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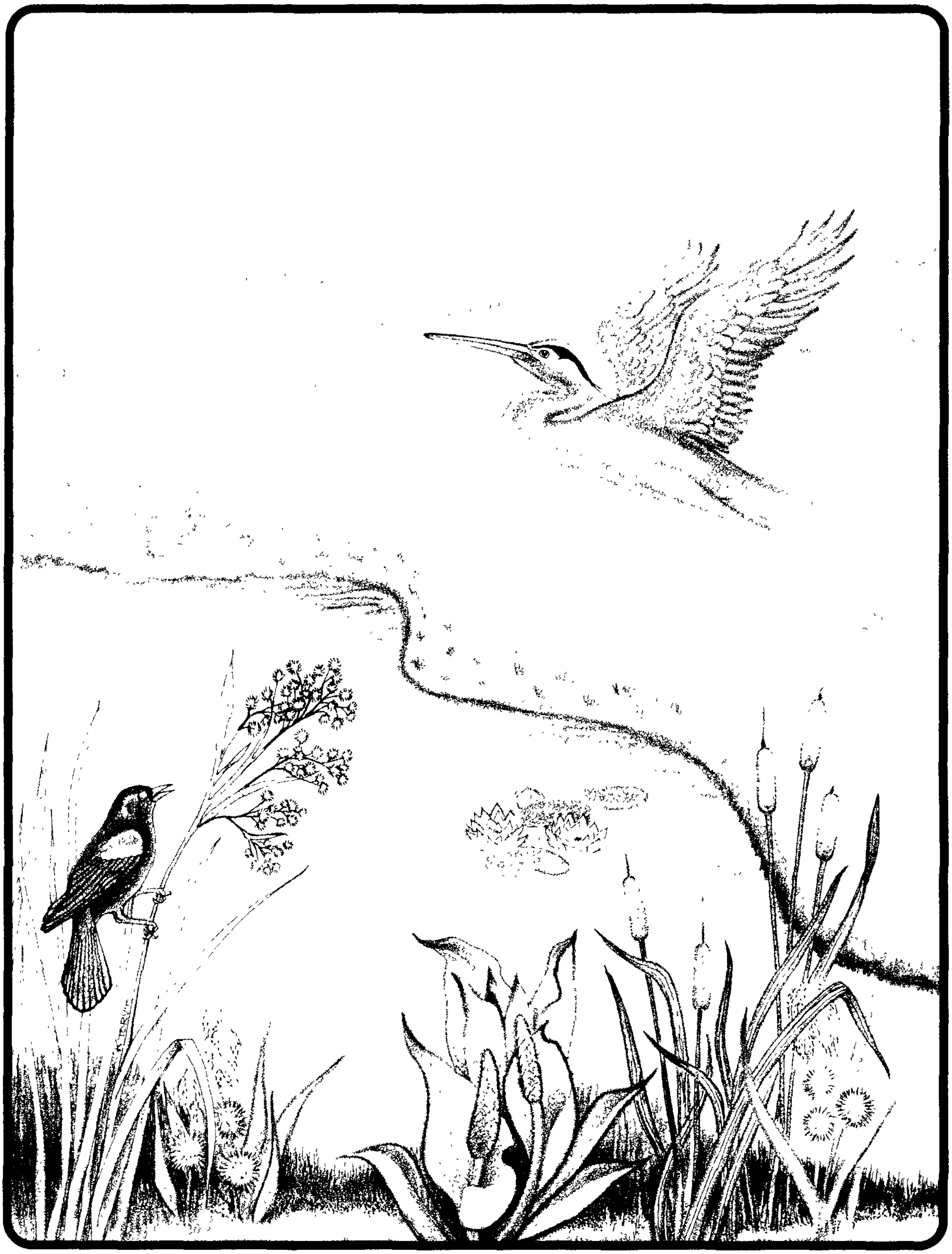
# Wetland Creation and Restoration: The Status of the Science Vol. II



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# WETLAND CREATION AND RESTORATION: THE STATUS OF THE SCIENCE

## Volume II: Perspectives

Edited by:

Jon A. Kusler
Association of State Wetland Managers
Box 2463
Berne, New York 12023

and

Mary E. Kentula
NSI Technology Services, Corporation
200 S.W. 35th Street
Corvallis, Oregon 97333

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Cover by Kathryn Torvik

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Roy R. Lewis III
*Lewis Environmental Services, Inc.*

## INTRODUCTION

This document includes a glossary that was prepared after review by all the authors. Four versions of the manuscript have been circulated for reviewers' comments, and each version was an improvement on the previous one. The specific definitions in the glossary represent an attempt to bring some order to the terminology applied to the topic of wetland creation and restoration. It has been our collective experience that much confusion exists about specific terms, and they are used in different ways by different authors in different parts of the country. Unfortunately, much of the existing confusion is becoming formalized as states, counties, and municipalities develop their own regulations related to wetland creation and restoration. This discussion of terminology is meant to highlight the major problem areas.

## HISTORICAL CONTEXT

In looking for a starting point we were able to find only three existing glossaries applicable to the topic. These were contained in the U.S. Army Corps of Engineers Wetlands Delineation Manual prepared by the Environmental Laboratory Waterways Experiment Station, Vicksburg (Environmental Laboratory 1987), the U.S. Fish and Wildlife Service's classification of wetlands and deepwater habitats of the United States (Cowardin et al. 1979), and the proceedings of a conference titled Wetland Functions, Rehabilitation and Creation in the Pacific Northwest: The State of Our Understanding, prepared by the Washington State Department of Ecology (Strickland 1986). Three additional glossaries (Helm 1985, Rawlins 1986, and Soil Survey Staff 1975) were recommended by reviewers and have been used to improve this section. To these combined glossaries were added definitions from individual authors of published papers or proceedings, for example Zedler (1984) and Schaller and Sutton (1978), and regulatory or review agency rule promulgation, such as U.S. Fish and Wildlife Service (1981). Where the existing definitions were checked against dictionary definitions, Websters Unabridged Dictionary, Second Edition (McKechnie 1983) was used as the reference dictionary. Some geological terms were taken from Bates and Jackson (1984) and Gary et al. (1972) as recommended by reviewers.

## DISCUSSION

The five key definitions are: mitigation, restoration, creation, enhancement, and success. Briefly, McKechnie (1983) defines these terms as follows:

**MITIGATION** alleviation; abatement or diminution, as of anything painful, harsh, severe, afflictive, or calamitous (p. 1152);

**RESTORATION** a putting or bringing back into a former, normal, or unimpaired state or condition (p. 1544);

**CREATION** the act of bringing into existence (p. 427);

**ENHANCEMENT** the state or quality of being enhanced; rise, increase, augmentation (p. 603);

**SUCCESS** favorable or satisfactory outcome or result (p. 1819).

For the purposes of this document, we are defining these terms so that there is as little ambiguity and overlap as possible. The glossary definition and an explanation of each of the key terms is provided below.

**MITIGATION** - For the purposes of this document, the actual restoration, creation, or enhancement of wetlands to compensate for permitted wetland losses. The use of the word mitigation here is limited to the above cases and is not used in the general manner as outlined in the President's Council on Environmental Quality National Environmental Policy Act regulations (40 CFR 1508.20).

**MITIGATION BANKING** - Wetland restoration, creation, or enhancement undertaken expressly for the purpose of providing compensation for wetland losses from future development activities. It includes only actual wetland restoration, creation, or enhancement occurring prior to elimination of another wetland as part of a credit program. Credits may then be withdrawn from the bank to compensate for an individual wetland destruction. Each bank will probably have its own unique credit system based upon the functional values of the wetlands unique to the area. As defined here, mitigation banking does not involve any exchange of money for permits. However, some mitigation programs, such as those in California, do accept money in lieu of actual wetland restoration, creation or enhancement.

**RESTORATION** - Returned from a disturbed or totally altered condition to a previously existing natural, or altered condition by some action of man. Restoration refers to the return to a pre-existing condition. It is not necessary to have complete knowledge of what those pre-existing conditions were; it is enough to know a wetland of whatever type was there and have as a goal the return to that same wetland type. Restoration also occurs if an altered wetland is further damaged and is then returned to its previous, though altered condition. That is, for restoration to occur it is not necessary that a system be returned to a pristine condition. It is, therefore, important to define the goals of a restoration project in order to properly measure the success.

In contrast with restoration, creation (defined below) involves the conversion of a non-wetland habitat type into wetlands where wetlands never existed (at least within the recent past, 100-200 years). The term re-creation is not recommended here due to confusion over its meanings. Schaller and Sutton (1978) define restoration as a return to the exact pre-existing conditions, as does Zedler (1984). Both believe restoration is therefore seldom, if ever, possible. Schaller and Sutton (1978) use the term rehabilitation equivalent to our restoration. For our purposes, "rehabilitation" refers to the conversion of uplands to wetlands where wetlands previously existed. It differs from restoration in that the goal is not a return to previously existing conditions but conversion to a new or altered wetland that has been determined to be "better" for the system as a whole. Reclamation is also used to mean the same thing by some, but "wetland reclamation" often means filling and conversion to uplands, therefore its use is not recommended.

**CREATION** - The conversion of a persistent non-wetland area into a wetland through some activity of man. This definition presumes the site has not been a wetland within recent times (100-200 years) and thus restoration is not occurring. Created wetlands are subdivided into two types: artificial and man-induced. An artificial created wetland exists only as long as some continuous or persistent activity of man (i.e., irrigation, weeding) continues. Without attention from man, artificial wetlands revert to their original habitat type. Man-induced created wetlands generally result from a one-time action of man and persist on their own. The one-time action might be intentional (i.e., earthmoving to lower elevations) or unintentional (i.e., dam building). Wetlands created as a result of dredged material deposition may have subsequent periods during which additional deposits occur. Man-initiated is an acceptable synonym.

**ENHANCEMENT** - The increase in one or more values of all or a portion of an existing wetland by man's activities, often with the accompanying decline in other wetland values. Enhancement and restoration are often confused. For our purposes, the intentional alteration of an existing wetland to provide conditions which previously did not exist and which by consensus increase one or more values is enhancement. The diking of emergent wetlands to create persistent open-water duck habitat is an example; the creation of a littoral shelf from open water habitat is another example. Some of the value of the emergent marsh may be lost as a result (i.e., brown shrimp nursery habitat).

**SUCCESS** - Achieving established goals. Unlike the dictionary definition, success in wetlands restoration, creation, and enhancement ideally requires that criteria, preferably measurable as quantitative values, be established prior to commencement of these activities. However, it is important to note that a project may not succeed in achieving its goals yet provide some other values deemed acceptable when evaluated. In other words, the project failed but the wetland was a "success". This may result in changing the success criteria for future projects. It is important, however, to acknowledge the non-attainment of previously established goals (the unsuccessful project) in order to improve goal setting. In situations where poor or nonexistent goal setting occurred, functional equivalency may be determined by comparison with a reference wetland, and success defined by this comparison. In reality, this is easier said than done.

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# GLOSSARY

**AREAL COVER** - A measure of dominance that defines the degree to which above-ground portions of plants (not limited to those rooted in a sample plot) cover the ground surface. It is possible for the total areal cover in a community to exceed 100% because (a) many plant communities consist of two or more vegetative strata (overstory, understory, ground cover, undergrowth); (b) areal cover is estimated by vegetative layer; and (c) foliage within a single layer may overlap.

**ARTIFICIAL WETLAND** - A created wetland requiring constant application of water or maintenance to provide wetland values.

**BASAL AREA** - The cross-sectional area of a tree trunk measured in square inches, square centimeters, etc. Basal area is normally measured at 4.5 feet (1.4 m) above ground level or just above the buttress if the buttress exceeds that height and is used as a measure of dominance. The most easily used tool for measuring basal area is a tape marked in units of area (i.e., square inches). When plotless methods are used, an angle gauge or prism will provide a means of rapidly determining basal area. This term is also applicable to the cross-sectional area of a clumped herbaceous plant, measured at 1.0 inch (2.54 cm) above the soil surface.

**BASELINE STUDY** - An inventory of a natural community or environment that may serve as a model for planning or establishing goals for success criteria. Synonym: reference study.

**BENCH MARK** - A fixed, more or less permanent reference point or object, the elevation and horizontal location of which is known. The U.S. Geological Survey [USGS] installs brass caps in bridge abutments or otherwise permanently sets bench marks at convenient locations nationwide. The elevations on these marks are referenced to the National Geodetic Vertical Datum [NGVD], also commonly known as Mean Sea Level [MSL] although they may not be exactly the same. For most purposes of wetland mitigation, they can be assumed to be equivalent although a local surveyor should be consulted for final determination. Locations of these bench marks on USGS quadrangle maps are shown as small triangles. The existence of any bench mark should be field verified before planning work that relies on a particular reference point. The USGS, local state surveyor's office, or city or town engineer can provide information on the existence, exact location and exact elevation of bench marks, and the equivalency of NGVD and MSL.

**CANOPY LAYER** - The uppermost layer of vegetation in a plant community. In forested areas, mature trees comprise the canopy layer, while the tallest herbaceous species constitute the canopy layer in a marsh.

**CONTROL PLOT** - An area of land used for measuring or observing existing undisturbed conditions.

**CONTOUR** - An imaginary line of constant elevation on the ground surface. The corresponding line on a map is called a "contour line".

**CREATED WETLAND** - The conversion of a persistent upland or shallow water area into a wetland through some activity of man.

**DEGRADED WETLAND** - A wetland altered by man through impairment of some physical or chemical property which results in a reduction of habitat value or other reduction of functions (i.e., flood storage).

**DENSITY** - The number of individuals per unit area.

**DIAMETER AT BREAST HEIGHT [DBH]** - The width of a plant stem as measured at 4.5 feet (1.4 m) above the ground surface or just above the buttress if over 4.5 feet (1.4 m).

**DISTURBED WETLAND** - A wetland directly or indirectly altered from a natural condition, yet retaining some natural characteristics; includes natural perturbations.

**DOMINANCE** - As used herein, a descriptor of vegetation that is related to the standing crop of a species in an area, usually measured by height, areal cover, density, or basal area (for trees), or a combination of parameters.

**DOMINANT PLANT SPECIES** - A plant species that exerts a controlling influence on or defines the character of a community.

**DRAINED** - A condition in which the level or volume of ground or surface water has been reduced or eliminated from an area by artificial means.

**DRIFT LINE** - An accumulation of debris along a contour (parallel to the water flow) that represents the height of an inundation event.

**EMERGENT PLANT** - A rooted plant that has parts extending above a water surface, at least during portions of the year but does not tolerate prolonged inundation.

**ENHANCED WETLAND** - An existing wetland where some activity of man increases one or more values, often with the accompanying decline in other wetland values.

**EXOTIC** - Not indigenous to a region; intentionally or accidentally introduced and often persisting.

**EXPERIMENTAL PLOT** - An area of land used for measuring or observing conditions resulting from a treatment (i.e., an installation of particular plants).

**FILL MATERIAL** - Any material placed in an area to increase surface elevation.

**FREQUENCY (vegetation)** - The distribution of individuals of a species in an area. It is quantitatively expressed as:

$$\frac{\text{Number of samples containing species A}}{\text{Total number of samples}} \times 100$$

**FUNCTIONAL VALUES** - Values determined by abiotic and biotic interactions as opposed to static measurements (e.g., biomass).

**HABITAT** - The environment occupied by individuals of a particular species, population, or community.

**HABITAT VALUE** - The suitability of an area to support a given evaluation species.

**HEADWATER FLOODING** - A situation in which an area becomes inundated primarily by surface runoff from upland areas.

**HERB** - A nonwoody individual of a macrophytic species.

**HERBACEOUS LAYER** - Any vegetative stratum of a plant community that is composed predominantly of herbs.

**HYDRIC SOIL** - A soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation. Hydric soils that occur in areas having positive indicators of hydrophytic vegetation and wetland hydrology are wetland soils.

**HYDROLOGIC REGIME** - The distribution and circulation of water in an area on average during a given period including normal fluctuations and periodicity.

**HYDROLOGY** - The science dealing with the properties, distribution, and circulation of water both on the surface and under the earth.

**HYDROPHYTE** - Any macrophyte that grows in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content; plants typically found in wet habitats. Obligate hydrophytes require water and cannot survive in dry areas. Facultative hydrophytes may invade upland areas.

**HYDROPHYTIC VEGETATION** - The sum total of macrophytic plant life growing in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content. When hydrophytic vegetation comprises a community where indicators of hydric soils and wetland hydrology also occur, the area has wetland vegetation.

**IMPORTANCE VALUE** - A quantitative term describing the relative influence of a plant species in a plant community, obtained by summing any combination of relative frequency, relative density, and relative dominance.

**INDIGENOUS SPECIES** - Native to a region.

**IN-KIND REPLACEMENT** - Providing or managing substitute resources to replace the functional values of the resources lost, where such substitute resources are also physically and biologically the same or closely approximate those lost.

**INUNDATION** - A condition in which water from any source temporarily or permanently covers a land surface.

**MACROPHYTE** - Any plant species that can be readily observed without the aid of optical magnification. This includes all vascular plant species and mosses (e.g., Sphagnum spp.), as well as large algae (e.g., Chara spp., kelp).

**MAINTENANCE** - Any activities required to assure successful restoration after a project has begun (i.e., erosion control, water level manipulations).

**MAN-INDUCED WETLAND** - Any area of created wetlands that develops wetland characteristics due to some discrete non-continuous activity of man.

**MEAN SEA LEVEL** - A datum, or "plane of zero elevation", established by averaging hourly tidal elevations over a 19-year tidal cycle or "epoch". This plane is corrected for curvature of the earth and is the standard reference for elevations on the earth's surface. The National Geodetic Vertical Datum [NGVD] is a fixed reference relative to Mean Sea Level in 1929. The relationship between MSL and NGVD is site-specific.

**MESOPHYTIC** - Any plant species growing where soil moisture and aeration conditions lie between extremes. These species are typically found in habitats with average moisture conditions, neither very dry nor very wet.

**MITIGATION** - The President's Council on Environmental Quality defined the term "mitigation" in the National Environmental Policy Act regulations to include "(a) avoiding the impact altogether by not taking a certain action or parts of an action; (b) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (c) rectifying the impact by repairing, rehabilitating, or restoring the affected environment; (d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and (e) compensating for the impact by replacing or providing substitute resources or environments" (40 CFR Part 1508.20(a-e)). For the purposes of this document, mitigation refers only to restoration, creation, or enhancement of wetlands to compensate for permitted wetland losses.

**MITIGATION BANKING** - Wetland restoration, creation or enhancement undertaken expressly for the purpose of providing compensation credits for wetland losses from future development activities.

**MONITORING** - Periodic evaluation of a mitigation site to determine success in attaining goals. Typical monitoring periods for wetland mitigation sites are three to five years.

**NATURAL** - Dominated by native biota and occurring within a physical system which has developed through natural processes (without human intervention), in which natural processes continue to take place.

**NUISANCE SPECIES** - Species of plants that detract from or interfere with a mitigation project, such as most exotic species and those indigenous species whose populations proliferate to abnormal proportions. Nuisance species may require removal through maintenance programs.

**OUT-OF-KIND REPLACEMENT** - Providing or managing substitute resources to replace the functional values of the resources lost, where such substitute resources are physically or biologically different from those lost.

**PHYSIOGNOMY** - A term used to describe a plant community based on community stratification and growth habit (e.g., trees, herbs, lianas) of the dominant species.

**PLANT COMMUNITY** - All of the plant populations occurring in a shared habitat or environment.

**PLANT COVER** - see AREAL COVER.

**PONDED** - A condition in which water stands in a closed depression. Water may be naturally removed only by percolation, evaporation, and/or transpiration.

**POORLY DRAINED** - Soils that are commonly wet at or near the surface during a sufficient part of the year that field crops cannot be grown under natural conditions. Poorly drained conditions are caused by a saturated zone, a layer with low hydraulic conductivity, seepage, or a combination of these conditions.

**PRODUCTIVITY** - Net annual primary productivity; the amount of plant biomass that is generated per unit area per year.

**QUANTITATIVE** - A precise measurement or determination expressed numerically.

**RECLAIMED WETLANDS** - Same as restored wetland, but often used in other parts of the world to refer to wetland destruction due to filling or draining.

**REHABILITATION** - Conversion of an upland area that was previously a wetland into another wetland type deemed to be better for the overall ecology of the system.

**RELATIVE DENSITY** - A quantitative descriptor, expressed as a percent, of the relative number of individuals in an area; it is calculated by:

$$\frac{\text{Number of individuals of species A}}{\text{Total number of individuals of all species}} \times 100$$

**RELATIVE DOMINANCE** - A quantitative descriptor, expressed as a percent, of the relative amount of individuals of a species in an area; it is calculated by:

$$\frac{\text{Amount of species A}}{\text{Total amount of all species}} \times 100$$

The amount of a species may be based on percent areal cover, basal area, or height.

**RELATIVE FREQUENCY** - A quantitative descriptor, expressed as a percent, of the relative distribution of individuals in an area; it is calculated by:

$$\frac{\text{Frequency of species A}}{\text{Total frequency of all species}} \times 100$$

**RELIEF** - The change in elevation of a land surface between two points; collectively, the configuration of the earth's surface, including such features as hills and valleys. See also TOPOGRAPHY.

