the basin will fill and drain. Piezometer or well data from a potential restoration site is less useful because the water table has been artificially lowered.

A significant problem with excavated wetlands is the lowering of the water table after the basin is excavated (Winston, 1997). Once the original annual high water table is perforated, the water table may automatically drop from a few inches to more than a meter. The lower level may be due to increased evaporation and plant withdrawal or from other factors. The excavated wetland will no longer be in contact with the water table and will have to be dug deeper, thus creating steeper sides or taking more land. Problems like this can be predicted using modeling tools such as MODFLOW, available from the U.S. Geological Survey. Other drawbacks can occur with excavations: the excavation may occur at the wetland/upland boundary, potentially resulting in a dry site; an excavation may perforate the bottom sealing layer of an existing wetland, causing the existing wetland to drain (Admiraal et al., 1997); or the excavation may result in deep water impoundments which are less desirable for wildlife. Many waterfowl species are less likely to use them because they do not thaw early enough in the spring, and because the birds must stay close to the shoreline to feed and are susceptible to predation (Galatowitsch and van der Valk, 1994).

Conclusion

Characterisitics of nearby natural wetlands should be identified, and wetland projects designed to replicate similar characteristics, thereby producing similar processes and functions. Success of wetland creation projects may depend on the similarity of the wetland planned to other natural wetlands. Success of restoration projects may depend on the degree of disturbance of a potential site.

Determining whether a project is a failure or success depends on the original goals. Well-defined and measurable goals can direct site designs and specifications, and aid in the monitoring process. While complete knowledge about a proposed wetland site may be impossible, collection of as much information as possible about a proposed site's hydrologic conditions are essential. By evaluating the data thoroughly, failures can be avoided, and the resulting project will be a closer approximation to the planned design.

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