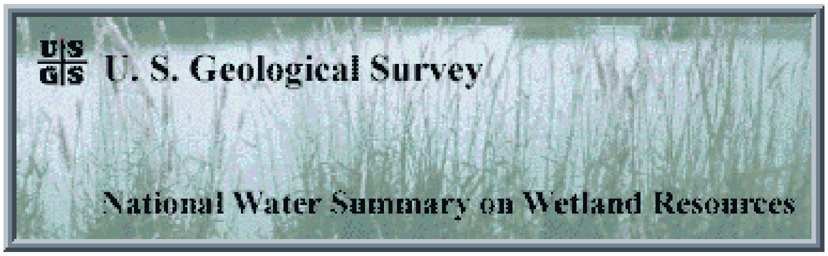

National Water Summary on Wetland Resources
United States Geological Survey Water Supply Paper 2425

Restoration, Creation, and Recovery of Wetlands

Wetland Restoration and Creation

By Mary E. Kentula, ***U.S. Environmental Protection Agency***

The benefits of restoration of degraded or destroyed wetlands and creation of new wetlands has only recently been recognized. As the population has expanded across the Nation during the past few centuries, wetlands have been drained and altered to accommodate human needs. These changes to wetlands have directly, or indirectly, brought about changes in the migratory patterns of birds, local climate, and the makeup of plant and animal populations. In the past, people used wetland plants and animals for shelter and food. More recently, people have become more aware of other benefits that wetlands provide water-quality improvement, flood attenuation, esthetics, and recreational opportunities. Now, it is recognized that numerous losses are incurred when a wetland is damaged or destroyed. Restoration and creation can help maintain the benefits of wetlands and their surrounding ecosystems, and at the same time accommodate the human need for development.

Wetland restoration rehabilitates a degraded wetland or reestablishes a wetland that has been destroyed. Wetland creation is the construction of a wetland on a site that never was a wetland. This can be done only on a site where conditions exist that can produce and sustain a wetland. Consequently, creation is more difficult than restoration. A term commonly associated with wetland creation is "constructed." A constructed wetland is a wetland created specifically for the purpose of treating wastewater, stormwater, acid mine drainage, or agricultural runoff (Hammer, 1989). As used in this article, "project wetland" refers to restored or created wetlands. (For a more complete discussion of the meaning of these terms and others associated with restoration and creation, see Lewis, 1990.)

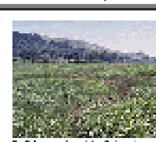

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Figure 52. View of a restored salt marsh in the Salmon River Estuary on the Oregon coast. *(Photographs courtesy of the EPA Wetlands Research*

Wetland alterations have brought about changes in the migratory patterns of birds, local climate, and make up of plant and animal populations.

Restoration takes place on land that has been, or still is, a wetland. A term commonly associated with restoration is "enhanced." An enhanced wetland is an existing wetland that has been altered to improve a particular function, usually at the expense of other functions. For example, enhancing a site to increase its use by a particular species of bird commonly limits its use as habitat for other species. (For information on functions of wetlands see the articles "Wetland Hydrology, Water Quality, and Associated Functions" and "Wetland Functions, Values, and Assessment" in this volume.)

Program.)

CHALLENGES OF RESTORATION AND CREATION

Ecological issues and physical limitations are important factors to consider when planning for wetland restoration or creation. The relative merits of destroying the function of an existing wetland, or other ecosystem, in exchange for another wetland function involves the consideration of numerous questions such as: (1) Which is more important, the existing or the replacement function? (2) Will the proposed wetland increase wildlife diversity? (3) Is the increased diversity worth the loss of habitat of any endangered species? Questions of this type always arise during planning for wetland restoration and creation.

A well-documented example of a physical limitation associated with restoring a wetland can be seen along the shoreline of the Salmon River Estuary, Oreg. (Frenkel and Morlan, 1990, 1991). In the past, many high

It is difficult to make a definitive statement about the ability to replace wetland functions. Goals for restoration and creation projects seldom are stated and information on the existing functions of the wetlands seldom are documented. This is due, in part, to the difficulty and expense of quantifying wetland functions. Also, responsible monitoring during construction and after completion of the project wetland is uncommon. Most information available on project wetlands is in the form of qualitative case studies.