**RESTORED WETLAND** - A wetland returned from a disturbed or altered condition to a previously existing natural or altered condition by some action of man (i.e., fill removal).

**SAMPLE PLOT** - An area of land used for measuring or observing existing conditions.

**SOIL** - The collection of natural bodies on the earth's surface containing living matter and supporting or capable of supporting plants out-of-doors. Places modified or even made by man of earthy materials are included. The upper limit of soil is air or shallow water and at its margins it grades to deep water or to barren areas of rock or ice. Soil includes the horizons that differ from the parent material as a result of interaction through time of climate, living organisms, parent materials and relief.

**SLOPE** - A piece of ground that is not flat or level.

**SUBSTRATE** - The base or substance on which an attached species is growing.

**TIDAL** - A situation in which the water level periodically fluctuates due to the action of lunar and solar forces upon the rotating earth.

**TOPOGRAPHY** - The configuration of a surface, including its relief and the position of its natural and man-made features.

**TRANSECT** - As used here, a line on the ground along which observations are made at some interval.

**TRANSITION ZONE** - The area in which a change from wetlands to nonwetlands occurs. The transition zone may be narrow or broad.

**TREE** - A woody plant >3.0 inches in diameter at breast height, regardless of height (exclusive of woody vines).

**UPLAND** - As used herein, any area that does not qualify as a wetland because the associated hydrologic regime is not sufficiently wet to elicit development of vegetation, soils, and/or hydrologic characteristics associated with wetlands. Such areas occurring within floodplains are more appropriately termed non wetlands.

**WATER TABLE** - The upper surface of groundwater or that level below which the soil is saturated with water. The saturated zone must be at least 6 inches thick and persist in the soil for more than a few weeks.

**WETLANDS** - Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

# INFORMATION NEEDS IN THE PLANNING PROCESS FOR WETLAND CREATION AND RESTORATION

**Edgar W. Garbisch**
*Environmental Concern Inc.*

*ABSTRACT.* This chapter addresses both the factors which should be considered at various stages of the permitting process and those which should be contained in plans to create or restore wetlands. The information wetland regulatory agencies need to critically evaluate proposed mitigation projects in terms of acceptability, feasibility, and soundness is presented. If the process suggested is followed, the permit conditions should contain (1) details of construction and landscape plans, (2) specifications to facilitate verification by the regulatory agencies that the wetland creation/restoration project has been constructed according to the plans, and (3) the criteria by which to determine if the project has been maintained and monitored during the life of the permit.

## INTRODUCTION

State wetland regulations and policies vary widely and many are still under development. Marked variances also occur in the administration of federal regulations in the east and probably nationwide. Consequently, it is not possible to recommend a planning process for wetland creation and restoration that will be uniformly acceptable. This chapter reflects the opinions of the author whose experiences have been limited largely to the eastern United States. Hopefully, the recommendations provided here will prove useful and applicable to some regions of the United States.

Much of the wetland creation and restoration work conducted throughout the United States results from regulatory requirements that compensation (mitigation) take place for permitted wetland impacts and losses. Prior to issuing permits, regulatory agencies review the applicants' mitigation plans to ensure that disturbed wetlands are restored or appropriate compensation is provided through compensation. If proposed mitigation plans are found acceptable, they generally become part of the permits together with stipulations or conditions relating to criteria for success and acceptability, timetables for wetland creation/restoration, monitoring, and reporting--especially when these stipulations or conditions have not been specifically addressed in the mitigation plans.

Most of the wetland creation/restoration plans published in the Corps of Engineers Public Notices lack the details necessary to evaluate their potential for successful execution. Such plans are often the only ones available for review by interested members of the general public and by the state and federal regulatory agencies. Moreover, they are often of insufficient detail for the agencies to verify that the "as built" project will compare acceptably to the one conceptually proposed. Without such details, the regulatory agencies must place full responsibility on the applicant, and indirectly on the applicant's mitigation consultant, to design and acceptably construct the wetland creation/restoration as called for in the permits.

If a regulatory agency is charged with the preservation of wetlands by legislation and policy, and if the agency permits a given wetland to be destroyed provided there is adequate compensation, then the regulatory agency's responsibility is to (1) engage in all aspects of review and evaluation of the wetland construction details, as well as other matters of planning, and (2) help ensure that such compensation is constructed successfully. Requiring "successful compensation" as a permit condition does not, in itself, ensure success. The compensation site and/or the plans and specifications may be inappropriate and success may not be possible. The regulatory agencies should have complete confidence in the compensation site and in the plans and specifications before making success a permit condition.

The objectives of this chapter are to define the information needed by the regulatory agencies at pre-permit application, at permit application, and during the life of the permit in order for proposed wetland creation/restoration mitigation projects to be fully and critically evaluated in terms of (1) acceptability, feasibility, and soundness of the proposed plan, (2) the construction performance as related to the project being constructed in accordance with the plans and specifications, and (3) the post construction performance as related to maintenance of hydrological requirements and vegetation establishment. All of the above combine to provide the regulatory agencies' planning process for wetland creation and restoration.

If a regulatory agency feels that it does not have in-house the qualified staff to conduct the necessary critical review and evaluation of detailed mitigation plans involving wetland creation/restoration, a qualified consultant might be retained to perform this service.

## PRE-PERMIT APPLICATION

The development of detailed construction plans and specifications for wetland creation/restoration mitigations is usually time consuming and expensive. Their submittal should not be required until such time that (1) the regulatory agencies have agreed that the proposed project will be permitted pending review and acceptance of a final mitigation plan or (2) it is determined to be in the best public interest that they be submitted (e.g., for complicated or controversial projects).

Generally, the regulatory agencies will not discuss wetland creation/restoration as a compensatory measure for proposed wetland losses and impacts at early stages of pre-permit application meetings. They must be assured first that all other measures to mitigate such losses and impacts have been explored. However, after this is done, the applicant should be prepared to discuss wetland creation/restoration when certain wetland losses and impacts are unavoidable. In this event, the applicant should have available for distribution and discussion a preliminary mitigation plan that contains the basic information provided below.

### PRELIMINARY MITIGATION PLAN

The Preliminary Mitigation Plan should contain the following:

1. **Text, 8.5" X 11" plans, and photographs describing the existing conditions at the project site** and particularly the wetlands on site and the portion(s) of these wetlands where disturbance and/or loss is unavoidable. Accurate areas of all wetlands to be disturbed and/or lost should be provided according to wetland type, if more than one type is involved.

2. **An evaluation of all wetlands that are proposed to be disturbed and/or lost** including their apparent stabilities, their dominant vegetative compositions, and their prevailing functions. An objective evaluation such as provided by WET (Wetland Evaluation Technique) to level-1 is suggested.

3. **Text, 8.5" X 11" plans, and photographs briefly describing the existing conditions at the wetland creation site.**

4. **Text and 8.5" X 11" plans that describe conceptually the proposed wetland creation** together with arguments, data, and calculations that demonstrate that the necessary hydrological requirements will be realized. Accurate areas of all wetlands to be created should be provided according to wetland type, if more than one type is proposed to be created.

5. **An evaluation of the proposed created wetland(s)**, as in Section 2, with an emphasis on functional replacement and enhancement relative to those functions provided by the existing wetland(s) to be lost.

6. **Text providing methods of any wetland restoration that is proposed** together with discussion of any possible enhancement of functional values that may be provided as part of the restoration. Issues related to the impact of soils compaction and other wetland disturbances on the success of the restoration should be addressed. If such impact(s) may limit the success of the restoration, approaches to circumvent the problem(s) should be discussed.

The Preliminary Mitigation Plan should not be a voluminous submittal. It should be brief and to the point. It is intended to be the precursor to the Draft Mitigation Plan which should be submitted later with the permit application, following reviews and comments by the regulatory agencies.

If the necessary hydrological requirements for the created wetland cannot be verified, monitoring of stream flows, ground water levels, etc. will be necessary for up to one year before the Draft Mitigation Plan can be prepared. Detailed soil borings throughout the proposed wetland creation site should be completed prior to preparing the Draft Mitigation Plan to verify that the soil characteristics will support the desired hydrology and functions of the created wetland.

## DRAFT MITIGATION PLAN

Following any necessary monitoring and testing, and receipt and consideration of comments by the reviewing agencies, the Draft Mitigation Plan can be prepared. The Draft Mitigation Plan is a revised Preliminary Mitigation Plan and will include changes primarily in Sections 4-6.

The 8.5" X 11" plans provided in the Draft Mitigation Plan should be sufficient to be included in the Corps of Engineers Public Notice. Larger plans that are reduced to 8.5" X 11" are not recommended, as details and letterings may be reduced beyond recognition. After receipt of the comments on the Public Notice and review of comments derived from any public meetings, the regulatory agencies will come to a decision regarding issuance of permits. If the decision is to issue such permits pending receipt and acceptance of the construction and landscape plans and specifications for any created and restored wetlands, these materials must be provided. These plans and specifications together with the Draft Mitigation Plan constitutes the Final Mitigation Plan. The Final Mitigation Plan may have been requested by the regulatory agencies at an earlier time or it may have been provided voluntarily by the applicant.

## FINAL MITIGATION PLAN

### Draft Mitigation Plan + Construction and Landscape Plans and Specifications

The construction and landscape plans and specifications should be sufficiently detailed for bidding purposes, engineering and biological review, and verification of the "as built" condition. All monitoring, inspections, reporting, and maintenance during the life of the permit or during the required period of time should be detailed on the plans and specifications. The extent and duration of all landscape guarantees should be specified. It is recommended that the plans and specifications submitted as part of the Final Mitigation Plan include but not necessarily be limited to the following items:

1. **All plans should be scaled at 1" = 100' or larger** i.e., 1" = 50') and show 1.0' contours or less, if important.
2. **All slopes should be designed to be stable** in the absence of vegetation.
3. **Sufficient cross-sections of land and structures should be provided** so as to clarify all typical and atypical conditions.
4. **In addition to wetlands, all land** (e.g., transition and buffer zones and upland) included in the proposed mitigation should be shown.
5. **A summary of the sizes and types of wetlands** lost and created should be given.
6. **A summary of the sizes and types of non-wetland** habitats created as enhancement features should be given.
7. **The site hydrology should be clearly shown.** For example:

   Pool Elevation: if water level is static and non-fluctuating.

   Seasonal Pool Elevations: spring, summer, fall/winter if water level fluctuates.

   Tidal Elevations: when flooding water is tidal. Mean high water (MHW), and mean low water (MLW) should be indicated. Corrections to National Geodetic Vertical Datum (NGVD) or other local datum should be provided in the NOTES.

   Ground Water Levels: when flooding is temporary during times of storms and spring thaws. The expected seasonal ground water levels should be provided in the NOTES.
8. **Verification of hydrology should be detailed in the NOTES:** e.g., stream flow year-round and weir controls pool level; groundwater given in soil boring logs; stream/river water level data and analyses; calculations if stormwater is the only source of water; vegetation zonation of existing nearby wetlands sharing the same hydrology as the proposed vegetated wetlands; etc.
9. **The construction timetable should be provided** together with notations of any elements whose timing may be critical to biological success; e.g., coordination of completion of earthwork with the installation of certain species of plants to minimize the impact of salt buildup in soils; timing of plant installation to minimize the impact of waterfowl and drought; specify time windows for seeding to ensure vegetation establishment.
10. **The locations and elevations of all bench**

**marks on site** should be shown on the plans.

11. **A Summary** of the volume of earthwork and total tonnage of stonework should be given.

12. **The proposed disposition of any excavated materials** should be given.

13. **The elevations and elevation ranges for the planting and seeding** of all plant species should be shown. Plant spacings and seeding rates should be given.

14. **Landscape lists, notes, and specifications** should include the following:

    a. Plant lists for seeding and planting that provide total quantities, plant sizes, and plant conditions (e.g., bare root, can, peat pot, etc.). Acceptable substitutes should be indicated if the availability of some species might be limited.

    b. Because of the variable quality of nursery-produced wetland plant materials, acceptable plant conditions should be clearly specified. Some examples follow: Container grown nursery stock shall have been grown in a container long enough for the root system to have developed sufficiently to hold its soil together. Peat-potted nursery stock shall have been grown in 1.50" to 1.75" square peat pots long enough and under proper conditions for the root systems to be sufficiently well-developed through the sides and bottoms of the pots to prevent easy removal of the plants from the pots. Each pot shall contain a minimum of (specify) stems. Container grown nursery stock to be transplanted to wet areas year-round shall have been grown under hydric soil conditions for at least one growing season. The nursery providing these materials must certify that these growing conditions were met.

    c. Fertilization requirements that include rates and fertilizer formulations.

    d. Any special conditioning of the plant materials that may be required. For example, conditioning plant materials to specified water salinities or conditioning facultative/facultative wet species to hydric soil cultivation.

    e. Any geographical constraints regarding the origin of the plant materials.

    f. The names and addresses of all acceptable commercial sources of plant materials.

    g. A requirement that the supplier of seeds specified provide the purity and the current germination percentages of the seeds.

    h. What plant materials, if any, may be field collected and from where they will be taken.

    i. Construction details and timetable for any required controls against wildlife depredation.

    j. Details and definitions of any landscape guarantees, including the guarantee periods.

15. **Maintenance program during the guarantee period, the life of the permit, or other required period** should be detailed. Such maintenance may include invasive weed control of algae, common reed, purple loosestrife, etc.; removal of deposited litter and debris; watering; replanting; repair of water control structures; clearing of culverts; etc.

16. **Any critical elements and possible problems (with solutions)** that may influence the success of the project should be described, even if these items have been addressed in other sections; i.e., 9, 14i, 15. For example, a watering program for vegetation establishment in a floodplain wetland construction may be critical for success and should be restated, even though such a program was included in Section 15. In many instances, wildlife management will be critical for success and should be restated, even though Section 14i describes the item.

17. **Reporting timetable** during the life of the permit or until final approval should be included. The regulatory agencies will want to be informed periodically regarding the wetland construction progress. For example, is construction on schedule and, if not, why and what is being done to get it back on schedule. Are the criteria for success being realized (i.e., has the project been constructed according to the plans and specifications) and if not what corrective action is being taken. Reporting of the results of monitoring should be included in the reporting timetable. Generally, it would seem appropriate to report quarterly during the construction phase of the wetland and annually thereafter during the life of the permit or until final

inspection and approval. Photographs that are keyed on the site plan and that show the existing conditions should be included with all reports to facilitate verifications by the regulatory agencies.

18. **The monitoring program for the life of the permit** should be provided in the specifications or on the plans.

It is the author's opinion that if the wetland is constructed or restored according to the detailed construction and landscape plans and specifications that are part of the Final Mitigation Plan, the project must be considered successful. If the "as built" project is according to plans and specifications, then the wetland functional replacement and enhancement, as determined in Section 5 of the Draft Mitigation Plan, have been realized. Consequently, the monitoring program should be one of inspection and verification of the "as built" project according to hydrological performance, vegetation establishment, and other key elements in the plans and specifications. Scientific studies should not be part of a monitoring program sanctioned by the regulatory agencies. While such studies often will be important and should be encouraged, they should not be part of the required mitigation process.

## CONCLUSION: NEED FOR CERTIFICATION OF MITIGATION CONSULTANTS

To a very large degree, the success of wetland creation/restoration projects will depend on the correctness of the plans and specifications and the execution of the construction according to these plans and specifications. Consequently, it is important that people with a background in both wetland creation/restoration design and the practicalities of construction become associated with such projects. To ensure that future wetland creation/restoration projects are planned and directed by qualified people, it is suggested that the Preliminary, Draft, and Final Mitigation Plans be signed and stamped by an individual who has been certified as a qualified wetland creation/restoration scientist. It is further suggested that such a certification program be undertaken by an organization such as The Society of Wetland Scientists.

# WETLAND EVALUATION FOR RESTORATION AND CREATION

**Kevin L. Erwin**
***Kevin L. Erwin Consulting Ecologist, Inc.***

*ABSTRACT.* One of the principal questions that must be addressed when evaluating the success of a created, restored, or enhanced wetland is, to what extent does the wetland provide biological and hydrological functions similar to those of the original or desired "reference" wetland. Wetland evaluation methods are widely discussed throughout the literature. However, many would not be appropriate to evaluate a created or restored wetland, particularly given the time and financial limitations often placed upon the investigator and reviewer. The selected method must adequately characterize and evaluate the functions of the created and reference wetlands given the limitations of time, budget, type of wetland, size of wetland, context, degree of alteration from original wetland, location, and expertise of investigator. A qualitative wetland evaluation plan should include: a baseline vegetation survey, annual reporting of post construction monitoring conducted for a minimum of five years, fixed point panoramic photographs, rainfall and water level data, a plan view showing all sampling and recording station locations, wildlife utilization observations, fish and macroinvertebrate data, a maintenance plan, and a qualified individual to conduct monitoring. Quantitative evaluation is recommended when the proposed construction technique is unproven, where the ability to successfully create or restore the habitat is unproven, or when success criteria are related to obtaining specific thresholds of plant cover, diversity, and wildlife utilization. Quantitative evaluation should include: surface and groundwater hydrological monitoring, and vegetation analysis. The methods will often require some site specific fine tuning to prevent the over simplification of the wetlands complexity.

A rapidly accessible, easily understood, and cost effective database on wetland creation and restoration projects is needed to support environmental regulatory agency review, decision making, and action on specific projects. Any comprehensive wetland evaluation effort must be proceeded by the establishment of criteria which the investigator and regulator believe to be fundamental to the existence, functions, and contributions of the wetland system and its surrounding landscape. Failure to address the wetlands system's surrounding landscape leads to an inaccurate characterization of the wetland. Additional research is needed to establish the inter-relationships between wetlands, transitional areas, and adjacent uplands.

## INTRODUCTION

Wetland evaluation is needed prior to a project to set goals and develop a plan, as a component of the monitoring program, and as a means for ultimately determining compliance. Although the timing differs for each of these evaluations, the factors to be considered and the general needs and approaches are much the same.

The following chapter has been prepared to assist consultants, client/permit applicants, and regulatory personnel in evaluating restored and created wetlands. It does not exhaustively review potential evaluation approaches, but presents a general framework and discusses selected topics. The chapter draws heavily upon the author's own experience and his many discussions with colleagues. An extensive bibliography of publications dealing with wetland evaluation is provided to assist the reader. As can be seen from the bibliography, a number of efforts have developed and assessed methods for evaluating wetlands. The author draws your attention to: Golet 1973, Winchester and Harris 1979, Reppert et al. 1979, U.S. Army Engineer Division 1980, U.S. Fish and Wildlife Service 1980, Lonard et al. 1981, Adamus and Stockwell 1983, Adamus 1983, Euler et al. 1983, Lonard et al. 1984, and Marble and Gross 1984.

## EVALUATION NEEDS IN RESTORATION/CREATION

Evaluation may be needed for any or all of the following purposes:

1. **Assessing the Original Wetland.** The investigation must obtain, if possible, baseline data which evaluates the reference wetland's form and functions. The reference wetland may be the wetland to be impacted or another wetland chosen as a model for the mitigation project. This baseline data should be used to aid in the establishment of selected success criteria and the design of the wetland project.

2. **Setting goals for the enhancement, restoration or creation of a wetland required as mitigation.** Prior to designing the wetland required as mitigation, if possible, the wetland to be restored or enhanced, or an acceptable reference wetland should be evaluated. This information should be used to set goals for the mitigation project. It also should be used as a baseline from which to design the mitigation project and measure its success. In the case of wetland enhancement, the pre-enhancement baseline evaluation data will be compared with post-enhancement data.

3. **Assessing Project During Maturation.** Monitoring a project periodically during maturation will determine the need for corrections in design or maintenance to get the project back on course.

4. **Determining Post-Project Compliance.** At this stage the evaluation is used to establish compliance with goals or success criteria and to obtain the regulatory agencies' approval.

5. **Describing the Long Term Status.** Information about the wetland's responses to changes in site conditions (i.e., increased water levels, decreased hydroperiod, or colonization by problematic exotic vegetation) is obtained. This will indicate the ability of the system to persist.

The following is a general discussion of factors and considerations in wetland evaluation. It is intended as an overview of the choices available and not as an instructional guide to performing detailed data collection and analysis. These methods, when used individually or in some combination, will provide a varied database: qualitative or quantitative, inexpensive or costly, and relatively quick or lengthy.

## PRACTICAL CONSIDERATIONS

What is the practical approach to wetland evaluation in a particular restoration/creation context or at a specific stage of a project? The answer depends upon a variety of factors. Economic and spacial constraints must be considered for each project evaluation. The investigator should evaluate the available methods and select or develop the method best suited to the situation given its limitations. In many instances the limitations placed upon the investigator have a greater influence on the methods finally selected than the objectives of the study.

### TIME

Time may be a factor when conducting baseline monitoring of a wetland area because of the constraints of the permit application review procedure. In most cases, the regulatory agency should require baseline monitoring to be presented with the permit application to aid in the evaluation of existing conditions and in the establishment of success criteria.

In many instances the investigator may not have the time necessary to conduct a thorough study over the desired number of wet/dry or growing seasons. In such cases, the investigator should choose a time which will provide the greatest amount of information about the site. This information should be easily gathered over time. The most satisfactory time for a limited event evaluation is during the late phase of the growing season and, if possible, when the site is inundated to allow for the collection of fish and macroinvertebrate samples.