Restoration and creation can help maintain the benefits of wetlands and accommodate the human need for development.

marsh wetlands along the Pacific coast were diked to remove them from tidal action. After the area was diked, the wetlands dried up and the land was used for pasture. In 1978, in an effort to restore the Salmon River Estuary to its original condition, two dikes were removed to allow the original wetlands to reestablish themselves. However, after 10 years, the resulting wetlands (fig. 52) were not typical of other high marshes along the estuary. The land behind the dikes had subsided over time, and the restored wetlands were more typical of wetlands at lower elevations nearer the estuary (low marsh). Although the wetlands continue to evolve as sediments are trapped and deposited by the vegetation (thus raising the elevation), it might take another 50 years for the restored wetlands to become similar again to the original high marsh (Frenkel and Morlan, 1991). The time required and the ability to develop a fully functional soil system in project wetlands may be major determinants of the eventual acceptance or rejection of restoration and creation as management options.

DESIGNING FOR SUCCESS

Much of the written material on wetland restoration and creation deals with "project design." Project design considers a large number of site-specific, interdependent factors that determine the structure and function of a wetland. Although there is no "cookbook" for restoring or creating wetlands, documents describing general approaches to restoration and creation and the conditions conducive to project success are available (Garbisch, 1986; Marble, 1990; Pacific Estuarine Research Laboratory, 1990; Hammer,

Hydrologic analysis.- Hydrologic conditions probably are the most important determinants of the type of wetland that can be established and what wetland processes can be maintained (Mitsch and Gosselink, 1993). Elements of site hydrology that are important to maintaining a wetland are inflows and outflows of ground water and surface water, the resulting water levels, and the timing and duration of soil saturation or flooding.

One factor influencing hydrology is the

1992; Maynord and others, 1992). Elements common to wetland project design are site-selection criteria, hydrologic analysis, water source and quality, substrate augmentation and handling, plant material selection and handling, buffer zones placement, and long-term management. A brief overview of each element is presented here in a sequence similar to that followed in project planning.

Site selection.- Sites for project wetlands often are selected on the basis of available land, or on policies that require wetlands to be restored or created to compensate for nearby wetland losses (mitigation). A wetland's structure, function, and ability to persist over time are greatly influenced by its location. Wetlands in settings with limited human influence can differ greatly in structure and function from wetlands in settings dominated by human activities. Therefore, the present and projected land uses of the surrounding area are a consideration when selecting the site. The characteristics of existing wetlands, in the same general area, or in an area with similar land uses, can be used as models for what might be expected of the project wetland. Benefits that extend beyond the wetland itself can be derived from the placement of a wetland if care is taken in site selection. For example, restoration of riverbank wetlands between agricultural land and a stream can improve downstream water quality (Olson, 1992).

configuration of the basin (depression) containing the wetland. The position of the basin surface relative to the water table influences the degree of soil saturation and flooding. To ensure that standing water is present year round, many project wetlands are excavated so that the deepest part of the basin is below the lowest anticipated water level. The slope of the basin banks determines how much of the site will be vegetated and by what kinds of plants (fig. 53). This is because the slope determines how far the substrate (soil or rock material that forms the surface of the basin) will be from water and how much of the substrate has the necessary conditions of wetness for specific plant species (Hollands, 1990). The ability to maintain the desired plant community, therefore, is ultimately dependent on the hydrology of the site. In a properly constructed freshwater marsh, the lowest point of the wetland will be inundated to a depth and for a period long enough that emergent vegetation can persist, but not so long as to destroy the plants.

Benefits can extend beyond the wetland if care is taken in site selection.

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Figure 53. The relative position of a basin substrate, the water table, and differences in vegetation resulting from the degree of basin slope.

Water source and quality.- Although it is commonly acknowledged that site hydrology is a major determinant of the success or failure of wetland restoration or creation, the influence of water quality often is ignored. Inputs of chemicals from the surrounding landscape can overwhelm a wetland's ability to improve water quality and can change the characteristics of the site. For example, deicing salts are used extensively along highways and, if they enter a wetland, can alter the productivity and composition of its plant community, possibly favoring nuisance species such as purple loosestrife (Niering, 1989).