### BUDGET

In some instances (i.e., where the project is small or where a public agency is involved) only limited funds will be available for evaluation. In cases where budget constraints exist, some compromises will inevitably be necessary. The investigator must choose an evaluation method and monitoring plan which is the most efficient and provides the greatest amount of desired information at the least cost ("the most bang for the buck").

## TYPE OF WETLAND

Certain methods are more appropriate for one type of wetland than another (i.e., line intercept for nonforested wetlands and line strip or belt transects for forested wetlands). In addition, the fact that certain wetland habitats have proven to be less difficult than others to restore or create should have a bearing on the evaluation method used, and the scope of the baseline monitoring of the reference wetland and the post-construction monitoring.

## SIZE OF WETLAND

The size of the wetland, the number and types of habitats to be evaluated, and the parameters to be examined will place constraints on the method selected.

## CONTEXT

The selection of an evaluation method should depend upon whether single or multiple parameters are chosen as success criteria for the enhanced, created, or restored wetland. If wildlife utilization is the major goal, then a detailed vegetative analysis could be replaced by a more simple floral characterization with greater emphasis on monitoring for wildlife utilization. The science of creating certain marsh habitats is more advanced than for most forested wetland habitats (e.g., bottomland hardwoods), therefore, the monitoring of a marsh restoration project may need to be intensive for a shorter period of time. Many marsh restoration projects can be successfully completed and agency approval received within three growing seasons following construction, whereas a forested wetland project may take one to three decades.

## DEGREE OF ALTERATION FROM ORIGINAL WETLAND

The greater the deviation of the proposed restoration or enhancement project from the original wetland, the more comprehensive the baseline and post wetland construction evaluation methods should be.

## LOCATION

Wetlands are "open" systems with strong links to their adjacent ecosystems. A major factor determining the ecological value of the wetland is its relationship with other ecosystems. These relationships make the wetland an integral part of the landscape of a region or watershed.

## EXPERTISE

The biases, objectives, and the expertise of an investigator will influence the choice of a method, therefore care must be taken to objectively select a method of evaluation that can successfully be used. This caution also holds true for the reviewer who must have an adequate understanding of the method and presentation of data.

# WETLAND FUNCTIONS NEEDING ASSESSMENT

At each stage, the wetland evaluation should be geared toward evaluating particular functions of the created or reference wetland. Excellent references on wetland functions are in the proceedings of a national symposium on wetlands held in 1978 (Greeson, Clark and Clark, 1979), in Reppert et al. (1979), Larson (1982), Adamus (1983), Sather and Smith (1984), Gosselink (1984), Mitsch and Gosselink (1986), and Kusler and Riexinger (1985).

The Federal Highway Administration's Wetland Functional Assessment Method recognizes eleven functions (Adamus 1983) which form a good checklist. These functions are:

## GROUNDWATER RECHARGE

Groundwater recharge by wetlands is generally poorly understood. The majority of hydrologists believe that while some wetlands do recharge groundwater systems, most wetlands do not (Sather and Smith 1984). The soils underlying most wetlands are impermeable which is why there is standing water during the annual cycle (Larson 1982). In the few studies available, recharge was related to the edge:volume ratio of the wetland. Recharge appears to be relatively more important in small wetlands such as prairie potholes than in large wetlands (Mitsch and Gosselink 1986). These small wetlands can contribute significantly to recharge of regional groundwater (Weller 1981). Heimberg (1984) found significant radial infiltration from cypress domes in Florida, with the rate of infiltration relative to the area of the wetland and the depth of the surficial water table. If groundwater recharge is a goal of the restoration or creation project, the design should emphasize the wetland edge to maximize potential for groundwater recharge.

## GROUNDWATER DISCHARGE

Wetlands are generally considered by hydrologists to be a discharge area in terms of total water budget, however, recharge and discharge may be occurring at the same time in some wetlands. The recharge/discharge relationship of a wetland is a function of groundwater piezometric surface ("head") relationships and antecedent conditions (Hollands 1985). Water may be recharging an aquifer and/or discharging to a down gradient wetland, attenuating flows, and possibly providing baseline water flows to the down gradient wetland.

## FLOOD STORAGE

Wetlands may intercept and store stormwater runoff, and hence change sharp runoff peaks to slower discharges of longer duration. Since it is usually the peak flows that produce flood damage, wetlands can reduce the danger of flooding (Novitzki 1979, Verry and Boelter 1979). A study undertaken by Ogawa and Male (1983) found that for floods with a 100-year recurrence, interval or greater, the increase in peak stream flow was very significant for all sizes of streams when the wetlands within the watershed were removed.

Ogawa and Male (1983) summarized that the usefulness of wetlands in reducing downstream flooding increases with: (a) an increase in wetland area, (b) the seriousness of the flooding downstream of the wetland, (c) the size of the flood, (d) the closeness to the upstream wetland, and (e) the lack of other storage areas such as reservoirs. These factors should be considered if the proposed restoration or creation project is within a flood prone area where some improvement to these conditions is desirable.

## SHORELINE ANCHORING

Wetlands such as tropical mangrove forests and temperate Spartina-Juncus saltmarshes, bind shoreline sediments with their root systems, thus anchoring the substrate. The aboveground biomass provides friction to overland sheetflow, wave energy, and storm surges, providing a degree of stabilization to the shoreline under natural conditions.

## SEDIMENT TRAPPING

Wetlands can serve as sinks for particular inorganic nutrients. Many marshes are nutrient traps that purify the water flooding them. Wetlands have several attributes that cause them to have major influences on chemical materials that flow through them (Sather and Smith 1984). Mitsch and Gosselink (1986) describe these attributes in the following manner:

A. A reduction and velocity of streams entering wetlands, causes sediments and chemicals to drop into the wetland.

B. A variety of anaerobic and aerobic processes such as denitrification and chemical precipitation remove certain kinds of chemicals from the water.

C. The high rate of productivity of many wetlands can lead to high rates of mineral uptake by vegetation and subsequent burial in sediments when the plants die.

D. A diversity of decomposers and decomposition processes occur in wetland sediments.

E. A high amount of contact of water with sediments, because of the shallow depths, lead to significant sediment-water exchange.

F. The accumulation of organic peat in many wetlands causes the permanent burial of chemicals.

## FOOD CHAIN SUPPORT

Wetlands possess an inherent ability to trap nutrients. They often store nutrients when there is an abundance, then frequently release them when they are most needed (Niering 1985). In mature wetlands, food chains are elaborate, species diversity is high, the space is well-organized into many different niches, organisms are larger than in immature systems, and life cycles tend to be long and complex. Approximately 60% of the fish and shellfish species that are harvested commercially are associated with wetlands. For example, many fish species utilize wetlands as spawning and/or nursery areas. Some important species are permanent residents and others are transients that periodically feed in the wetlands. Virtually all freshwater species are somewhat dependent upon wetlands, often spawning in marshes bordering lakes or in riparian forests during spring flooding. Saltwater species tend to spawn offshore, moving into the coastal marshes during their juvenile stages, then migrating offshore as they mature. The importance of wetlands to the sport and commercial fishery harvest is well documented in the literature (Peters et al. 1979).

### WILDLIFE HABITAT

It has been estimated that within North America 150 kinds of birds and some 200 kinds of animals are wetland-dependent. Other animals including deer, bear, and racoon also use wetlands (Niering 1985). In addition, wetland habitats are necessary for the survival of a disproportionately high percentage of endangered and threatened species.

### ACTIVE RECREATION, PASSIVE RECREATION, HERITAGE, AND EDUCATION

Wetlands are living museums, where the dynamics of ecological systems can be taught. The high productivity of wetlands is related to the efficient functioning of both the grazing and detritus food chains. In many wetlands there are two major energy flow patterns: (1) the grazing food chain, which involves the direct consumption of green plants, and (2) the detrital food chain, composed of those organisms that depend primarily on detritus or organic debris as their food source. Often the two patterns are interrelated. In lake and pond ecosystems, submerged aquatic plants and floating algae serve as the basis of the food chain. Zooplankton feed on the algae and aquatic insects eat the zooplankton. These are eaten by small fish, which in turn are consumed by larger fish, which in turn may end up on a fisherman's dinner table. In streams, the main sources of organic input, or food for stream organisms, include partly decomposed leaves or other organic material flowing down stream. This debris, or detritus, may be caught in nets set by the larvae of caddis flies. Stone flies also glean the rocks for algae. These insects are in turn consumed by fish, many of which are commercially important.

Activities such as sport fishing along a wetland edge of a lake and canoeing through a hardwood swamp are pursued by thousands of people on a regular basis. Wetlands are an important national heritage providing the sites and experiences many of us attribute to our country's heritage.

### FISHERY HABITAT

Wetlands have been documented as important sources of food and habitat for sport and commercial fisheries. These outdoor laboratories can demonstrate such basic ecological principles as energy flow, recycling, and limiting carrying capacity (Niering 1985).

The Federal Highway Administration (FHWA) assessment procedures are among several which can by used for wetland evaluation for restoration/creation purposes. There are limitations, however, with this approach. Manual implementation of the FHWA assessment procedure (Adamus 1983) is cumbersome and time consuming. The U.S. Army Corps of Engineers Waterways Experiment Station (WES) developed a wetland evaluation technique (WET) that can reliably assess and partially quantify wetland functions and values for Corps of Engineers use. The main structural reorganization of the FHWA technique was to computerize the analytical portion. A discussion of WET is provided in Clarian (1985) and more detailed information on WET is contained in Winchester (1981a and 1981b).

## LEVEL OF DETAIL--DEGREE OF QUANTIFICATION

Having determined the stages in a restoration/creation project at which evaluation should take place and the functions that need assessment, the next major decision relates to the level of detail needed. In general, quantitative evaluation is much more expensive and time-consuming than qualitative approaches. However, quantitative approaches are essential in some instances.

To determine whether qualitative or quantitative evaluation methods are appropriate, the investigator should consider the established history of success in creating the type of wetland proposed for mitigation. In general, much more quantitative and detailed analyses are needed for wetlands with no history of success in creation or restoration.

Choosing the appropriate level and detail ofevaluation and the factors to be evaluated in a particular instance is a process that must be thoroughly considered by each party involved in the evaluation process including the investigator, the reviewer, and the client/applicant. Each should consider the appropriateness of the selected method to provide an adequate characterization of the wetland and the ability to produce the required data and analysis within a realistic time frame. The client or project manager must also assess his/her ability to provide the required budget for the expected duration of monitoring and reporting.

Assuming appropriate funding, enough time, and an attempt to create a wetland with no or little history of success, what should the proponent of a wetland restoration/creation project evaluate? The author suggests the "quantitative" evaluation described in the following section.

## QUANTITATIVE EVALUATION

When the investigator requires quantitative data, both detailed field studies and office evaluation are required. A detailed evaluation often involves hydrologic analysis, studies on plant and animal population dynamics, water quality sampling, soils analysis, topographic mapping, wildlife counts, and a regional watershed analysis. These studies are time consuming, labor intensive, costly, and subject to producing biased results when not properly conducted.

Quantitative evaluation is particularly needed when (1) the proposed construction technique is unproven, (2) where the ability to successfully create or restore the habitat has not been established, or (3) when success criteria are related to attaining specific thresholds of plant cover, diversity, wildlife utilization, etc. Properly applied quantitative evaluation may often be replaced by less intensive evaluation methods after a sufficient period of study (i.e., the latter stages of a restoration/creation project).

Investigators need rapidly accessible, easily understandable, and cost effective data in support of environmental regulatory agency review, decision making, and action on specific projects pursuant to local, state, and federal policies and regulations. A variety of systematic and quantified approaches for evaluating either individual or the full range of wetland functions have been developed by agencies and researchers (see Appendix I). These assessment models vary from very simple to quite sophisticated in the types of factors considered. Their outputs range from a qualitative to a quantitative evaluation of a particular wetland's ability to provide a particular service or function. Some models produce a single numerical rating for the wetlands, while others provide a rating for each function.

## HYDROLOGY

Hydrology is the single most important factor to consider in designing and implementing restoration/creation projects for specific types of wetland systems and their related functions.

### GROUNDWATER

Gathering actual wetland groundwater data is time consuming and expensive; extrapolating data from one wetland to another can be problematic. No quick, accurate, and inexpensive groundwater function predictors are available. Even hydrogeologists experienced in wetland hydrology cannot consistently predict the hydrogeologic functions of specific wetlands (Hollands 1985). Data requirements for understanding the groundwater function of a specific wetland include:

1) Geologic history, including an understanding of the current theories relative to the geologic processes that created the topographic and hydrologic setting in which the wetland is located, (e.g., bedrock and surficial geology).

2) Stratigraphy of the geologic units underlying the wetland and their physical properties, such as permeability.

3) History, stratigraphy, and physical properties of the wetland's organic or mineral soils.

4) Description of the wetland vegetative community.

5) Groundwater and surface water hydrology, including a water budget for the wetland based on items 1 through 4 above.

The recharge/discharge relationship of a wetland is a function of groundwater (head) relationships and antecedent conditions. To determine head relationships, nested water table observation wells (piezometers) are required. These permit simultaneous measurements of head at various levels within the aquifer.

Measurements for at least one year should be required to establish a complete record of recharge/discharge functions. This is normally a costly process.

Perched wetlands, water table wetlands, and other hydrogeologic classifications such as artisan and water table/artisan wetlands (Motts and O'Brien 1980) also require nested wells for identification. Hydrogeologic classifications of wetlands are important in understanding a wetland's water balance and the effect of hydrology on other wetland functions (Hollands 1985). The wetland hydrogeologic classification that appears to be most used by non-hydrogeologist wetland regulators is that of Novitziky (1978). Novitziky classified wetlands in Wisconsin as "surface water depression", "groundwater depression", "surface water slope" or "groundwater slope". This classification combines topography, surface water, and groundwater parameters. However, without wetland specific hydrogeologic data, it is doubtful if this method can be accurately applied by non-hydrogeologists (Hollands 1985).

### SURFACE WATER

A hydrological model should be developed to determine the watershed dynamics which affect the subject wetland system. Usually a very simple model can at least establish the extent of the watershed, timing and volume of input to the wetland, depth and duration of flooding, and discharge from the wetland. Post-construction monitoring of the created wetland should establish where fine tuning is required in order to provide the desired levels of inundation and hydroperiod. As noted above, the wetland's relationship to the surrounding groundwater system should be identified when constructing the hydrological model. Water quality analysis is also recommended at upstream and downstream locations as well as within the wetland itself to determine inputs to the wetland and its present ability to handle pollutants. Riparian wetland systems will require evaluation of stream flow and the sedimentation process.

Ideally, monitoring of ground and surface water quantity and quality should be done in the reference wetland area for at least one annual cycle, and if possible, including two wet seasons and one dry season. Similar monitoring for the created wetland should be done until the project goals are met and possibly longer where this information is of value to the long term management of the system. Factors critical to the maintenance of the wetlands's hydrology and that of surrounding lands should be used to assist in future land use decisions and to prevent adverse impacts from taking place.

## VEGETATION

Analysis of the vegetation in a wetland system is usually second only to understanding the hydrology of the area when characterizing the wetland and evaluating its functions. The method of monitoring/evaluation will depend on the type and size of the wetland. The methods discussed below are "goal oriented", that is, they will provide sufficient data to adequately characterize the reference and created wetland systems for quantitative measurement of success criteria.

In order to adequately characterize reference wetland vegetation within the scope of most mitigation related evaluations, three methods are recommended and described below: (1) belt transects for forested wetlands, (2) replicate quadrats for herbaceous wetlands, and (3) multiple quadrats for shrub wetlands.

### BELT TRANSECT

This method, also called the modified line intercept method (Bauer 1943), consists of observation of plant species occurring along a belt transect extending through the study area. A single belt transect 6.10 meters in width divided into 15.25 meter intervals is established through each forested wetland. The belt transect is positioned so that each vegetation zone of the wetland is sampled. Belt transects should extend into adjacent upland in order to characterize the wetland-upland ecotone as well as the upland habitat. Each interval of the belt transect (quadrat) covers 93.025 square meters. Within each quadrat canopy, midstory, and groundcover taxa are recorded. The diameter at breast height (DBH) of all canopy trees (DBH > 25.4 millimeters) are measured to the nearest 30.48 millimeters. Trees with multiple stems originating from a common trunk are recorded as individual trees. The percent cover of midstory taxa (DBH < 25.4 millimeters and 457.2 millimeters or greater in height) should be estimated for the entire quadrat. Percent cover of ground cover taxa (less than 0.91 meters in height) is estimated for the entire quadrat. Water depth and percent cover of bare ground should also recorded.

## REPLICATE QUADRATS

The vegetation within individual reference or created herbaceous wetlands should be delineated into major macrophyte zones. Seven 1 $m^2$ quadrats are established in each zone. The vegetation within the quadrat is divided into as many as three strata based on relative height. The percent cover of each taxa within each strata is estimated and the average height recorded. Water depth and percent cover of non-vegetated areas should also be recorded.

## MULTIPLE QUADRATS

The ground cover in a shrub dominated wetland is recorded for seven replicate 1 $m^2$ quadrats as described above. Two 3.0 meter x 3.0 meter quadrats should be established to describe the shrub strata. Within both quadrats the number and average height of individuals from all non-herbaceous taxa is recorded and the DBH of the five largest individual's of each taxa is recorded.

These sampling methods were developed and used for several reasons. First and most important, these methods have been modified and refined to develop a standardized method for establishing an absolute measure of species occurrence by using defined frequency intervals and cover estimates. Use of small continuous frequency intervals allows increases or decreases of colonizing vegetation to be accurately mapped and subsequent changes easily followed with time. In addition, since frequency data is based on species presence or absence it is absolute. Therefore, no error is introduced as is the possibility when using ocular estimates. Frequency is needed in determining cover percentages. Although cover estimates are not absolute (and may be somewhat variable when performed by different people), they serve as comparative indices for evaluating cover between different treatments and/or wetlands.

Occurrence of non-vegetated areas (bare ground) throughout the transects were given the same consideration as plant species cover. Bare ground or non-vegetated surfaces are present in all systems and as such are not necessarily a definitive characteristic of newly created wetland areas. Bare ground is defined as all ground area not covered by some form of vegetative structure as viewed from above. Analyses of bare ground allows for determining vegetation stratification. With bare ground considered, vegetation coverage of an area will seldom be greater than 100% cover. Analyses may indicate that a great degree of plant stratification occurs; however, areas are most often not 100% covered by vegetation. The bare ground method is recommended because coverages based totally upon species occurrence (which often total much greater than 100%) may no longer be an acceptable method of reclamation success determination.

# CREATED OR RESTORED WETLANDS

The methods recommended to characterize the plant community within created or restored wetlands overlap in scope with the reference wetland evaluation methods. The differences are those modifications required to monitor survival and growth of planted woody species in a created or restored wetland. The line-strip (elongated quadrat) technique (Lindsey 1955, Woodin and Lindsey 1954) has been used to facilitate an intensive, accurate, and repeatable sampling program. Permanent quadrats are established at a constant width to allow for a maximum sampling of trees concomitant with planting density such that generally four to five parallel planting rows (average 1.525-3.05 meter centers) can be monitored within each quadrat. Elongated quadrats can be extended parallel to the slope of the wetland to allow for survival and growth comparisons to be made on a gradient from flooded through moist to dry conditions. Best and Erwin (1984) and Erwin (1987) used this method to evaluate the effects of hydroperiod on survival and growth of tree seedlings in a phosphate surface-mined reclaimed wetland.

## MEASUREMENT PARAMETERS AND CRITERIA FOR PLANT CONDITION ASSESSMENT

All trees occurring within the sample quadrat should be measured during the growing season for height. Water depth in the quadrat should also be measured. Qualitative observations should be made concerning the individuals' overall appearance. Generally seven different categories are suggested for condition assessment. Categories and descriptive criteria are:

### Live

Tree appears in apparently good condition--leaves green, no symptoms of wilting, die back, or chlorotic appearance of leaves.

#### Stressed

Tree appears to be in a generally poor condition--chlorotic leaves, wilting, and leaf drop.

#### Tip Die Back

The main stem is in good condition, but the most apical portions are in very poor condition exhibiting wilting and die back symptoms.

#### Basal Sprouts

The main stem is dead but new growth is initiated from the stem base or the root stock.

#### Not Found

In some cases seedlings are not found during a particular sampling period. If a seedling is not found on two successive sampling periods, the seedling is counted as dead.

#### Apparently Dead

The general appearance of the stem is dry and brittle with no live wood observed and there is no observable green foliage growth.

#### Dead

A decision as to whether a tree is dead is generally made only following a sampling period in which the tree was classified as "apparently dead". Only if initial observation indicated that the stem was in such poor condition that survival was unlikely should a tree be listed as dead.

To completely evaluate the potential for "forest" development in a created or restored wetland, crown cover should be recorded for species above the herbaceous stratum. In addition, trees producing seed should be noted. Table 1 is a summary of planted tree survival (total of all species), change in height and crown size from a created wetland in central Florida (Erwin 1987).

These methods for evaluating a created forested wetland have provided data which established trends of survival and growth for certain tree species after four years of monitoring (Erwin 1987). Forested wetland creation projects should be monitored using this method for a minimum of five years. The established trends will dictate whether further intensive monitoring is required or if a reduced periodic evaluation is appropriate to maintain conditions required for maturation of the system.

### BIOMASS

Biomass of vegetation per unit area may be an important parameter to be measured in a restored wetland when standing crop of the restored wetland is a criteria for its success. For small quadrats and herbaceous vegetation, the biomass can be measured by cutting all above ground matter, drying it in an oven, and weighing it. Ideally roots are also excavated, but they are often ignored and consequently most of the biomass data represents only the above ground plant matter. Quadrat size and shape are important. The significantly limiting factor is generally man-hours and the cost to perform the analysis.

Productivity can be determined from these measures as the rate change and biomass per unit area over the course of a growing season, or a year or several years during the maturation of a restored or created wetland. This process is described below.

### PRODUCTIVITY

Productivity may be a criteria for evaluating the success of wetland to be created or restored.

The most accurate means of measuring primary productivity is to measure the net photosynthetic rates of photosynthetic tissues, and extrapolate to the community level, using the net production per gram of biomass of each species in a community. Obviously, this assessment of net primary productivity is not possible under the circumstances associated with the typical wetland creation or restoration project. Consequently, the most practical measurement of net primary productivity (NPP) in frequently conducted by calculating the change in biomass through time where $NPP = (W_{t+1} - W_t) + D + H$ where $W_{t+1} - W_t$ is the difference in standing crop biomass between two harvest times, D is the biomass lost to decomposition and H is the biomass consumed by herbivores during the period between harvests.

Above ground biomass may be measured with little error in herbaceous vegetation by replicate samples harvested randomly from a grid. This technique is most effective with annual vegetation, where little biomass is lost to decomposition during the growing season. If herbivore activity is significant, comparisons between replicate samples taken inside and outside herbivore enclosures are often employed (Barbour et al. 1987).

Table 1. Summary of planted tree survival, change in height and crown size during 1987 growing season.

| | SURVIVAL | | | | | |
|---|---|---|---|---|---|---|
| | SPRING | | SUMMER | | FALL | |
| | Number/Acre | % | Number/Acre | % | Number/Acre | % |
| Live | 757 | 71 | 696 | 65 | 679 | 63 |
| Dead | 315 | 29 | 382 | 35 | 406 | 37 |

| GROWTH (HEIGHT cm) | | |
|---|---|---|
| SPRING | FALL | |
| Height | Height | Change in Crown |
| 123 | 151 | +28 |

| CROWN (DIAMETER cm) | | |
|---|---|---|
| SPRING | FALL | |
| Height | Height | Change in Crown |
| 38 | 46 | +8 |

## MACROINVERTEBRATE MONITORING

One of the least known facets of freshwater wetland systems is the role of the macroinvertebrate fauna. These communities are very important, forming an intermediate level in the wetland's food chain, providing a primary food source for higher organisms such as fish and wading birds. Certain macroinvertebrate species are excellent indicators of water quality.

Comparisons from one marsh to the next, even when they may closely resemble one another with regard to hydrology and physiognomy, may yield different species composition and diversity. Species composition, richness, and diversity will depend on the season in which the monitoring was conducted, the macrophyte community from which the samples were taken and the method of collection.

The lack of baseline data for wetland habitats makes it impossible to detail the exact degree of macroinvertebrate utilization in a wetland creation project. However, monitoring should be required to determine whether, in fact, a project is being utilized by at least some of the desired species. The Macroinvertebrate monitoring program should be designed to complement the wetland community and water quality monitoring of the project. The objective is to develop a predictive model of success for the long term trends in biological community development in a created wetland. In riparian systems where flowing water is present, the use of Hester-Dendy multi-plate artificial substrate samplers seasonally, in combination with some of the methods described below, may be appropriate. A number of monitoring plans included in recently issued permits have required the use of Hester-Dendy plate samplers in freshwater marsh systems where no flowing water is present. The author's research indicates that the use of Hester-Dendy plate samplers in static water situations provides unrepresentative data when compared with other methods. Thus, they should not be used in these situations.

Substrate coring and leaf and/or stem scraping are usually satisfactory methods for obtaining quantitative data as long as the substrate areas are measured and computed for each sample. This method has not been widely used in many wetland systems, probably due to the great expense in time and labor. It is often common to find stem samples harboring few organisms. The author has used the method on many reference and created wetlands and has observed that proper qualitative sampling, usually consisting of dipnet samples, can provide a more accurate characterization of the wetland. Sample size should be as large as possible with collections made within each niche of each macrophyte community.

Seasonal data collection for at least one annual cycle is recommended for the natural wetland to be altered. Monitoring of the created wetland should be continued until the vegetation-related goals are met. Freshwater marsh and some salt water marsh creation projects generally will require less intensive monitoring over a shorter period of time (two to five years) than forested wetland projects.

## WILDLIFE UTILIZATION

The most widely used generally successful method of evaluating wildlife utilization of a natural or created site is reliable observation. The observations are made during the correct season, time of day, and over a satisfactory number of events for the type of wildlife anticipated by qualified personnel. Once again, where more specific goals have been established with regard to particular species utilization, more intense monitoring may be required which may involve quantitative surveys to determine, for example, the number of nests per acre or breeding pairs per season. Wildlife utilization of a wetland creation project is almost always one of the specified or inferred goals, but actual monitoring or observation of wildlife utilization is often lacking in the permit conditions. Special consideration should be given to endangered, threatened, or listed species (of special concern). The reference wetland should always be evaluated with respect to current or possible future utilization by and suitability for listed species. Habitat characteristics that are necessary for use by listed species should be thoroughly documented. In addition, the wetland's proximity to other wetlands or specific types of upland habitat may dictate its degree of utilization by particular wildlife species. Thus, it is important to describe the location and type of connecting corridors.

There are cases when the proposed biological structure of a created wetland focuses on preserving those species threatened with extinction. Managing a created habitat to favor these endangered species will inevitably hamper the growth of some more abundant species. This approach is appropriate if the criterion is to preserve a full diversity of species regardless of relative abundance. However, management is often intensive.

## RARITY

An often overlooked aspect of wetland

evaluation is the rarity or uniqueness of one or more components of the habitats within a region. While fish, wildlife, and vegetation are usually evaluated, other aspects are often overlooked. Items of importance include the rarity of the specific habitat in that particular stage of succession; geomorphology; water quality; and other characteristics such as stream flow and cultural criteria such as archaeological, scientific, and public/recreation significance.

## SOCIAL ECONOMIC VALUES

Sather and Smith (1984) state that nonconsumptive values up to this time have been given secondary status to other wetland values for which scientific criteria can be developed or direct economic gain can be realized (Sather and Smith 1984, Gosselink et al. 1974, and Niering 1985). This is partly related to the fact that aesthetic or cultural values are more difficult to measure since they involve a more personal approach as well as value judgments (Niering 1985). There is a need to further develop a method for assessing nonconsumptive values of wetlands (Niering and Palmisano 1979).

## ECOLOGICAL WATERSHED CONTEXT

The author believes that wherever possible, wetland evaluation should be broadened to assess original or restored/created wetlands in their broader ecological and hydrologic context, including regional wetland functions. Any comprehensive wetland evaluation effort should be preceded by the establishment of certain criteria or goals which the investigator believes to be fundamental to the existence, functions, and contributions of the wetland system to its surrounding landscape and vice versa. Failure to address the wetland system's surrounding landscape leads to inaccurate characterization of the wetland. Additional work is needed to develop definitive techniques and models for better assessing the importance of individual wetlands in a broader watershed context for flood control, flood conveyance, pollution control, food chain support, habitat, and other purposes. However, approximations can be made with existing approaches. Inter-relationships between wetlands, transitional areas, and immediate uplands need to be studied to determine the importance, not only of adjacent lands, but of the functioning of wetlands in adjacent areas as total systems.

# QUALITATIVE EVALUATION

As discussed above, quantitative and detailed evaluations are rarely possible for all wetland functions and all aspects of a wetland at any stage in a wetland restoration/creation project due to cost or time limitations. In some instances, they are simply not needed, as, for example, with proven designs or in the later stages of a restoration/creation project where the goal is to determine compliance rather than to design a system.

The author's experience with wetland reclamation in Florida suggests that successful freshwater marsh creation (see Erwin this volume), and mangrove and saltmarsh creation, can take place with more generalized qualitative evaluations. Proper planning, design, and management can result in the creation of a functioning freshwater marsh within three full growing seasons (Erwin 1986). In this case, qualitative baseline monitoring of the reference wetland and post-construction monitoring of the created wetland for a minimum of three or four years is usually adequate.

The topics needing attention in a quantitative evaluation remain much the same in a qualitative evaluation, but the approaches differ.

The author offers several suggestions with regard to specific aspects of qualitative approaches in the following sections.

# VEGETATION MAPPING

Vegetation mapping of wetlands can provide both physiognomic and floristic information, and may be useful in several different ways. If the wetland area to be evaluated is too large to evaluate by the methods previously described due to short time allotted for analysis and/or a restricted budget, vegetation mapping on an aerial photograph verified by groundtruthing may be the answer. The investigator should try to distinguish as many different communities or vegetation types as possible and outline the boundaries of each on the aerial photograph. Species richness and assorted observations on topography, water depth, and wildlife utilization should be recorded for each vegetative type. Acreages for each type can then be computed from the vegetation map.

Vegetation mapping may also be used in a final, but long term phase, following short term intensive data collection using the previously described methods. A vegetation map could be prepared on a currently studied wetland and correlated with data for each mapped vegetation type (Figure 1). The author has satisfactorily used this method for evaluating large landscapes with wetlands. Vegetation mapping on high quality aerial photographs (black and white, color, and infrared sensitive film) taken on an annual cycle can confirm the continuity of trends or changes in habitat types and vegetative cover. Figure 2 is a vegetation map of a portion of a wetland reclamation study site where the quantitative data collected will be correlated with the detailed mapping (Erwin 1987 and Erwin this volume). While this method does not produce the detailed data previously produced by belt transects, it will provide a relatively inexpensive and reliable confirmation and description of the habitat. Maps should be regularly groundtruthed to confirm the reliability of the habitat types and boundary definitions. Recently developed computer aided drawing (CAD) allows for great flexibility in generating scaled vegetative maps and habitat acreage figures.

In addition to generalized vegetation maps, a more specific qualitative baseline vegetation survey should be performed in most cases. Transects should be established through wetlands to be preserved, impacted, and created so that each major vegetation zone, including adjacent upland habitat, will be represented. Each major vegetation zone should be identified and a sampling station (3.0 meter x 3.0 meter quadrat) located within each zone. All plant species should be recorded. Relative abundance and percent cover of species should be noted. The same transects and stations should be used for all future post-construction monitoring.

An example of the results obtained using this method is shown in Table 2, which represents baseline vegetation monitoring data collected in four quadrats from one of several transects (Transect D, shown in Figure 3) established in selected preserved and constructed wetlands of a proposed surface water management system. Each major vegetation zone is represented.

Transect D (Figure 3) was aligned to intersect each major vegetation zone in which a 3.0 meter x 3.0 meter quadrat (sampling station) was established. All plant species were recorded. Percent cover was estimated for each species. The results are presented in Figure 4. Figure 4 also illustrates the basic structural differences in major species composition and cover between the three macrophyte zones of this marsh and the adjacent uplands. In some of the quadrats the vegetated areas were structurally complex and the stratified vegetation layers yielded cover values greater than 100% (Table 2). The same transects and quadrats will be used for all future monitoring.

In some cases where multiple wetlands are present (i.e., Cladium, Pontederia, and Spartina marshes), it may be possible to group wetlands of similar physiognomy and monitor a subset of each group using this method as a minimum requirement. This will still provide the required data as long as the investigator selects a representative wetland from each group and all vegetation zones are monitored. If there are adjacent upland habitats that are recognized as an important component of the wetland system, the transects and quadrats should extend into the adjacent upland habitat.

# POST CONSTRUCTION MONITORING

Project evaluation is essential both during and after construction to determine compliance with project goals and permit mid-course corrections. Certain aspects of such evaluation may need to be quantitative (depending upon the project goals and measures of success), but much of it can be qualitative. Based upon the author's experience, the following are suggested as key components of a monitoring plan for post project evaluation.

## MAINTENANCE PLAN

The methods to be used for maintaining the wetland after construction should be submitted with the original baseline survey. The plan should address removal of nuisance species, i.e., Melaleuca, Brazilian pepper, purple loosestrife, and cattails, and assure an 80% survival rate for planted or recruited species. An evaluation of the success of the maintenance effort should be discussed in annual reports.

## ANNUAL REPORTS

Post-construction monitoring should be conducted annually for five years (minimum three years) at the end of the wet season (October-

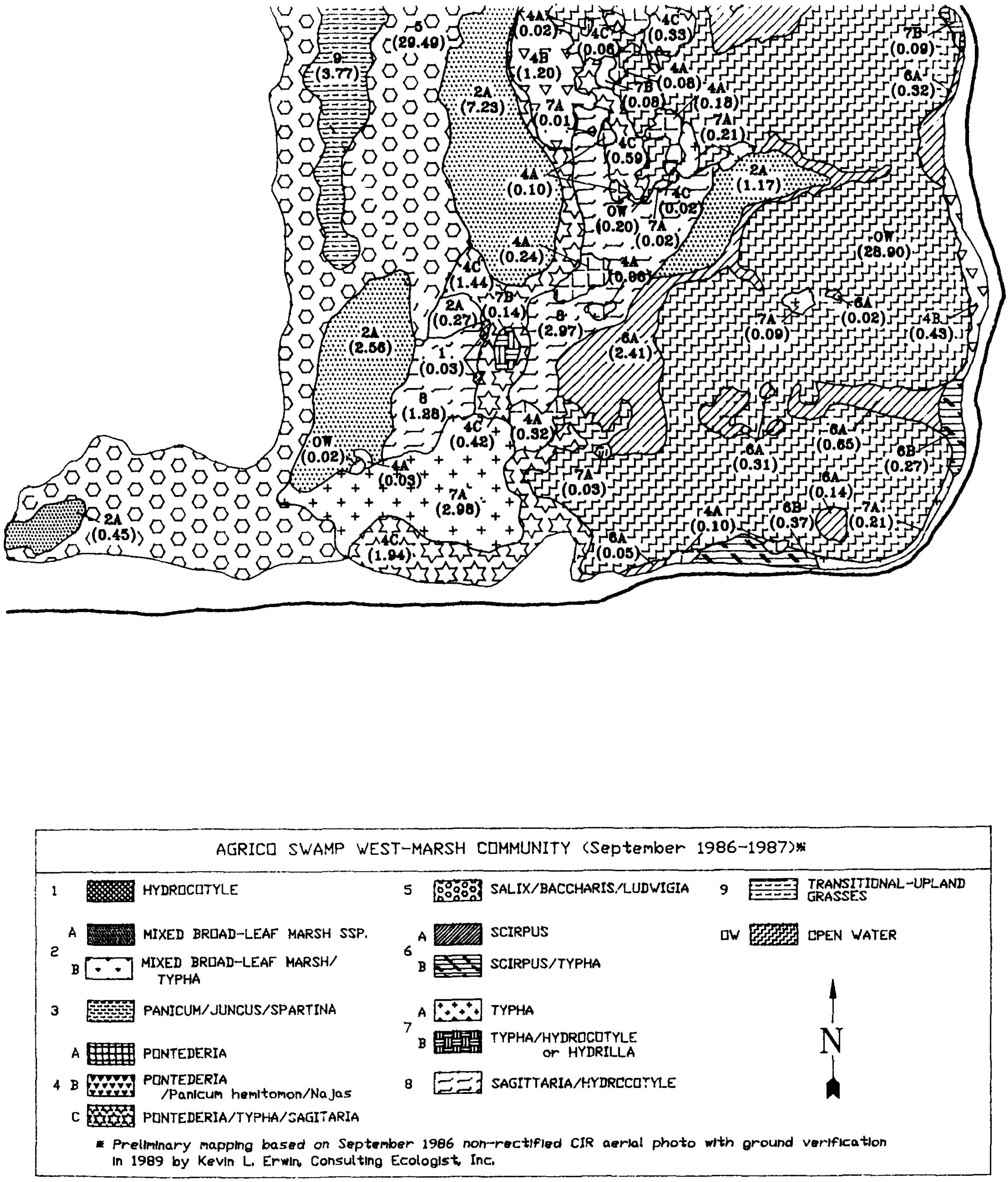



Figure 1. Vegetation map of plant communities, acreages, and percent cover on a 106.94 acre parcel in southwest Florida produced by Computer Aided Drawing (CAD).

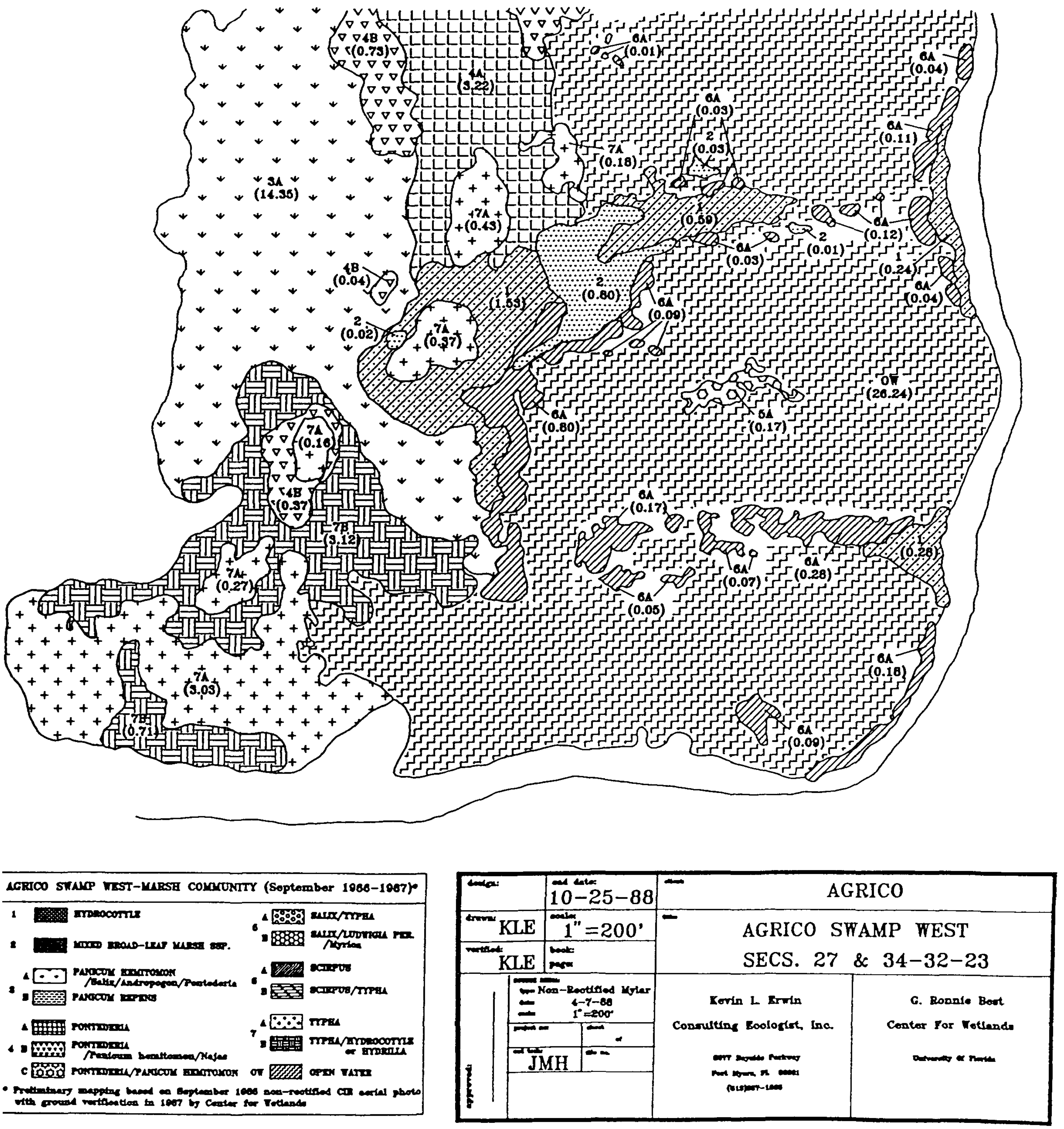
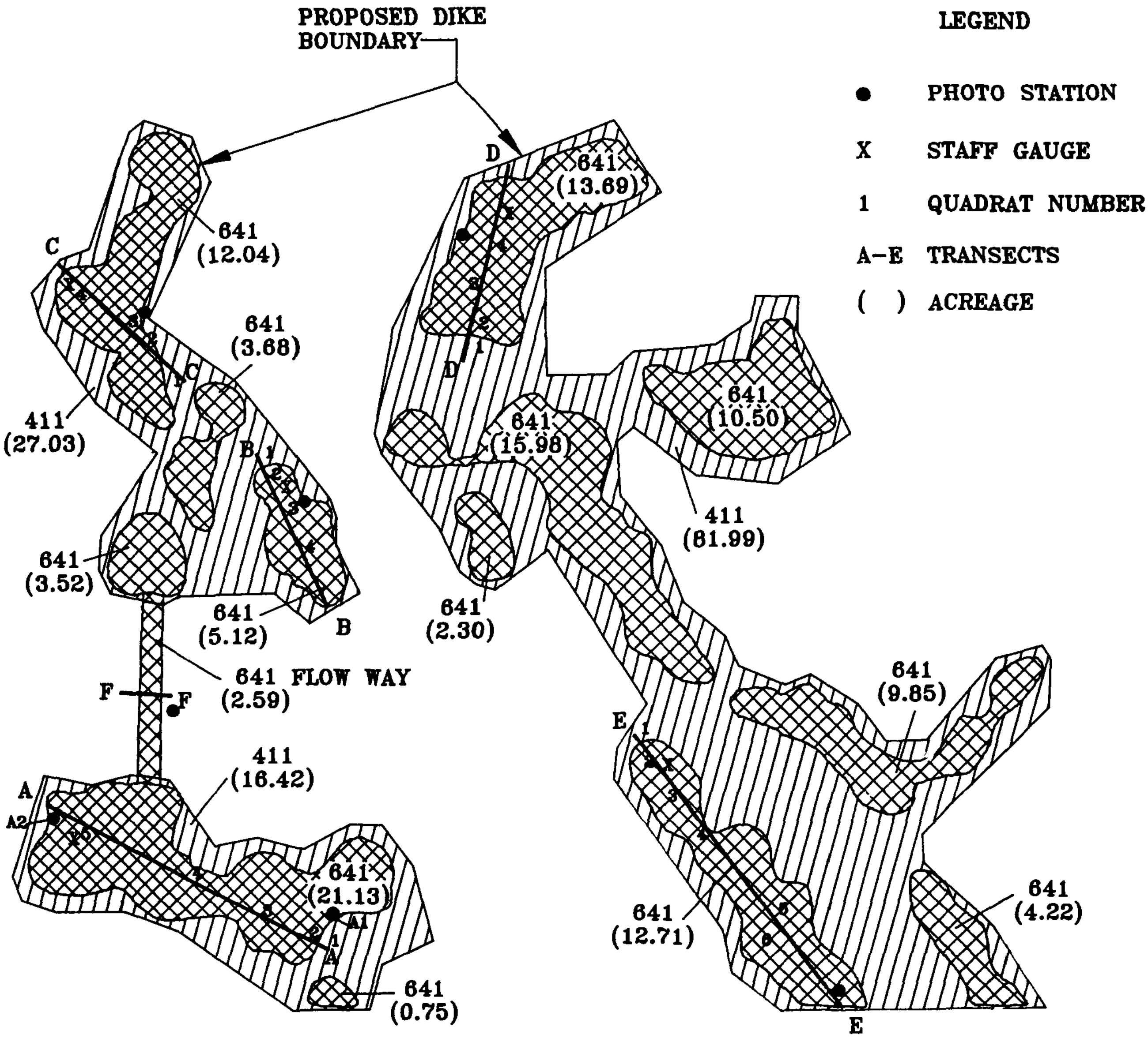



Figure 2. A portion of a vegetation map of plant communities and acreages for a wetland reclamation study site (Agrico Swamp West) in central Florida produced by computer Aided Drawing (CAD).