Substrate augmentation and handling.- Wetlands are characterized by hydric soils, which develop as a result of an area being saturated, flooded, or ponded long enough during the growing season to develop anaerobic (oxygen-deficient) conditions (U.S. Soil Conservation Service, 1991) (fig. 54). Most of the chemical reactions in wetlands take place in the soils, where most chemicals are stored (Mitsch and Gosselink, 1993). The soils of project wetlands are receiving increased attention as studies link substrate characteristics to ecological function. Although a created wetland may be structurally similar to a natural wetland, its hydrology may differ greatly from that of the natural wetland if the permeability of the substrates differ (O'Brien, 1986). In addition to differences in permeability, soils in project wetlands commonly have a smaller amount of organic matter than soils in similar natural wetlands. Because organic matter in soils stores nutrients that are critical to plant growth (Pacific Estuarine Research Laboratory, 1990), the smaller amounts of organic matter in soils of project wetlands may limit plant growth

Plant material selection and handling.- Vegetation is the most striking visual feature of a wetland. Because of the unique and stressful conditions that develop in wetlands, varying from long periods of flooding to periodic drying, plants and animals found there have developed distinctive mechanisms to deal with these stresses and conditions. It is important to recognize the constraints of this unique environment when planning a project wetland. Plant communities established in project wetlands will fare better if they closely resemble communities in similar, local wetlands. To increase the likelihood of successful colonization, Garbisch (1986) suggests that project managers:

- Select herbaceous species that rapidly stabilize the substrate and that have potential value for fish and wildlife
- Select species that are adaptable to a broad range of water depths. A survey of vegetation at wetlands of the type being created or restored can identify the conditions of "wetness" needed by species
- Avoid choosing only those species that are foraged by wildlife expected to use the site-muskrats and geese have been known to denude sites
- Avoid committing significant areas of the site to species that have questionable potential for successful establishment

In addition, Stark (1972) suggests the selection of "low maintenance" vegetation.

Hydrologic conditions probably are the most important determinants of wetland types and processes.

(Langis and others, 1991). Augmenting, or mulching, the substrate of project wetlands with materials from a "donor" wetland can increase soil organic matter and provide a source of needed plant species, microbes, and invertebrates. Mulching makes the substrate more conducive to rapid revegetation by reducing the evaporation of pore water, runoff, soil loss and erosion, and surface compaction and crusting (Thornburg, 1977). Mulching also can cause problems such as the introduction of unwanted plant species.

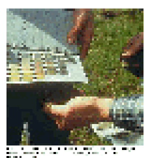

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Figure 54. Scientists checking to see if a soil sample has the unique coloration typical of wetland (hydric) soils. *(Photograph courtesy of the EPA Wetlands Research Program).*

Buffer zone placement.- Protective measures are needed for many restored and created wetlands, particularly in urbanized areas. This protection can take the form of an undeveloped, vegetated band around the wetland; a fence or barrier; or a lake or sediment basin. This buffer between the wetland and surrounding land is desirable; however, the characteristics of an appropriate vegetated buffer are not well defined. Although composition is important, width is the most frequently cited characteristic of an adequate buffer zone. Requirements for both composition and width are dependent upon the adjacent land uses, their potential effect on the functions of the wetland, and the requirements of the animals that will use the wetland and

Long-term management.- Careful monitoring of newly established wetlands and the ability to make mid-course corrections are critical to long-term success. However, few project sponsors have been willing to assume long-term responsibility for managing these new systems (Kusler and Kentula, 1990b). Because of this, project wetlands that are designed to be self-sustaining or self-managing will have the best chance of survival. The installation of control structures, such as tide gates or pumps, that will require maintenance and are subject to vandalism could be disadvantageous to the life of the project wetland.

Chemicals from the surrounding landscape can overwhelm a wetland's ability to improve water quality.

buffer area. Buffers are used to:

- Deter predators from entering wetlands
- Trap and prevent undesirable materials from entering the wetland through runoff from the surrounding landscape
- Provide habitat for wildlife that depend on uplands in addition to wetlands for part of their life cycle

EVALUATION OF SUCCESS

One of the most vexing aspects of wetland restoration and creation projects is defining success, primarily because there is no generally accepted definition. This is true for many reasons-lack of clearly stated objectives, lack of long-term monitoring (Kusler and Kentula, 1990b), and the subjective point of view of the definer (Roberts, 1993). The vast majority of project wetlands are ecologically young-10 years of age or less. The lack of information on ecologically mature projects limits the ability to predict whether or not the functions of project wetlands can replace the functions of natural wetlands. Nevertheless, the results of ongoing research and good professional judgment can be used to provide insight into the selection of projects that have a high probability of success.