Table 2. Baseline vegetation data (%-Cover, Ht.-Water Depth) from four 3 m x 3 m quadrats along a wetland/upland transect (Transect D) in a surface water management system. M: Species present within Macrophyte community, but outside of sample quadrat.

| SPECIES | QUAD D1 % | Ht (cm) | QUAD D2 % | Ht (cm) | QUAD D3 % | Ht (cm) | QUAD D4 % | Ht (cm) |
|---|---|---|---|---|---|---|---|---|
| Background | 15 | | 5 | | 65 | | | |
| Water depth | | dry | | moist | | 7-8 | | |
| Beak rush<br>Rhynchospora spp. | | | | | 1 | 30-60 | | |
| Broom sedge<br>Andropogon spp. | | | | | <1 | 8 | | |
| Cyperus sedge<br>Cyperus spp. | | | | | M | | | |
| Floating orchid<br>Habenaria repens | | | | | | | <1 | 30 |
| Floating heart<br>Nymphoides cordata | | | | | 1 | -- | | |
| Gallberry<br>Ilex glabra | 10 | 122-183 | | | | | | |
| Green algae | | | | | 5 | -- | | |
| Joint grass<br>Manisuris spp. | | | 70 | 30-60 | | | | |
| Ludwigia<br>Ludwigia repens | | | <1 | 8 | | | | |
| Marsh aster<br>Aster spp. | | | | | M | | | |
| Maiden cane<br>Panicum hemitomon | | | M | | 30 | 30-60 | | |
| Marsh fleabane<br>Pluchea rosea | | | 1 | 30 | | | | |
| Paspalum<br>Paspalum spp. | | | <1 | 25 | | | | |
| Pickerel weed<br>Pontederia lanceolata | | | | | | | 90 | 30-75 |
| Plume grass<br>Erianthus spp. | | | | | M | | | |
| Red root<br>Lachnathes caroliniana | | | M | | <1 | 0.25 | 15 | 60-90 |
| Rusty lyonia<br>Lyonia ferruginea | 1 | 30 | | | | | | |
| San Palmetto<br>Serenoa repens | 80 | 90-120 | | | | | | |
| St. Johns wort<br>Hypericum spp. A | | | 25 | 60-90 | | | | |
| St. Peter's wort<br>Hypericum stans | M | | | | | | | |
| Sundew<br>Drosera spp. | M | | <1 | 8 | | | | |
| Hire grass<br>Aristida stricta | 5 | 15-30 | | | | | | |
| Yellow eyed grass<br>Xyris spp. | | | 1 | 30-90 | | | | |




COVERTYPE SUMMARY

| COVER TYPE | AREA (ACRES) |
|---|---|
| 411 Pine Flatwoods | 125.44 |
| 641 Fresh Water Marsh | 118.08 |
| *** Total *** | 243.52 |

| | |
|---|---|
| cad date: 1-16-89 | |
| drawn: CS; scale: 1" = 660' | Reservoir South Wetland Monitoring Plan |
| verified: CS | Kevin L. Erwin Consulting Ecologist, Inc. |
| JMH | 2077 Bayside Parkway Fort Myers, FL 33901 |
| SUBJECT TO CHANGE WITH FIELD VERIFICATION | (813)337-1505 |

Figure 3. Locations of transects, quadrats, water level recording stations, and photo location stations in preserved and created marshes within a surface water management-reservoir system.

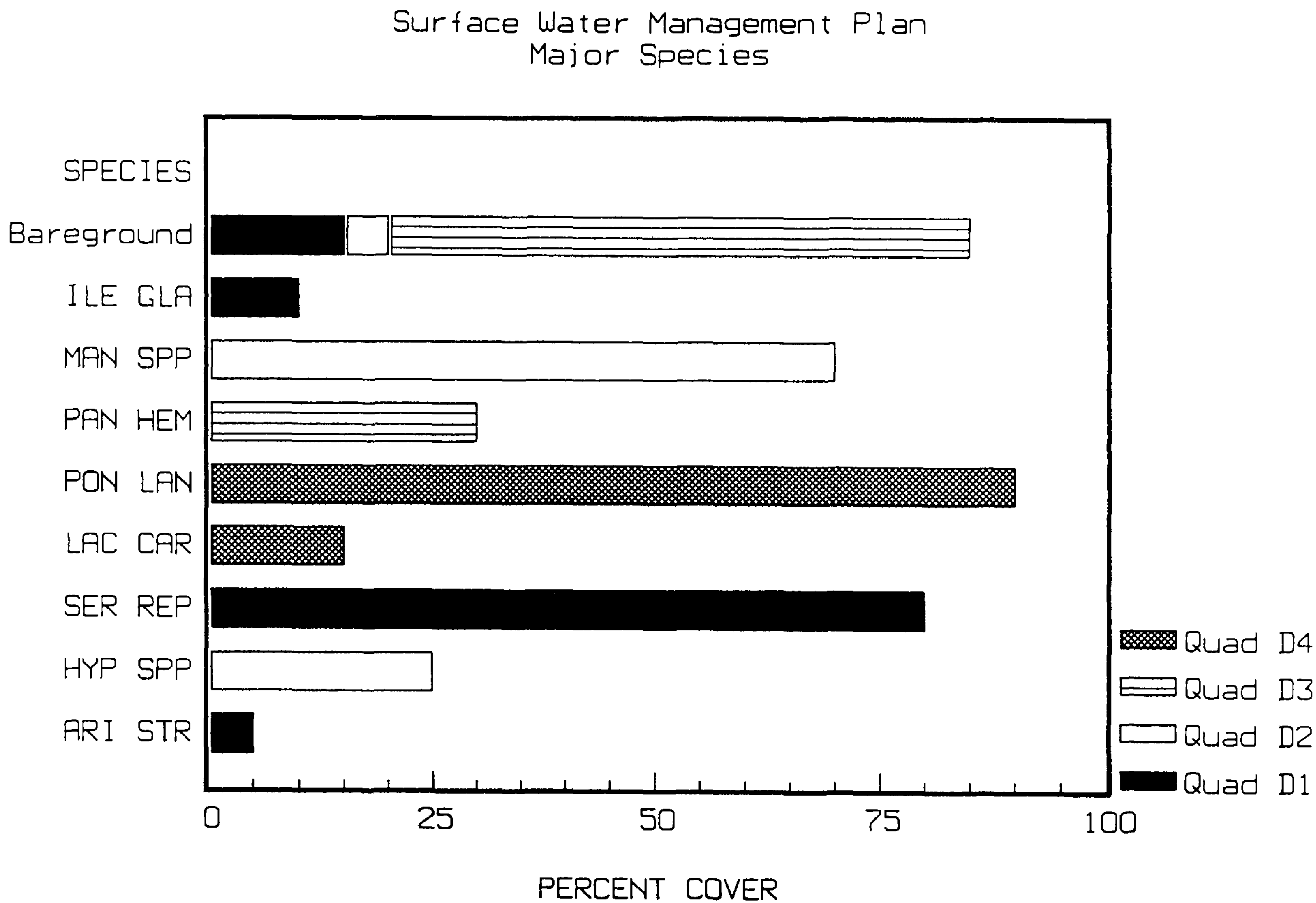



Figure 4. A histogram illustrating the structural differences of major macrophyte species composition and percent cover in the three macrophyte zones of a marsh (D2, D3, D4) and the adjacent upland (D1) along transect D.

November). Reports should be submitted within 90 days following sampling, and should document any vegetation changes including percent survival and cover of planted and/or recruited species (trees and herbs). Issues related to water levels, water quality, sedimentation, etc., should be addressed and recommendations or changes for improving the degree of success discussed.

### FIXED POINT PANORAMIC PHOTOGRAPHS

Establish locations for fixed point photos in each wetland area to be monitored by providing a range pole in each section of photo panorama for scaling purposes. Photos should provide physical documentation of the condition of the wetland and any changes taking place within it. They should accompany the baseline vegetation survey and each annual report. Photo points and range pole locations are to remain the same throughout the duration of the monitoring program.

### RAIN GAUGE

A rain gauge in a conveniently located area of the project site should, in general, be provided. It is unnecessary for some projects. Rainfall should be recorded daily. A summary of rainfall should accompany annual reports.

### STAFF GAUGE

Staff gauges should be provided in each wetland area to be monitored. Staff gauges should be located in the deepest portion of the wetland and set to National Geodetic Vertical Datum (NGVD) elevation. Water levels should be recorded monthly and summarized with annual reports.

### PLAN VIEW

A plan view showing locations of transects through wetland areas with rain gauge, staff gauge(s), and photo points should be provided with the baseline vegetation survey.

### OBSERVED WILDLIFE UTILIZATION

Qualitative observations of wildlife utilization of the created/restored wetland should be recorded during all visits and annual surveys. If wildlife utilization is a major success criteria, extensive observations should be taken at least monthly.

### FISH AND MACROINVERTEBRATES

Qualitative macroinvertebrate and fish should in many instances, be collected within each macrophyte zone containing standing water. Samples should be collected utilizing a D-frame dip net for a period of at least 20 minutes per station. All samples should be field sorted, preserved in 70% ethanol, and identified to the lowest possible taxon. A checklist of species collected should be compiled for submittal with annual reports.

## CONCLUDING REMARKS

Wetland evaluation approaches including post project monitoring must, of course, be tailored to the specifics of the site and project goals. This requires expertise and creativity on the parts of the project designers and reviewers. Without such expertise and creativity, huge amounts of money may be spent on gathering useless data while no attempt is made to gather essential data. Qualified wetland scientists with knowledge of wetland ecology, hydrology, wildlife, and an appreciation of practical considerations in restoration or creation must be involved in the design and execution of evaluation efforts.

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# APPENDIX I: A SELECTED BIBLIOGRAPHY ON WETLAND EVALUATION


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# WETLAND DYNAMICS: CONSIDERATIONS FOR RESTORED AND CREATED WETLANDS

**Daniel E. Willard and Amanda K. Hiller**
***School of Public and Environmental Affairs***
***Indiana University***

"Who can explain why one species ranges widely and is very numerous, and why another allied species has a narrow range and is rare? Yet these relations are of the highest importance, or they determine the present welfare, and, as I believe, the future success and modifications of every inhabitant of this world." (Darwin, 1859).

***ABSTRACT.*** Wetlands are affected by intrinsic and extrinsic forces. Managers cannot always predict or control the extrinsic forces leading to wetland changes, nor can they predict the range of species adaptations to those changes. Managers should plan for extreme circumstances by including mechanisms for wetland adjustment and persistence and by maintaining multiple sites as refugia to spread the risk of catastrophe. Our recommendations include:

- creating buffer zones and corridors

- recreating spatial and temporal habitat variability

- maintaining marginal wetlands as reserve sites

- planning for worst case scenarios (cumulative impacts)

- suggestions for managing for uncertainty and risk in wetland restoration and creation.

## INTRODUCTION

For the purpose of this chapter, we consider wetlands as ecosystems with water. As such they respond to biological, chemical and physical change and they demonstrate properties more or less common to other ecosystems. Many of these properties have been discussed at length in many textbooks of ecology. Here we will review several concepts that seem to have applicability to restoration and creation of wetlands.

This discussion focuses on the methods by which wetland ecosystems change and the methods by which plant and animal species adapt to those changes. To introduce the discussion we will briefly review succession, which we call "change by intrinsic elements" and perturbations, which we call "change by extrinsic forces". Because many wetlands are open ecosystems, these kinds of changes often operate together in ways that make them difficult to distinguish. For restoration and creation purposes, this separation helps managers understand what parts of the ecosystem they can manipulate, what parts change in fairly predictable ways and what parts remain uncertain.

Planning and regulation must consider landscape consequences. Often when we cannot understand the consequences of change at the local level, we can gain insight by looking at the change regionally, or vice versa. The role of a wetland in the landscape depends on its change pattern, its proximity to other habitat and its persistence. These considerations become particularly important as wetlands become stressed. That a wetland has become entangled in the permit process may provide sufficient evidence for stress.

## EQUILIBRIUM, INTRINSIC ELEMENTS AND EXTRINSIC FORCES

Wetlands are dynamic systems. While some wetlands appear constant on a human-relevant time scale (e.g., bogs and fens), others change much more frequently. Generally, newly restored or created wetlands are not in equilibrium and may undergo a period of adjustment before functioning in socially and ecologically desirable ways. Some ecologists consider internal vegetation readjustments not as change, but rather as the maintenance of ecosystem equilibrium through homeostatic balancing. Urban et al. (1987) show that our perception of the significance of wetland responses changes as the scale from which we view changes. For them equilibrium is a function of geographic scale and may emerge if that scale is large enough. DeAngelis and Waterhouse (1987) state that wetland changes may occur regularly or irregularly and may result from internal or external causes. Each of these views attempts to understand the relation between the internal dynamics of ecosystems and external events that affect ecosystems.

Managers, restorers, and creators of wetlands act through extrinsic forces on wetlands. These extrinsic forces can cause modifications in the intrinsic elements so that the wetland provides functions which society values. Unfortunately the application of management to wetlands is not yet an absolute science, so outcomes vary. Unpredictable natural extrinsic forces such as drought, fire, or insect infestation further complicate the wetland manager's ability to predict the outcome of his or her project with confidence. Those who work in environments affected by anthropogenic sources of extrinsic forces, such as cities or heavily farmed land, should consider the sorts of wetland ecosystems which can tolerate these forces.

## HIERARCHICAL SYSTEMS APPROACH

We discuss wetland creation and restoration considerations from the perspective of wetland dynamics. We take a hierarchical systems approach (which looks at a hierarchy of individualistic events) with particular emphasis on the landscape ramifications of wetland dynamics and management activities. Urban et al. (1987) defines "landscape as a mosaic of patches, each a component of a pattern". Landscape ecology focuses "on the wide range of natural phenomena by considering the apparent complexity of landscape dynamics and illustrating how a hierarchical paradigm lends itself to simplifying such complexity".

Random stochastic events play an extremely important role in the creation and development of wetlands. Habitat can only change in certain ways at certain rates. The dominant variables controlling a wetland frame the possibilities for wetland response to a stochastic event. Community responses to intrinsic elements limit the possible responses to extrinsic forces. In other words, if the wetland is in state X then a, b, and c are possible responses, but if it is Y then d, e, and f are possible. This ecological "roulette" confuses the outcome of any wetland change sequence. Managers are stuck with statements like, "If x doesn't happen and y happens the way it usually does, this wetland will look like this in 10 years." Annoyingly, x and y are uncontrollable.

## LOCAL WETLAND CHANGE IN A REGIONAL CONTEXT

Andrewartha and Birch (1984) describe the differential effects of local and regional extrinsic events on populations and species. Local populations of plants and animals prosper and wane in response to the interaction between their population dynamics and the local environmental conditions. In wetlands subject to change, local populations may vary considerably from season to season and year to year. Contrarily, regional populations may remain relatively constant. This regional constancy results from the asynchrony of the separate local populations: when some have low levels, others are high.

Bertness and Ellison (1987) studied change patterns in New England salt marshes. Local small scale extrinsic events caused differential plant mortality. These short term disturbances changed the relationship between species, allowing those with greater colonizing ability to recolonize disturbances. This scrambled the areal distribution of the species and provided new patterns.

Most plants and animals which have evolved to exploit wetlands have adapted to the change patterns of wetlands. Plants and animals have considerable physiological and genetic adaptability. Clausen et al. (1940) showed with altitudinally separate populations of Phlox along an environmental gradient that ecotypic variability allows many plant species to use a variety of habitats. McNaughton (1966) showed that Typha latifolia varies somewhat within populations and broadly across its range. Typha can adjust its position along a gradient quickly through vegetative growth.

Animals adapt to changing wetland conditions through a variety of behavioral strategies in addition to the genetic and physiological mechanisms suggested above. These strategies include movement, dispersal, environmental change, or no action. Weller (1981) describes a variety of behavioral adaptations for freshwater species (e.g., muskrats, Ondatra; black terns, Chlidonias niger). Many species have adapted to wetland environments which combine both spatial and temporal heterogeneity. This heterogeneity allows internal adaptation.

Most species do not occupy all of their environment at any given time. Skeate (1987) demonstrated regular periodic movement by 22 bird species to exploit ripening fruit in northern Florida hammocks. These birds opportunistically actively foraged on only a small segment of their habitat at any one time. The portion of the habitat which the birds were not using at any time was relieved of predation until it had replenished the supply of fruit. Wiens (1985) shows the effect of local rainfall on establishing varied patches in the desert. Areas that receive rain at a particular time "reset" themselves and begin new intrinsic change sequences. In a single square kilometer several different sequences operate simultaneously. Switching from patch to patch allows more species of animal to exploit these local areas. This opportunistic habitat switching is a behavioral adaptation to changing conditions in the landscape. The survival of the animals depends to some extent on the continuing pattern of changes in the various patches included in their range.

Opportunistic habitat switching may lead to fluctuating population levels on a given wetland. Willard (1980) describes the resetting of small ephemeral farm ponds in Wisconsin and their subsequent use by migratory shorebirds. Generally, farmers drained the ponds on their farms every four or five years, but patterns varied. The shorebirds preferred ponds on the first and second wet year because the opportunistic invertebrates on which the birds prey had higher population densities during those years. The shorebirds exploited fairly specific environments by finding which pond provided that environment at a given time. Myers et al. (1987) discusses the importance of these changing patches of foraging habitats to transcontinental migratory shorebirds. They argue that even though the ruddy turnstones (Arenaria interpres) and red knots (Calidris canutus) used the wetlands of Delaware Bay only as stopover sites, these sites were essential to their survival. "On these stopovers they [the birds] doubled their weight in preparation for the last stage of their migration from South America to the Arctic."

For many of the species we have just discussed, the various patches of habitat are isolated from one another. Each small bit of habitat may be of essential importance to a species which uses it only irregularly, yet short-term observation of these wetland habitats may reveal little habitat value. The loss of these apparently low-value isolated sites may appear as a small loss of acreage but may instead constitute a large loss for the survival potential of some desirable species. This critical, but ephemeral habitat contributes to the difficulty of measuring the cumulative impacts of threats to these otherwise unimportant appearing wetlands. When Gosselink and Lee (1987) analyzed cumulative impacts in bottomland hardwoods, they expressed these impacts as a special case of hierarchical organization of the landscape. They considered that an area contains a pattern of optional patches that a population can use. The areas they described often contained watersheds. By analogy they described the collection of disjunct sites used by a duck as a "duckshed". This analogy helps understand the movement and flow of the population as it exploits available habitat within an area.

Lewin (1986) describes the necessary movement of African elephants (Loxodonta africana) within their large home range. Elephant foraging behavior destroys trees so that elephants must move continually. However, as they eat the canopy trees they open up the forest for the rapidly increased growth of new forage plants. The "elephantshed" must be big enough to allow this cycle to take place before the elephants revisit. The foraging activity of the elephants causes faster regrowth. In the absence of elephants, the forage plants become replaced by non-elephant food plants. The interaction of the elephant and its food plants maintains a persistent community which is composed of a fairly rapidly changing array of habitat patches. In this case the animal itself causes the local inconstancy of habitat, but is adapted to achieve a balanced ecosystem which allows both the animal and its food to survive. From this Lewin suggests that change can provide persistence for organisms and that if we attempt to manage for constancy we may ultimately fail to conserve the very resources we intended to save. He summarizes by urging that we manage for persistence, not constancy.

All change may not necessarily help wetland species. Many impacts, both natural and human-induced, are environmental changes of great magnitude and size. These extrinsic forces sometimes cause environmental change beyond adaptability of the species. Andrewartha and Birch (1984) explain the effect of local and regional environmental events on the range and success of species. They suggest that populations succeed best when local habitat patches change asynchronously. By the same reasoning, not all of the habitat patches change in a manner, or at a rate, beyond the ability of the species to adapt at the same time. In essence, each population distributes risk by using independently varying habitats, so that as some of these habitats become depleted others will improve. Plants and animals maintain themselves by using each site to its limit. Some regional extrinsic forces can affect all of the habitat sites of a species, but most affect only a portion of the species range. Those sites which remain habitable act as reserves to "spread the risk". As human activities remove portions of habitat, even though these parts seem marginal at the time, we may have critically reduced the species' ability to react to other perturbations, by removing these "reserve" or "emergency" habitats, and increasing the risk of population extinction.

An example may help tie these ideas together. The Kesterson (California), Stillwater (Nevada), and Malheur (Oregon) National Wildlife Refuges all provide wetland habitat for a variety of water birds. All occur in essentially desert habitats where they experience irregular cycles of drought and flood. Each refuge cycles differently. A population of White Pelicans (Pelecanus erythrorhynchos) uses several of these refuges alternatively. The number of individuals on each refuge varies from year to year as the population tries to exploit the best conditions. All these refuges (and probably the Great Salt Lake) constitute the "pelicanshed". All the refuges act to allow pelicans to "spread the risk".

In contrast the sandhill crane (Grus canadensis) populations, which winter on the gulf coast and nest in eastern Canada, all concentrate on the Jasper-Pulaski Wildlife Refuge in northern Indiana during spring and fall migration. Because wetland habitat in the midwest is so reduced, the cranes have few other choices. For several weeks each year the entire population is at risk on the same site. If that small refuge fails to provide resting and forage for the cranes because of drought, fire, or contamination the crane population will suffer severely. Wildlife managers have attempted to adapt other sites with some success, but have difficulty convincing politicians that it is wise to conserve habitat on the speculation that a species might need it briefly sometime.

The sandhill crane population during migration has only a single locality which all of the subpopulations use. An impact to this site affects the entire crane population. Since the pelican population is comprised of several scattered subpopulations, there is a greater likelihood that the population as a whole will survive environmental changes at a particular refuge. These wetlands taken together comprise a single pelican habitat unit. Should one of the several refuges suffer an impact which reduces its habitat value, the other refuges will still support viable populations. The removal of any one option lowers the survival ability of the pelicans by reducing their ability to distribute risk, but they will survive. However, for the cranes the Jasper-Pulaski Refuge and surrounding fields constitute the only option for migratory stopover. The loss of this site would cause the crane population considerable distress. The problem is real because currently each refuge has a water quality problem induced by agriculture, with the problems differing in kind and severity.

# RESTORATION AND CREATION CONSIDERATIONS AND RECOMMENDATIONS

## PERSISTENCE VS. CONSTANCY

In some cases the wetland complex survives because various portions of the system continually change from one type to another, but the sum of each habitat type more or less balances. This dynamic balancing, which may destroy a particular type of a subunit, also creates that type elsewhere in the wetland system. This principle of dynamic balancing is not new, but merely adds a temporal dimension to the concept of spatial heterogeneity. Simply stated, some wetlands persist by balanced change over time and space.

Resilience is a measure of the ability to persist in the presence of perturbations arising from weather, physiochemical factors, other organisms, and human activities. (Krebs 1978). Persistence is "continuous existence" (Webster 1970).

A conceptual difficulty arises until we clarify whether we wish to maintain any wetland at a specific locality, or whether we wish to maintain a specific kind of wetland at a specific locality. In many cases the goal requires that the site support a persistent bundle of wetland functions, not necessarily a wetland that looks a particular way. Because form and function are related, some wetland types do perform some functions better than other types. Operationally, the regulator has to balance form, function, and persistence.

When planning and managing a wetland system it is important to examine the goals of the project. A balance must be found between form, function, and persistence. For example, wetlands are often created for stormwater retention. These need to be persistent functional wetlands. In other cases maintaining specific habitat characteristics requires management practices emphasizing constancy.

Managed habitats can fail by becoming too constant, changing the wrong way, or changing too fast. Jacobson and Kushlan (1986) and Kushlan (1987) illustrate habitat sharing on an alternate time basis for endangered species in the Everglades National Park. These species require quite different seasonal water levels. Natural flood and drought cycles alternatively allowed manatees, crocodiles, woodstorks and other significant species high reproductive success. Each got a turn often enough to maintain viable populations. This was at least the situation before Florida irrigation and drainage projects limited the upper end of the gradient. Now animals using it can find no appropriate sites during high water years. Current regulated water use must recreate these variable sequences. Many organisms exist through their ability to adapt quickly. Habitat must vary if these species are to survive.

## FREEBOARD, BUFFERS, AND CORRIDORS

Our management practices have hurt the habitat value of scattered wetlands by limiting the adaptability of individual wetlands. Individual wetlands have considerable but limited powers of recovery. Managers often place dikes or other structures in the flood plain so that wetlands cannot expand up gradient during high water periods, leading to limited adaptability. Artificial wetland boundaries often cut off the 100 or 50 year high water level of the wetland (e.g., Great Salt Lake). Wetland creation, restoration and other management plans must contain considerable "freeboard" for extra protection.

Unconfined wetlands allow vegetation to grow up and down the bank and adjust itself to changing hydroregimes. Steep landward banks may occur as a result of bulkheads on bars or beaches, levees on stream channels, or seawalls on lakes. The steep sides of confined systems remove the potential for adjustment and therefore force the loss of plant species, animals and habitat. Buffers are needed to avoid such losses. Buffers allow for the expansion and contraction of the plant communities to respond to variations in hydroperiod, and thus increase the probability of persistence.

Planning for environmental corridors helps reduce the isolation of the wetlands in or adjacent to the corridors, which in turn facilitates movement and recolonization of these wetlands. The corridors themselves can provide a variety of beneficial functions, as well as acting as buffers.

An increase in the area of a created wetland may be as simple as adding a modest buffer area and yet may have a large improvement in persistence. The buffer will allow the biota in the wetland to adapt to changing water levels. The buffer can also become additional refugia for the resident animals.

Little formal information exists on the definition and construction of buffer zones. But the rationale and need for buffers seem clear. Buffers provide an area of refuge for plants and animals between their normal or preferred habitat and human activities.

## SPATIAL AND TEMPORAL HETEROGENEITY AND SIZE

Increased freeboard, corridors, and buffer areas add internal spatial and temporal heterogeneity to a wetland construction and restoration project. Because these forms of habitat may provide water connections between potential portions of the wetland, they can become reserve sites and refugia for aquatic plants and animals which disperse through water. All of these techniques increase the "effective" size of the site.

The effective size of a wetland includes the area of the wetland available and accessible to the plant and animal species of concern. In practice, the effective area for a species is measured by determining the interconnections available with the dispersal mechanisms used by that species. For example, if a manager wished to use topminnows (Poecilidae) for mosquito control, he or she should provide water connections for at least some portion of the year between the portions of the site that might allow mosquitos to breed. The best season for dispersal will vary depending on the climate and the natural history of the species.

Given the heterogeneity discussed above, larger wetlands invariably provide greater habitat value (Andrewartha and Birch, 1984). This occurs for two reasons. First, greater area provides additional spatial heterogeneity and consequent opportunity to spread the risk. Second, additional spatial heterogeneity over a larger area creates a more complex pattern. This pattern complexity allows for an increase in habitat diversity which supports and encourages greater species diversity (MacArthur 1972). In terms of genetic resilience, more species present on the site help guarantee that some species will adapt and survive if severe impacts occur. In this sense, species diversity spreads the risk.

## MANAGING UNCERTAINTY

Two kinds of uncertainty simultaneously plague and bless careful managers. The first of these includes our inability to predict with certainty both natural and anthropogenic extrinsic impacts. The second includes the unpredictable behavioral adaptations that plants and animals sometimes make.

The poet Robert Burns once said that the best laid plans of mice and men oft times go astray. For those who attempt to manage natural resources this regularly applies. Things happen. In the midwest within the last year we have experienced a 17-year cicada (Magicicada septendecim) outbreak, record high wind conditions, and a prolonged summer drought. All of these have increased the danger from fire. While scientists predicted the cicada emergence, the event happens so infrequently that little was known about the effects of the cicadas on natural ecosystems. Thus, managed habitats may combine natural events which occur simultaneously through chance. This stochastic summing of independently varying impacts can over stress the adaptability of the species and the ecosystem even when the same impacts taken singly would cause changes well within the homeostatic limits of the ecosystem.

A third subtle uncertainty frustrates wetland restoration efforts. Wetlands often act as sinks for waterborne contaminants. Many accumulate potential pollutants while they act to clean water. These contaminants can build up to levels which harm wetland plants and animals.

Our land use management practices have hurt the habitat value of many scattered wetlands by creating habitats which contain threats animals cannot detect. Animals lack the ability to detect many fatal pollutants such as DDT, selenium, mercury, and PCBs. A wetland with valued habitat characteristics, but accumulated contaminants may lure animals to their death. For example, wetlands which receive high Habitat Evaluation Procedure (HEP) ratings may have contaminants present. These contaminants may occur at levels of concern while the site is otherwise physically and biologically attractive to the important species. Our study of the Kesterson National Wildlife Refuge may help us understand this problem.

Wetland evaluation systems seldom include detailed chemical analysis and even if evaluation considers the presence of chemical contaminants, the data are often not available to predict impact on particular species. For many contaminants, we know little about their effect on plants and animals. Chemical analyses are also costly (up to $1000/sample) and often raise questions which defy easy solution.

In some parts of the United States, wetlands have become so reduced that little habitat remains and plant and animals quickly colonize even marginally appropriate sites. Thus, managers accidentally create or restore wetlands which can become attractive nuisances.

We know of no easy answer to the contaminant problem. If the situation indicates that such a problem might exist (e.g., an abandoned landfill, an agricultural wastewater sump, an area which receives stormwater runoff from urban or industrial sites, the prudent manager should get some samples analyzed for potential pollution problems. Site restoration may require pollutant removal or abatement. Unfortunately, this may involve hazardous waste control agencies and years of cost and delay. Due to the different responsibilities and training of agency personnel, habitat assessments rarely consider pollutant hazards and chemical analyses seldom contain wildlife risk estimates. Improved agency coordination and an interdisciplinary approach to wetland evaluation could help identify these problem areas.

To counter the potential for adverse and unpredictable impacts, wetland restoration and creation projects could be designed and planned for a variety of unknown worst cases. No simple recipe exists to assure the health and survival of the wetland, but applying a few guidelines taken from our discussion may help:

1. Understand the natural history of the individual species of interest.

2. Provide extra space and diverse conditions to improve the odds for survival of a variety of species.

3. Provide spatial heterogeneity which usually increases with size and gradient.

4. Plan reserve sites as refugia when possible. Many species of plants and animals require reserve sites. HEP analysis can often recognize candidate reserve sites even though the population levels of the target species may be low at the time.

5. Imagine the consequences of potential adverse impacts. Try to design safeguards against these.

6. When the potential for chemical contamination exists, attempt to get an analysis of the risk to the plants and animals that may use the site.

## DISCUSSION OF RECOMMENDATIONS

Assume that all wetlands naturally change in size, in community structure and in locality. That is, they get bigger and smaller; they become different sorts of habitats and, from time to time, wetlands appear on the landscape and disappear. Wetlands probably maintain some regional dynamic balance, but this balance is not precise.

It is difficult to design for precise wetland types and boundaries. They both change regularly. Design for a general type which contains elements for self regulation and maintenance. Regulators should set standards for long term monitoring that demand "persistence" not "constancy" for restored and created wetlands.

Don't get concerned if the restored or created wetland does what it will, as long as it does something (Lewis, pers. comm. 1987). Remember that the homeostatic strength of any wetland or habitat cluster causes the system to adjust to some external perturbations and not others. Most landscape units develop as a result of probabilistic external events which no one can control.

Encourage designs which include room for change in size and type. Hydraulic gradients allow greater spatial heterogeneity to develop. Climatic variation may cause vegetation to self-adjust higher or lower on the gradient. Rare species of plants and animals may require more rigid designs. Species achieve rarity in several ways. Some exploit specialized local niches which occur infrequently in the landscape (Yucca Night Lizards, Xantusia vigilis, Limpkins, Aramus guarauna; Southern Cougar, Felis concolor). Occasionally these species become locally abundant. Other rare species scatter widely and exploit ephemeral circumstances that provide food, reduced competition, or predation (White Pelicans). The former depend on persistent local conditions which wetland builders have difficulty constructing. These local habitats may represent the species only chance. The latter fall prey to incremental habitat destruction because each part of their habitat is scattered over a large region and is ephemeral.

We recommend that managers plan for the worst combination of events the wetland they are restoring or creating may encounter. Natural causes may force animals into marginal habitats as refuges. These then become essential. The current population of animals may be at a low and will use this habitat later. An animal population may use a currently marginal or unused site as a reserve under different unpredictable circumstances.

All wetlands have some public value, though sometimes these values are not readily apparent. Some disturbed wetlands have reduced functional value. Undisturbed naturally functioning wetlands are essentially irreplaceable in the short run.

Expect change in size, wetness and ecosystem type in created and restored wetlands. Therefore, they should be designed well "oversize" compared to the wetlands for which they compensate.

Unfortunately, the natural variability of ecosystems, the unpredictability of extrinsic forces, and the perversity of complex systems make any absolute guarantee of success impossible. Therefore, in addition to worst case and oversize design, most projects should include a monitoring program geared to some explicit but flexible and realistic goals. To protect against the potential (if improbable) failure of the project, the project sponsors should be asked to provide, in every permit, some financial guarantee such as a long term bond. This bond should cover the cost of trying to repair the original effort or if necessary, trying again.

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# RESTORATION OF THE PULSE CONTROL FUNCTION OF WETLANDS AND ITS RELATIONSHIP TO WATER QUALITY OBJECTIVES

Orie L. Loucks
*Holcomb Research Institute*
*Butler University*

***ABSTRACT.*** Many wetlands and wetland restoration opportunities occur in the poorly drained headwaters of streams, along the stream floodplains, and at discharge points to larger water bodies. All of these are greatly changed by upland development that accelerates flows and increases the runoff pulse from headwater areas. In turn, the runoff increases scouring and transport of sediments, and subsequent deposition in or erosion of downstream wetland types. Successful restoration must consider how the hydrologic pulse may have been changed and whether pulse control measures can bring stream flows within a range consistent with historical development of downstream wetlands.

Comparison of spring versus summer loadings pulses indicates major differences in the seasonality of transport of excess nutrients into wetlands and downstream water bodies. The annual average loading is misleading, indicating that statements on wetland functions which ignore their role during pulsed events probably understate their significance in the landscape. Modelling studies of runoff and sediment transport suggest the combination of reduced soil exposures and restoration of wetland cover in temporary detention areas can produce major benefits in stream water quality. With additional parameters, quantitative estimates could be made of the cumulative impact of wetland restoration toward mitigation of flood peaks and the transport of sediment and toxic substances into adjacent aquatic systems.

At present, the general physical relationships between land use and hydrology provide only a guide to the prospective benefits we associate with investment in wetland restoration. They suggest how to evaluate tradeoffs in benefits and costs between a lower cost investment higher in the watershed (carried out over large areas), versus investment in a higher risk but potentially higher quality wetland restoration along the main stem or outlet of a drainage system. Although limited predictive capabilities exist for assessing the efficacy of restored wetlands, they have not been subjected to quantitative testing within the environment of wetland restoration technology. There is a need for more complete treatment-response modeling and model testing if the predictive capability needed to improve wetland restoration is to become available.

## INTRODUCTION

Many studies have shown that impairment of rural (and suburban) surface water quality occurs during infrequent but unusually large storm events. These events produce pulses in runoff, leading to flood peaks, unusual levels of sediment transport or "washouts", and mobilization of contaminants from agricultural lands or industrial sites. Studies also have shown that hydrologic detention in wetlands, or other means of delaying the peak hydrologic response, provides important buffering in the transport of sediment and chemicals by reducing the size of the pulsed events. This chapter examines the basic principles of hydrologic response and material transport, emphasizing pulsed events, and considers the potential for improving water quality and aquatic ecosystem functions through restoration of pulse-control processes in wetlands.

To meet these objectives the paper reviews the relevant literature on wetland hydrology, sediment transport and nutrient detention. Historical or "reference ranges" in hydrologic or detention functions are emphasized as well as modern conditions, as a synthesis of both will contribute to understanding the potential for restoration. In landscapes where widespread alteration of hydrologic and related wetland functions has occurred, little possibility exists for consensus on a normal or reference state for wetland functions, particularly for processes that ameliorate unusual pulsed events. One important reference point, however, is the buffering associated with the original vegetation and wetlands of a watershed. In the long-run, the success of a newly created or restored wetland needs to be evaluated in relation to the capacity of even the most natural of remaining wetlands to function within present-day hydrologically altered watersheds.

The question of how to further reduce the effects of unusual hydrologic events, including the transport of foreign substances, is significant now because the Agricultural Stabilization Act of 1985 could withdraw up to 50 million acres of land from agricultural use. Implementation of this program is already being seen as significant for further wetland restorations. Although the set-aside programs (sodbuster and swampbuster) emphasize highly erodible soils, some of the alternate uses will permit the restoration of wetlands, or more likely restoration of the buffering capacity of vegetation and wetlands in the headwater areas of watersheds. Indeed, a potential exists to focus certain of the set-aside programs so that they greatly enhance the water quality improvement potential of wetlands in agricultural areas, thereby enhancing the recovery of wetland functions and downstream water quality.

# PRINCIPLES EVIDENT FROM EXISTING STUDIES

## DISTRIBUTION OF WETLANDS ON A LANDSCAPE

Although wetland types vary widely from one area to another across the landscapes of the United States, a very common wetland type, making up by far the largest part of wetland acreages in the central regions, are depressions that provide temporary detention of water. These wetlands are characterized simply by poorly drained soils (gleysols) and the presence of a number of wet-habitat indicator species. This wetland type is best illustrated by the shallow basin type described by Novitzki (1979), Figure 1. Frequently these shallow wetlands are drained for agriculture, and no longer function as wetlands. They are not usually protected by state or federal wetland programs, and most often are not subject to permitting or mitigation requirements. Indeed, although the classification by Cowardin et al. provides for the inclusion of such temporarily flooded wetland types within the palustrine wetland systems, and they can be mapped by following the distribution of gleysol soils, they are not well illustrated in the cross-sectional diagrams shown by Cowardin et al. (1979).

Despite the very large area of temporary detention in many watersheds, the withdrawal of shallow basin wetlands through ditching and drainage has greatly increased the rate at which water is discharged from the upland landscape into the remaining wetlands, streams and floodplains. The importance of this relationship is shown in Figure 2, where the stream hydrograph with good retention has a much lower flood peak and a longer discharge time than the stream without detention (Reppert et al. 1979). The presence of the drainage channel system increases the flood peak and greatly increases the potential for transport of substances into the aquatic environment (Carter et al. 1979, Novitzki 1979).

## DETENTION IN NATURAL DRAINAGES

Studies in the Lake Wingra Basin around Madison, Wisconsin from 1969 to 1974 (Loucks and Watson 1978, Loucks 1981, Loucks 1986) have illustrated the hydrologic and nutrient detention potential of wetlands in natural drainage systems. One part of this study focused on a comparison of the modern hydrology of the Lake Wingra basin with the pre-settlement hydrology reconstructed from measurements on a subwatershed within the University of Wisconsin Arboretum. Data summarized by Prentki et al. (1977) have shown that the natural subwatershed (Marshland Creek, a large natural area of forest, prairie and shallow basin wetlands), yielded much less runoff than that characterizing watersheds of similar size in the suburban areas around the Arboretum. Runoff from the natural watershed occurred only during snowmelt when the soils were still partially frozen. Runoff occurred from the other watersheds during almost every significant rain event throughout the study period. The hydrology for the entire Lake Wingra basin, for both present and presettlement conditions, is summarized in Table 1. The runoff under current conditions, where shallow basin wetlands have been filled or drained, is about twice that estimated for the presettlement watershed. A related decrease of almost ten percent is shown for the inflow from springs and groundwater to the lake.