Various attempts have been made to define success criteria for wetland projects. The earliest criteria assumed that if conditions were correct for the establishment of wetland vegetation, then other ecological functions would either be present or develop over time.

The Wetlands Research Program of the U.S. Environmental Protection Agency (EPA) is developing an approach to establish quantitative performance criteria for project wetlands. In this approach, groups of natural wetlands serve as reference sites against which project wetlands are judged. For example, Zedler (1993) uses reference data from natural marshes being used by clapper rails (an indigenous bird species) to define criteria that can be used to judge the suitability of restored and created habitat for the birds. Older project wetlands also are used as reference sites against which to judge newer project wetlands, both to verify that development is as expected and to identify developmental patterns that may have resulted from changes in project design (Kentula and others, 1992). This approach is designed to produce results that are regionally applicable to wetland protection and management.

Now, it is known that a site "green" with vegetation does not necessarily mean success, and the standards by which projects are judged are more likely to be tied to wetland functions.

One tool for comparing the characteristics of project wetlands with similar, naturally occurring wetlands is a performance curve (fig. 55). Functions in a group of restored wetlands can be expected to increase gradually with time to a point of maturity at which time the level of function has stabilized. The mean level of function in mature project wetlands is generally less than that for natural wetlands. Rate and time of maturation and functional level at maturity will differ from project to project, depending on the type of wetland being restored. The curve provides information on when to monitor, how restored wetlands typically develop, and when project goals have been met. Changes in the characteristics of project wetlands can be expected in response to the maturation process, but also in response to changes in the environment. Information on the development of project wetlands and similar natural wetlands helps managers determine whether an observed change is typical for a particular year or stage of development.

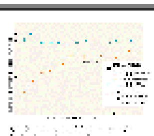

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Figure 55. Typical performance curve illustrating the comparison of groups of natural wetlands and restored

Over time, successful project wetlands can be expected to become similar to comparable natural wetlands. A comparison of plant diversity on project wetlands and similar natural wetlands in Oregon (Kentula and others, 1992), Connecticut (Confer and Niering, 1992), and Florida (Brown, 1991) showed that, although the level of diversity differs with each project, diversity tends to be higher on each project wetland than on its natural counterpart. The type of wetland studied was a pond with a fringe of freshwater marsh (fig. 56). If a project wetland develops as hoped and expected, after 2 to 5 years it probably will have a plant diversity greater than or equal to that of similar natural wetlands. As competition for space and resources increases and the plants more completely cover the site, the diversity usually decreases and the plant community tends to become more like that of a mature site.

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Figure 56. This pond with a fringe of marsh in Portland, Oreg., is a restored wetland and is an example of the type of freshwater project wetland most common in this country. *(Photograph courtesy of the EPA Wetlands Research Program.)*

Plants in project wetlands fare better if they closely resemble those in similar, local wetlands.

wetlands of the same type and similar size in the same land-use setting. *(Source: Modified from Kentula and others, 1992.)*

STATUS OF THE SCIENTIFIC KNOWLEDGE OF RESTORATION AND CREATION

Current scientific knowledge about successful wetland restoration and creation has been documented in "Wetland Creation and Restoration: The Status of the Science" (Kusler and Kentula, 1990a). Although the literature on wetland restoration and creation has increased since the publication of that book, the general assessment presented still applies. Key points from the Executive Summary (Kusler and Kentula, 1990b) are discussed below. (Additional information on restoration of aquatic systems, including wetlands, can be found in a recent publication by the National Research Council Committee on Restoration of Aquatic Ecosystems, 1992.)