Because the concentrations of nitrogen and phosphorus are higher in runoff waters compared to groundwater, the hydrologic changes have resulted in large differences in the nutrient

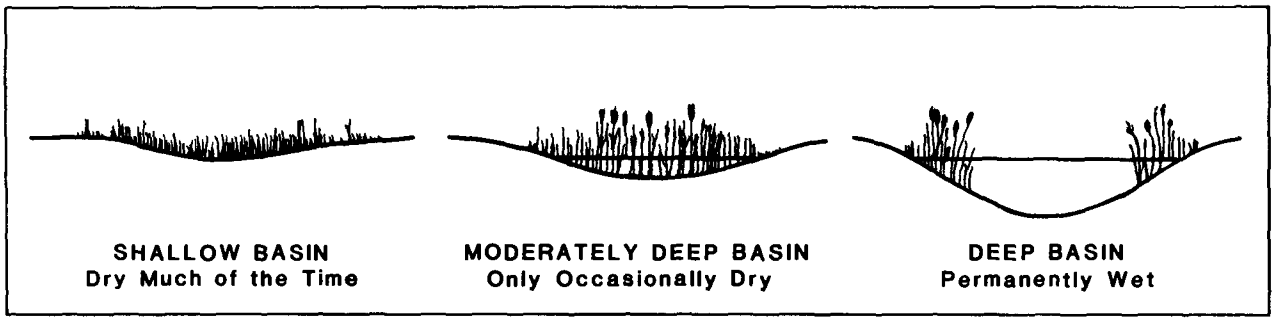



Figure 1. Different plant communities in surface water depression wetlands related to water permanence and basin depth (Novitzki 1979).

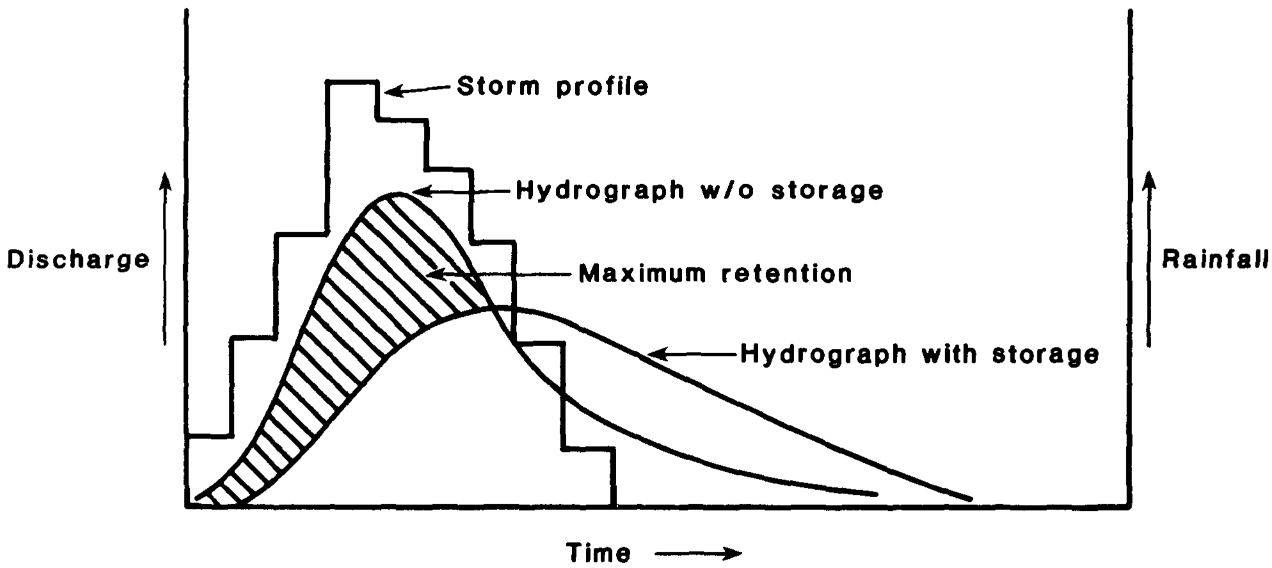



Figure 2. Flood hydrographs for watersheds with and without wetland storage capacity (from Reppert et al. 1979).

loadings to this lake, as summarized in Table 2. Nitrogen input has increased slightly due to the increased runoff. Phosphorus has much higher concentrations in runoff, and along with the increased proportion of surface runoff, yields an increase of almost two-thirds in the loading of this key nutrient. This level of increase, resulting in large part from the loss of temporary detention, produces what is widely recognized as a water quality impairment.

A key question then is whether the restoration of wetlands or other temporary retention basins at locations between the altered uplands and the receiving wetland or lake systems would reduce the effects from pulsed transport of phosphorus during storm events. Research reported by Flatness (1980), Huff and Young (1980), and Perry et al. (1981) provides an opportunity to answer this question. West Marsh, a small area remaining at the west end of Lake Wingra, is the receiving site for storm drainage from a golf course and urban area on the west side of the City of Madison, Wisconsin. Measurements of water inflow, and the net detention of water and nutrients, were carried out over a two year period (Flatness 1980). Two findings are significant: first, the largest part of the net flow through of water, sediment, and nutrients across the marsh and into the lake occurred during the spring runoff when the marsh was frozen (as was seen in the natural watershed in the Arboretum). The transport of water and nutrients is large enough during this time that the annual average detention achieved by the wetland, expressed on an annual basis (as has been done in the past), is a very modest 10 percent.

The second finding, however, is that during the summer when evaporation from the marsh is high and the potential for nutrient uptake also is high, the wetland functioned so as to detain 83 percent of the incoming phosphorus (Table 3). When this result is considered in the context of how the lake ecosystem functions through the seasons, one recognizes that the spring influx of phosphorus meets a very large percentage of the lake requirement at that time (as the algae and zooplankton populations increase in mass by an order of magnitude). During the summer no additional input of phosphorus is needed for a healthy and fully functioning lake ecosystem (remineralization is quite sufficient). These relationships indicate a major difference in the seasonality of pulsed transport of nutrients to the lake. In this case, focus on the annual average (Table 3) is misleading, indicating that statements on wetland functions that pass over their role during pulsed events will also understate their significance in the landscape.

## MODELING AREAWIDE SEDIMENT SOURCES AND DETENTION

Consider another study of detention of sediment and water within the shallow basin systems of an agricultural landscape: an analysis of Finley Creek, a small watershed northwest of Indianapolis, Indiana. This watershed was studied as a part of the research on Eagle Creek between 1978 and 1982. The study was designed to evaluate how much sediment and nutrient input could be reduced through changes in tillage practices on this largely agricultural watershed, chosen as representative of land use and runoff in central Indiana. The watershed contributes to the water supply for the City of Indianapolis.

A capability for evaluating runoff, transport, and deposition of sediment within a small watershed was developed by Beasley and others at Purdue University (Beasley et al. 1985, Huggins et al. 1982, Lee et al. 1985.) Their work led to the ANSWRS model (Areal Nonpoint Source Watershed Response Simulation). The model is, in effect, a fine grid geo-information system that allows two-dimensional calculation of the proportion of runoff from each area in the watershed. Given the volumes of water from each area and the rates of flow (from the runoff and slopes), the amount of sediment mobilized from the eroding surfaces can be calculated. These calculations then allow estimation of the sediment subsequently deposited in the temporary detention depressions (shallow basin wetlands) in the watershed (see Figure 3), or carried on to the stream itself. The model also calculates the residual transport of sediment to the stream, thereby allowing estimation of the potential for water quality improvement through more environmentally compatible cultivation measures. The studies have shown reductions of as much as 36 percent in sediment input as a result of changes in the tillage practices on the gentle slopes. These results were obtained without considering the introduction of natural vegetation, greenways, or restored wetlands near the stream itself, steps that would further reduce sediment transport to the streams.

Given evidence that even the small, shallow basins in this watershed play a large role in holding water and sediment (at least during the growing season), these modeling results suggest the combination of reduced tillage and restoration of wetlands could produce major benefits in stream water quality. Using the model with additional parameters (for the effects of increased permanent green cover), an estimate can be made of the areawide cumulative impact of wetland restoration toward the mitigation of flood peaks and transported sediment and associated chemicals.

Table 1. A comparison of hydrologic inputs for a modern and predisturbance watershed, in volumetric and percent-of-total forms. (From Loucks and Watson 1978).

| | Hydrologic Input ($10^3$ $m^3/yr$) | | | |
|---|---|---|---|---|
| Source | Present | Percent | Presettlement | Percent |
| Rainfall | 920 | 15 | 920 | 15 |
| Runoff | 990 | 16 | 450 | 7 |
| Springs and Groundwater | 430 | 69 | 4500-4700 | 78 |
| TOTALS | 6200 | 100 | 5900-6100 | 100 |

Table 2. Estimated present and presettlement loadings, Lake Wingra. (From Loucks and Watson 1978).

| | Nitrogen Loading (kg $yr^{-1}$) | | Phosphorus Loading (kg $yr^{-1}$) | |
|---|---|---|---|---|
| Source | Present | Presettlement | Present | Presettlement |
| Rainfall | 1200 | 1200 | 34 | 34 |
| Runoff | 5200 | 3000 | 710 | 320 |
| Springs and Groundwater | 18000 | 18000-19000 | 160 | 170-180 |
| Dryfall | 1900 | 1800-1900 | 95 | 92-95 |
| N Fixation | 3800 | (assume 3800) | -- | -- |
| TOTALS | 30000 | 28000-29000 | 1000 | 620-630 |

Table 3. Phosphorus mass balance for Wingra runoff water, August 1975-August 1976 (From Livingston and Loucks 1978).

| | Dissolved Reactive Phosphorus | | | |
|---|---|---|---|---|
| Season | Input (kg/day) | Output (kg/day) | Retention (kg/day) | Percent |
| Autumn (14 August - 13 December) | 0.380 | 0.318 | 0.061 | 16 |
| Winter (14 December - 10 February) | 1.232 | 1.231 | 0.002 | 1 |
| Spring (11 February - 7 May) | 3.862 | 3.553 | 0.309 | 8 |
| Summer* | 0.145 | 0.024 | 0.120 | 83 |
| Annual* | 1.282 | 1.155 | 0.127 | 10 |

*Assumes 100 percent infiltration for summer except 15 May and 24 June runoff event.

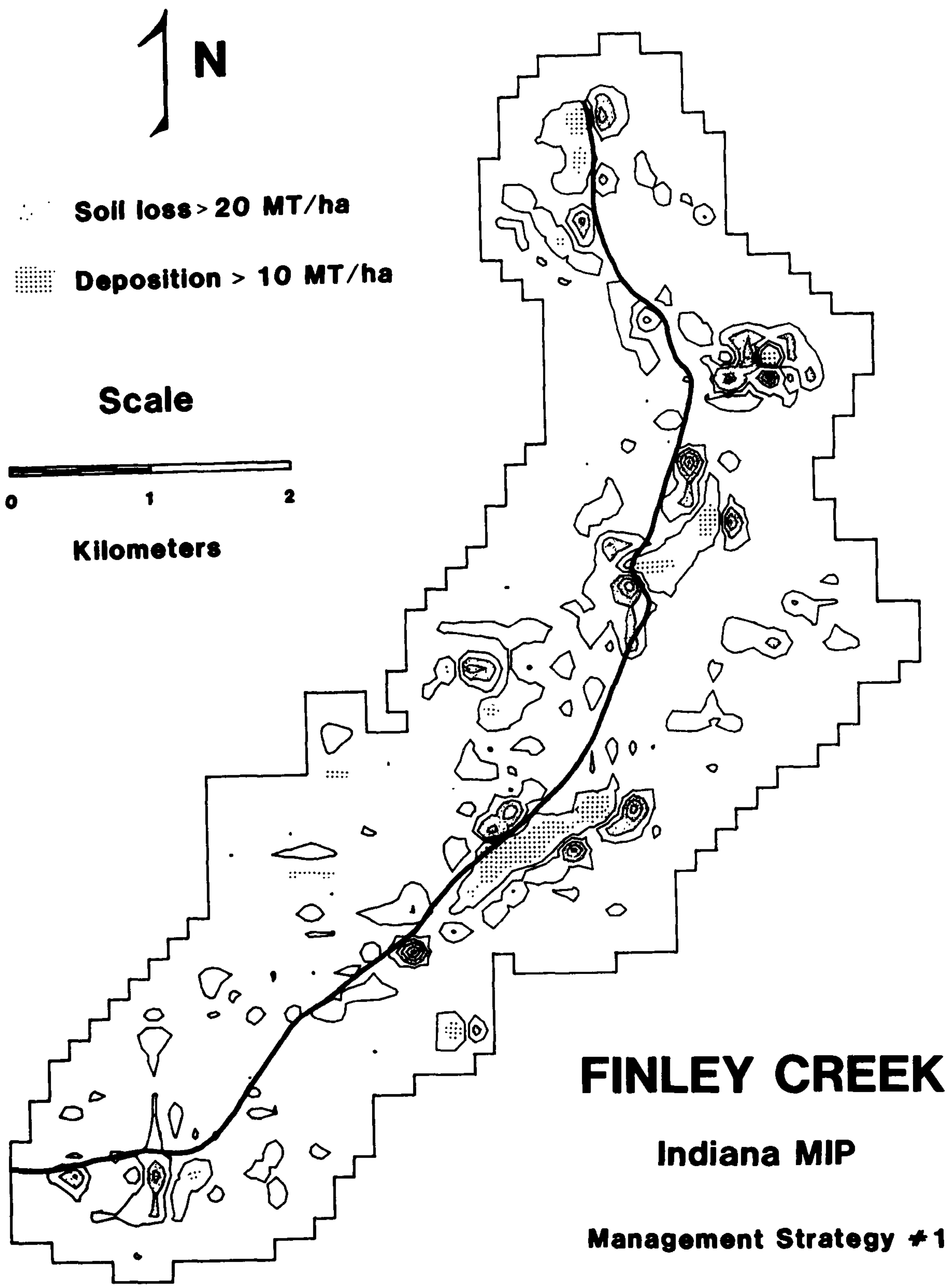
# RESULTS FROM EXPERIENCE IN LAKE RESTORATION

Research on lake restoration (Cooke et al. 1986), related to the lake/watershed studies cited previously, also should be considered for its potential relevance in a synthesis of mitigative measures for wetlands. The principles of lake restoration have matured over the past fifteen years, and are beginning to be viewed as a predictive science, despite our recognition that virtually no two lakes are alike or will respond similarly to the same treatment. The investigations used to design and evaluate the prospective response of lakes to restoration measures show that, before mitigation can be expected to meet goals set for a given lake, key characteristics of that system need to be understood. These include knowing the entire hydrology of the lake and watershed, particularly flushing time (i.e., the time required for the incoming water volume to equal the volume of water in the lake or wetland), the annual and seasonal net loading of sediment and nutrients (expressed in terms of equivalent weight per unit area of lake), and seasonal hydrologic fluctuation, shoreline aeration, and related questions of sediment toxicities. Let us consider how the lake restoration procedures and principles would apply to evaluating the potential for success in wetland restoration.

Prior to restoration, the essential principles for wetland evaluation need to address the hydrology of the wetland, just as it would be addressed in evaluating the restoration of a small lake. Included are questions of the total magnitude of the hydrologic inflows and outflows, from which can be calculated an apparent flushing time. The flushing-time term already is recognized as the dominant factor in coastal wetlands where tidal processes produce daily flushing (de la Cruz 1978). Freshwater wetlands, on the other hand, experience flushing principally during unusual runoff events, although not all freshwater wetlands experience flushing. In addition, just as for lakes, the relative importance of surface water input as opposed to groundwater input, and how the balance of these inputs controls the resultant chemistry of the wetland, are essential to understanding the biological community that can be sustained on a restored wetland.

Related to these questions are the seasonal and longer-period hydroperiods for the sites being considered for restoration. Although we are accustomed to dealing with annual averages, the key characteristics of the wetland and the associated water courses are often dominated by pulsed events only partially mediated by the system as a whole--as the examples cited earlier in this chapter illustrate.

For the annual hydroperiod of wetlands, saturation is expected during the winter or spring, followed by a major drying down in most parts of the country during the summer. Here, as we saw earlier, one needs to consider a reference


N
Soil loss > 20 MT/ha
Deposition > 10 MT/ha
Scale
0
1
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Kilometers
FINLEY CREEK
Indiana MIP
Management Strategy #1

pattern: What was the pre-alteration fluctuation pattern influencing or controlling a wetland type for which we may now be setting restoration goals? An estimate of pre-alteration properties should be compared with the existing hydroperiod, so as to evaluate whether the transition from present conditions to the patterns associated with the proposed restoration can be achieved. Illustrative data on the changes induced in a wetland hydroperiod, and the associated wetland degradation, are reported by Bedford and Loucks (1979).

Another important property, the logarithmic relationship between annual flood peak (expressed as the ratio to mean annual flood), and the return interval over which unusual events are expected to recur in small watersheds is shown in Figure 4. This relationship is similar to one used to estimate the hundred-year flood peak for rivers. In restoring wetlands, the size and return-period of extreme events must be considered, whether the event is a 100-year flood, a 20-year unusual event (at twice the mean annual flood), or the 5-year pulse (at 30 percent greater than the annual flood). There is always some probability, perhaps one in a hundred (which approaches certainty for 100 or more wetland or stream systems in any given year), that extreme events will affect a wetland restoration. The significance of return-time considerations lies in the fact that restoration on a large number of wetlands must be designed for events that are unusual locally, but fairly frequent over a large population of wetlands. Indeed, the threat of serious erosion of wetlands, or even burial through sediment transport from the adjacent uplands, must be incorporated into restoration designs.

Consider also the well-known exponential rise in sediment load associated with increased water flow rates. Few studies discuss the increased transport of toxic substances to the aquatic environment under peak flow conditions, but exponential increases in transport seem to be the best first approximation for estimating these components as well. When these two relationships are combined (probability of extreme events in a large population of wetlands, and exponential increase in sediment and toxic substance transport), one begins to appreciate the potential for relatively simple, physical predictive tools to aid in understanding the wetland functions sought in restorations. Indeed, restoration of sediment and nutrient detention may be achieved more effectively through a large number of relatively low-cost wetlands in the upper reaches of watersheds than through a similar number of often high-cost (and high-risk) wetland restorations farther down in the watershed. These wetlands are more subject to being overwhelmed by large-volume flows and transport from the relatively uncontrolled system above them.

## IMPLICATIONS FOR RESTORATION OF THE PULSE CONTROL FUNCTION

An important part of the design of a wetland restoration intended to improve pulse control rests with characterizing the processes involved. The discussion above has introduced the concept of small, but large-area influences, the central principle in "buffering". The regulatory aspect of this question is evident in requirements for a "buffer zone" to be established along the margins of important wetland habitats. Debate currently focuses on whether a "buffer" should be 50, 100, or up to 300 feet wide. This concept and terminology is used despite the fact that a technical definition of "buffer" emphasizes properties of resilience, i.e., the capability to continue to resist an altered state despite an unusual degree of input or force toward that alteration. Wetlands distributed in the shallow basins throughout the headwaters of a watershed, unrelieved by present-day tile-drainage and channeling, provide buffering capability in the original technical sense. On the other hand, a strip of land retained around the edge of a wetland provides important habitat for species that may utilize the wetland border as shielding from human activity. This strip of upland cover, however, provides little buffering capacity for the hydrologic and sediment pulses from upstream, which represent the greatest intrusion into the wetland during pulsed events. These two different functions now being associated with "buffering" should be made more explicit during permit review, and documentation of each aspect should be required when proposing mitigation. For the present, provision for the wetland margin buffer zones exists in some permitting procedures, and although broad mitigative functions are an accepted benefit from these reserves, serious differences of opinion will remain until the terminology and listing of benefits are more precise.

Given that unbuffered events impacting wetlands can be many times larger than average peak flow conditions, designs for an optimal buffering capacity to control man-induced peaks should seek a severalfold reduction in the size of these fluctuations. A reduction in the size and frequency of these events, expressed in clearly measurable standards (e.g., as in Figure 4), should be articulated as a performance criterion for wetland restoration. Such measures should then be incorporated into design criteria for restoration projects. In the examples considered here, one reference point for performance criteria is the magnitude of the extreme-event pulses in natural systems, while the magnitude of the extreme-event pulses characteristic of urban watersheds is an opposing reference point. Major pulse reduction can be expected downstream when restoration is carried out close to the headwaters of small drainage systems, but water quality benefits will be expressed locally as well as downstream. However, as more and more of the area of a drainage basin loses this "headwater" buffering capacity, the more extreme are the pulsed events midway or lower in the watershed and the more difficult is restoration or protection of wetland functions in those areas.

These general physical relationships can provide only a guide to the expectations likely to be associated with investment in wetland restoration. However, they also are a means for guiding estimates of the long-term survivability of a restoration project, at least in relation to the return-time of extreme events that could negatively impact the restoration. These physical relationships also suggest how we might evaluate the tradeoff in benefits and costs. In its simplest form, the tradeoff is between a lower-cost investment higher in the watershed (little more than small area set-asides), versus investment in a higher risk (but potentially higher quality) wetland restoration along the main stem or outlet of a drainage system. Additional research is needed before fully quantitative expressions of these tradeoffs can be formulated.