The status of scientific knowledge about wetland restoration and creation differs by wetland function, type, and location. It is still uncertain if the full suite of functions provided by a particular wetland type can be replaced. Full functional replacement has not yet been demonstrated. In the case of specific functions, the most is known about replacement of flood storage and waterfowl habitat, and the least is known about water-quality-improvement and ground-water-associated functions. The more complex the hydrology and ecology of a system, the more difficult it is to

With respect to types and locations of wetlands, the most is known about restoration and creation of intertidal salt marshes along the coasts of the United States, in particular, the tall cordgrass marshes of the Atlantic coast. However, these salt marshes comprise only about 5 percent of the total wetland area of the Nation and are only a small part of the marine and estuarine wetlands.

Much less is known about restoration and creation of inland freshwater wetlands, such as ponds, forested wetlands, or bogs and fens. Among these wetlands, most is known about restoration and creation of those dominated by open water, such as ponds, and the associated herbaceous vegetation. Much less is known about replacing forested wetlands because of the time needed for woody vegetation to mature. Experts agree, however, that the ecosystems that are least likely to be successfully replaced are bogs and fens. These are the wetlands with deep organic soils that have developed over thousands of years and that have hydrologic conditions that are difficult, if not impossible, to duplicate.

restore the system. Complete restoration might be impossible in some systems.

FEDERAL AGENCY RESEARCH ON WETLAND RESTORATION AND CREATION

Several Federal agencies have missions, and therefore conduct research activities, that involve wetlands. This section presents a brief overview of Federal research on wetland restoration and creation. [For more information on wetland research by Federal agencies, see the publications of the Wetlands Research Program of the U.S. Army Corps of Engineers (Corps) and the article "Wetland Research by Federal Agencies" in this volume.] The Corps has been leading an effort to provide a reference source on current wetland research being conducted by Federal agencies. The first edition (U.S. Army Corps of Engineers, Wetlands Research Program, 1992) presents information provided by the Corps, the EPA, the Soil Conservation Service (renamed Natural Resources Conservation Service in October 1994), the Forest Service, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the Bureau of Reclamation, and the U.S. Geological Survey. The Corps surveyed over 25 agencies in 1993. To complement the Corps' reference source, the U.S. Fish and Wildlife Service is maintaining the Wetland Creation/Restoration data base to provide a current compilation of the published literature. A hard copy of the bibliographic material contained in the digital data base also has been produced (Schneller-McDonald and others, 1989).

Federal agencies' research into wetland restoration and creation generally falls into two categories-design implementation and performance evaluation. Major contributions on project design have been made by agencies involved in large-scale development, like the Corps (Maynord and others, 1992) and the Federal Highway Administration (Marble, 1990). The EPA has focused its research on evaluation to support the agency responsibilities under Section 404 of the Clean Water Act (Zedler and Kentula, 1986; Leibowitz and others, 1992). Agencies responsible for stewardship of living resources, such as the National Marine Fisheries Service, have produced information that will increase their effectiveness in management (Thayer, 1992).

Ecosystems that are least likely to be successfully replaced are bogs and fens.

The Natural Resources Conservation Service and the U.S. Fish and Wildlife Service probably will contribute the most information on practical, low-cost approaches to wetland restoration under the 1990 Farm Bill (Food, Agriculture Conservation and Trade Act of 1990-(P.L.101-624) and the Wetland Reserve Program. Under these programs, thousands of wetland acres previously converted to agriculture have been restored to wetlands. To support these efforts, both agencies have produced guidelines for their field personnel who are working with the farmers to restore wetlands (U.S. Soil Conservation

Service, 1992; Wenzel, 1992). (For more information on legislation affecting wetlands, see the article "Wetland Protection Legislation" in this volume.)

CONCLUSIONS

Wetland restoration and creation is more an art than a science, and functional replacement of wetlands has not been conclusively demonstrated. At the same time, the growing body of literature and experience is increasing the ability to discern which projects have a high probability of restoring or replacing damaged or lost ecosystems. Two factors that most limit the effective use of restoration and creation are: (1) lack of information on ecologically mature restored and created wetlands, and on the maturation process; and (2) the limited number of well designed and well constructed project wetlands that can be used as models.

In general, restoration is likely to be more successful than creation. Restoration of a damaged or destroyed wetland will have a greater chance of establishing the range of prior wetland functions, including critical habitat. Also, chances are greater for the long-term persistence of a restored wetland than for one created where none existed before.

Restoration is likely to be more successful than creation.

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