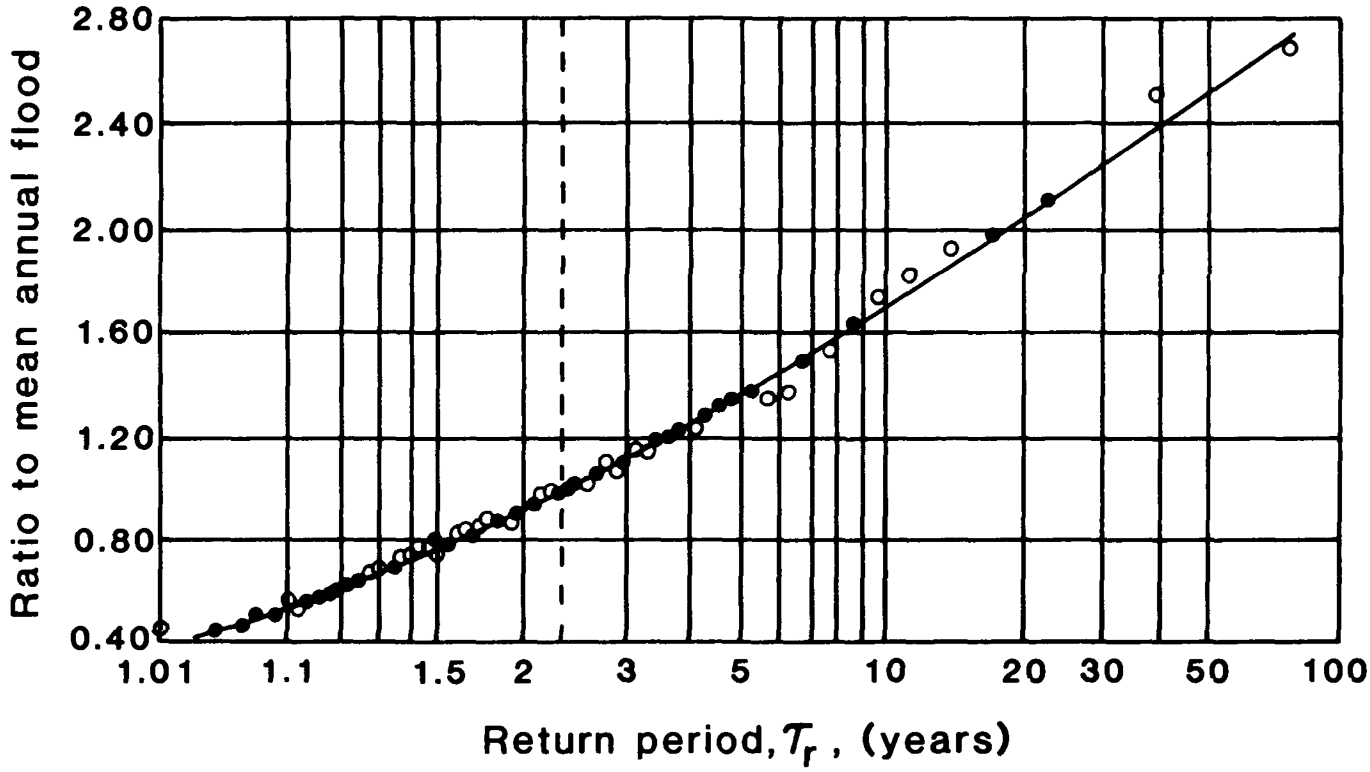


Figure 4. Regional-flood-frequency curve for selected stations in the Youghiogheny and Kiskiminetas River basins (Pennsylvania and Maryland), showing the return time for pulsed events expressed as a ratio to mean annual flood. A reduction in the hydrologic detention of wetlands raises the slope of this curve (U.S. Geological Survey, from Linsley et al. 1975).

## RESEARCH NEEDS

While wetlands function in many important ways, and while technology exists for proceeding with confidence on a moderate number of restoration goals, great limitations exist in our understanding of the variability in response among sites. These limitations restrict our ability to predict the outcomes of restoration measures. Priority research needs for improving our understanding of risks and benefits in wetland restoration, particularly during pulsed events, can be addressed under the following four headings:

1. A need exists for additional case studies of hydrologic and water quality responses to the distribution of wetland buffering capacity under a wide variety of weather conditions, soils, and topography. These studies should include an increased emphasis on the role of wetlands in intercepting and retaining nonpoint source pollutants, including toxic substances mobilized from adjacent uplands.

2. Although some quantitative predictive capability exists for assessing the efficacy of restored wetlands, or of specific components in the restoration processes, these have not been subjected to significant testing or validation. There is a need for more complete treatment-response modeling and model testing if the predictive capability required for improved designs and implementations is to become widely available.

3. A need has developed for specific case studies regarding the benefit and cost relationships from allocating a "buffer zone" around wetlands where development is underway. How much benefit is achieved from a 100-foot or 300-foot strip along the edge of a wetland receiving the discharge from a highly developed watershed? What response can be expected from a restoration and rehabilitation under such conditions? A tradeoff may exist between values in the 300-foot strip, some of which may not be of great benefit to the wetland, and a comparable investment at strategic locations in headwater areas. This research requires predictive capabilities for both the border or edge benefits of the buffer zone, as well as the pulse-control processes.

4. Finally, research should evaluate the hierarchical relationships among hydrologic and nutrient pulse control functions, as one proceeds from the small watersheds that we are beginning to understand to the larger watersheds and landscapes where water quality questions are paramount. Do new principles come to bear? Can a geoinformation system such as the ANSWRS model be extended to adjacent watersheds to assess cumulative impacts from the restoration of a pattern of wetlands across the landscape? The tools appear to be available to address these questions, and they should be evaluated as soon as possible.

Some of the above research needs require a strategy either of establishing new wetland study sites, or broadening the depth and perspective of existing wetland research sites and initiatives. Because so much already is underway, the research needs described here need not be thought of as requiring a new program, but rather a re-articulation of several existing studies in order to meet additional needs. Limited work on wetlands already is underway through the Long-Term Ecological Research sites sponsored by the National Science Foundation, and relevant modeling is underway at several of the EPA research laboratories and through their supporting institutions. Together, these initiatives indicate sufficient work-in-progress to conclude that the above research is a reasonable target for a five-year program.

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# VEGETATION DYNAMICS IN RELATION TO WETLAND CREATION

**William A. Niering**
*Connecticut College and Connecticut College Arboretum*

*ABSTRACT.* An understanding of the ecological processes involved in wetland vegetation development is essential to wetland managers concerned with wetland creation. Ascertaining a sound hydrologic system is basic in any attempt to re-create a wetland system since the vegetation and associated fauna are dependent upon a consistent but usually fluctuating hydrologic regime. Any hydrologic manipulations can also greatly modify what species will become established in a given site or those that may decline in abundance. Traditional succession-climax dogma has limited usefulness in interpreting vegetation change. Thus an understanding of the complex of factors involved in the process, including chance and coincidence, makes the task of the manager even more challenging.

Since vegetation change is not necessarily predictable and orderly, as is sometimes thought, it is often difficult to predict the ultimate vegetation in a given created site. Some wetland communities once created may be relatively stable; others may undergo directional or cyclic change, thus adding to the complexity of the ultimate vegetation.

Therefore, one of the major goals in wetland creation should be the persistence of the wetland as a self-perpetuating oscillating system. This can be achieved by assuring a sound hydrologic regime.

## INTRODUCTION

In wetland creation it is important to understand the patterns and processes involved in vegetation or biotic change. Such ecological concepts as succession and climax usually come to mind in this regard. However, depending upon one's interpretation, they can actually hamper rather than aid in understanding wetland dynamics. How do wetlands change? Is it an orderly, predictable, directional pattern as suggested by traditional succession? Will a given wetland reach a so-called climax state? Does it succeed to upland communities? Although most ecologists have modified their views concerning these concepts, there is still much debate concerning their interpretation as well as their continued use (Egler 1947; Heinselman 1970; Drury & Nisbet 1973; Niering & Goodwin 1974; Pickett 1976; McIntosh 1980, 1981; MacMahon 1980, 1981; Zedler 1981; Patterson 1986; Niering 1987).

The purpose of this chapter is to review wetland vegetation dynamics occurring in natural systems in order to provide a background for evaluating wetland change in created systems.

## WETLAND VEGETATION DYNAMICS

The concept of succession has been most closely associated with vegetation dynamics. As traditionally conceived by Clements (1916), it set forth a rather orderly, predictable and directional process for vegetation change in which one set of communities replaced another until a relatively stable system (climax) was established. It was primarily community controlled and, in the case of wetlands, the ultimate vegetation was believed to be an upland climax.

These traditional concepts have been considerably modified during the last half century. Yet, this does not diminish Clements' contribution to plant ecology since his six basic processes involved in vegetation change (nudation, migration, ecesis, competition, reaction and stabilization) are still relevant. However, it is now recognized that autogenic (soil development, competition for light, mineral depletion or accumulation) as well as allogenic factors (flooding, drought, fire, wind, and anthropogenic influences) are important in the process. In fact, the latter often have an overriding effect on the former. For example, a major disturbance that periodically interrupts a wetland ecosystem can produce changes that may last for decades or centuries. This introduces uniformitarian vs. catastrophic ecology (Egler 1977) in which the latter, representing allogenic change, may be so infrequent that it can be overlooked by short-term studies or by researchers who fail to recognize the role of historical factors. Disturbance is a natural and normal part of ecosystem dynamics (White 1979; Pickett & White 1985) to which ecological systems have become adjusted, especially in terms of their recovery (Marks 1974; Bormann & Likens 1979).

Gleason (1926) was one of the first to challenge Clements, especially his idea of the plant association and his organismic approach to vegetation. Instead, Gleason promoted the Individualistic Concept in which the differential establishment and survival of the various species in a given site were critical to the composition of any resulting unit of vegetation. In essence, the genetic characteristics of each species limit its ecological tolerance and every environment has its own biotic potential. For example, on an Alaskan floodplain, life history processes or species longevity, not facilitative interactions, explained forest development (Walker et al. 1986). This concept has been recently developed by van der Valk (1981, 1982) and applied to the prairie pothole wetlands (van der Valk & Davis 1978). He found 12 basic life history types in which the life forms of the plants, propagule longevity, and propagule establishment requirements are critical. Thus the plants which develop in a given situation will be dictated primarily by the life history requirements of each species and its presence or absence in the seed bank. No two sites, even though similar, will support exactly the same plant association.

An extension of the Gleasonian approach has resulted in the continuum concept in which discrete communities are not thought to exist, but rather continua, since species tolerances overlap along environmental gradients. In studying shoreline vegetation Raup (1975) was unable to recognize sufficient integration of species populations to identify community types and thus proposed the term "assemblages" which is logical in certain wetlands. It is also important to recognize that vegetation is highly variable and that a community is really a relative continuum between two discontinua (Egler 1977).

Chance and coincidence are especially relevant in wetland vegetation development (McCune & Cottam 1985; Egler 1987). The role of these stochastic factors is often difficult to measure and quantify and therefore sometimes overlooked. The three successional models (Facilitation, Tolerance and Inhibition) proposed by Connell and Slatyer (1977) are also relevant in understanding wetland dynamics. The Facilitation model relates to autogenic processes resulting in vegetation change in which the existing biota so influence the environment as to induce replacement of one set of species by another. Accumulation of solely organic sediments may lead to such changes, but evidence of autogenic development at the community level is limited. This model is the traditional concept of vegetation change as conceived by Clements. It can occur but it is only one of several possible processes or models that can be involved in vegetation change. The Tolerance model implies that various species may continue to become established over time, and that differential tolerance to light, and other limiting factors, will determine those species which will ultimately dominate. The Inhibition model suggests that those species which get established initially following a disturbance may well inhibit others from taking over. This may be relevant in wetland situations where relatively pure stands of cattail (Typha spp.) or reed grass (Phragmites australis) initially get established and essentially exclude other species. This parallels Egler's (1954) Initial Floristic Composition factor which sets forth the same idea. For example, in intertidal rocky shore wetland communities where new sites are exposed following scouring, those species that get established first frequently exclude others (Lubchenco & Menge 1978; Sousa 1979). In fact, this results in the patch pattern dynamics so typical in intertidal systems (Paine & Levin 1981; Dethier 1984). The concept of inhibition is somewhat counter to the concept of succession, since the vegetation development may be arrested at a phase that is not considered "climax". The role of these models, and possibly other factors, should be carefully evaluated when interpreting the causal factors contributing to biotic change.

## WETLAND ZONATION AND VEGETATION CHANGE

Wetlands have long been regarded as transitional communities with a trend toward terrestrialization or upland communities (Gates 1926). In fact, this general misconception is still portrayed in certain current biology and environmental texts using successional diagrams which show a series of belts from open water to upland forest and suggesting that one vegetation belt is replacing another centripetally. This zonation pattern often represents a set of species populations that has found its optimum ecological requirements or tolerance in terms of water depth and frequency and duration of flooding. Thus these belts may not be a successional sequence of one community replacing another, but may represent relatively stable vegetation types possibly in a state of flux, depending upon changing hydrologic conditions

(Gallagher 1977). Yet, there may be situations where purely autogenic processes are involved in this developmental sequence.

In Michigan, Daubenmire (1968) indicates that upland trees cannot grow on peat soils and that a transition to upland will not occur. In Connecticut, Nichols (1915) also indicates that replacement of forested wetlands, such as red maple swamps, by upland oak forest is highly unlikely. More recently Walker (1970) states that, "Although certain sequences of transition are 'preferred' in certain site types, variety is the keynote of the hydroseral succession. In spite of this the data clearly indicate that bog is the natural 'climax' of autogenic hydroseres throughout the British Isles and the transition from fen to oak wood is unsubstantiated."

Bogs frequently exhibit distinctive belts but fail to represent a successional sequence. In Connecticut, Egler (personal communication) found trees the same age in all belts, indicating the effect of post-fire or cutting. At Cedar Creek Bog in Minnesota, Buell et al. (1968) followed vegetation change over three decades. They found that the width of the bog mat did not change in position over this time. However, the width of the various vegetation belts did change. The larch-shrub zone expanded outward into the floating sedge mat, greatly reducing its width. An earlier droughty period apparently favored sedge development but as the water level rose over the 33 years of observation, shrubs and larch trees expanded outward. Yet Lindeman (1941) observing this bog over part of the same period (1937-1947) found that the mat had advanced one meter, which emphasizes the limitations of short-term observations. At Bryants Bog in Michigan, studied since 1917, the bog mat has advanced into the bog pool in an irregular manner averaging 2.1 cm per year (Schwintzer & Williams 1974). In 1972 the open water was 76% of its extent in 1926. The mat vegetation has also changed over more than five decades. The advancing leatherleaf belt which was dominant in 1917 was succeeded by a high bog shrub community in the drier years and eventually by a bog forest by the late 1960's. Then in the early 1970's the trees died as the water level rose and leatherleaf was reestablished. This emphasizes the dynamic non-predictable cyclic pattern of vegetation change. In Connecticut, I have observed the mortality of a mature spruce bog forest due to extreme prolonged flooding. In fact, beaver activities play a major role in altering bog vegetation (Rebertus 1986) and vegetation along boreal forest streams (Naiman et al. 1986). In the Minnesota peatlands, Heinselman (1970) found no consistent trend toward mesophytism, terrestrialization, or uniformity but rather a swamping of the landscape, rise in water tables, deterioration of the growth and a diversification of landscape types. In the northern Canadian peatlands both water level fluctuations and fire are primary factors governing vegetation change. Here long-term records show that the spatial-temporal approach does not accurately describe the dynamics of peatlands (Jasieniuk & Johnson 1982).

In the bottomland hardwood forests six vegetation zones can often be recognized, based on soil moisture and hydrology. However, as Wharton et al. (1982) point out, the term "zone" is somewhat misleading since many of these plant communities are arranged in a mosaic pattern, depending upon the hydrologic conditions. Along the Northeast riverine systems the vegetation pattern is also related to the frequency and duration of flooding (Metzler & Damman 1985).

In the marine environment, mangrove and salt marshes also exhibit distinct belting patterns. In south Florida three mangroves - the red (Rhizophora mangle [most oceanward]), black (Avicennia germinans), and white (Laguncularia racemosa [most landward]) - frequently form a belting pattern which has been interpreted as a succession oceanward (Davis 1940). Egler (1948) questioned this interpretation and, more recently, Ball (1980) found that interspecific competition was an important factor in controlling the zonation. In Panama, Rabinowitz (1975) found that reciprocal transplants can grow well in either zone. She also found that a primary mechanism controlling zonation is tidal sorting of propagules due to their size, rather than habitat adaptation. It appears that, once a given zone reaches equilibrium, it is unlikely to change unless disturbance occurs (Odum et al. 1982). In fact, major storms such as hurricanes are prime site builders for the establishment of mangrove (Craighead & Gilbert 1962; Craighead 1964). However, in Australia, biotic influences such as seed predation by crabs can also have a significant influence on these intertidal mangrove forests (Smith 1987).

Tidal wetlands of the Northeast offer still another example of close integration between vegetation change and hydrology. With coastal submergence peat cores document a vegetation development from the intertidal salt water cordgrass (Spartina alterniflora) to salt meadow cordgrass (Spartina patens). There is also a tendency for spike grass (Distichlis spicata) and switch grass (Panicum virgatum) to replace upland species as the marsh advances landward with sea level rise. However, once the high marsh has developed, oscillations in the vegetation patterns are primarily hydrologically induced. Waterlogged, poorly drained sites favor the short form of S. alterniflora. This condition can be induced by mosquito ditching, with the levees along the ditches preventing the flooded high marsh from draining.

Once the high marsh has developed, myriad vegetation changes can occur as documented by the hundreds of peat cores taken by Orson (1982) in tracing the ontogeny of the Pataguanset marshes in Connecticut, and by the author along the coastline of Connecticut. For example, a single core 1 meter in length, representing 500-1000 years, may show five or six vegetation types or changes based on the preserved rhizomes in the core (Niering et al. 1977). There appears to be no predictable unidirectional pattern. Hydroperiod, changes in micro-relief, accretion rates, salinity, redox potential, storms, and other factors make these systems too complex to be orderly or predictable (Niering & Warren 1980). As stated by Miller and Egler (1950), "...the present mosaic may be thought of as a momentary expression, different in the past, destined to be different in the future, and yet as typical as would be a photograph of moving clouds."

## WETLANDS AS PULSED SYSTEMS

Odum (1971) set forth the concept of pulsed stability as related to wetland systems. Subjected to more or less regular but acute physical disturbance imposed from without, they are often maintained at an intermediate state in development. This may further reflect why traditional successional concepts frequently have limited application in wetland systems. Tidal wetlands, for example, may be maintained in a relatively fertile state by a "tidal energy subsidy" which provides rapid nutrient cycling and favors substrate aeration. Among the freshwater systems the prairie potholes are pulsed in an even more striking manner, often completely drying up in droughty periods and then reappearing with the advent of adequate precipitation. During droughts, aerobic breakdown of the organic matter replenishes the nutrient supply to favor future productivity. In south Florida, the Everglades is another fluctuating system. The importance of this pulsing is dramatically correlated with the successful breeding of the wood stork (Kahl 1964) since lower water levels are necessary to concentrate small fish to feed nestlings. Yet, an "energy subsidy" from agricultural runoff, with its nutrient enrichment, can actually be deleterious to the low nutrient demanding sawgrass, resulting in its demise and favoring a dramatic increase in cattail. The sawgrass (Cladium jamaicensis) can also be destroyed by peat fires which recently have increased due to drainage. Under the natural fluctuating water regime the Glades burned when flooded and viable sawgrass marsh was maintained (Egler 1952). Other wetlands that are pulsed by drought and fire are the evergreen shrub pocosins along the southeast coastal plain (Richardson 1981) and the Okefenokee Swamp where fire and drought have set the pattern for vegetation change for decades (Schlesinger 1978; Hamilton 1984). As previously mentioned, dry periods favor rapid decomposition and peat fires can aid in maintaining more hydric conditions. Some species like the bald cypress, which normally grows under flooded conditions, actually require bare soil conditions for seedling establishment.

The pulsing concept is especially relevant in wetland creation. Will there be fluctuating hydrologic conditions in the newly created wetland? Fixed water levels are not the rule in nature. Continuous flooding or the absence of pulsing are deleterious to most trees. Pulsed, not static water regimes, should be one of the major objectives in any mitigation project, especially those in inland waterways and lake systems.

## WETLAND DEVELOPMENT AND ECOSYSTEM PROCESSES

In respect to ecosystem development, Odum (1969) set forth a series of ecosystem processes--community structure and energetics--as related to the stage of maturity in the process. Mitsch and Gosselink (1986, see Table 7-1, p. 160-1) illustrate how this scheme relates to some of the major wetlands in the United States. It is obvious that wetlands are highly variable with respect to these criteria, exhibiting aspects of both immature and mature systems, an attribute to be expected in pulsed systems. For example, in most wetlands, except bogs, mineral cycles are open and life cycles are short, typical of immature systems; food chains, however, are often complex, characteristic of mature systems. Figure 1 attempts to more holistically integrate the multiplicity of factors involved in biotic change for both terrestrial and wetland ecosystems without using traditional succession-climax dogma. Relatively stable states can occur only to

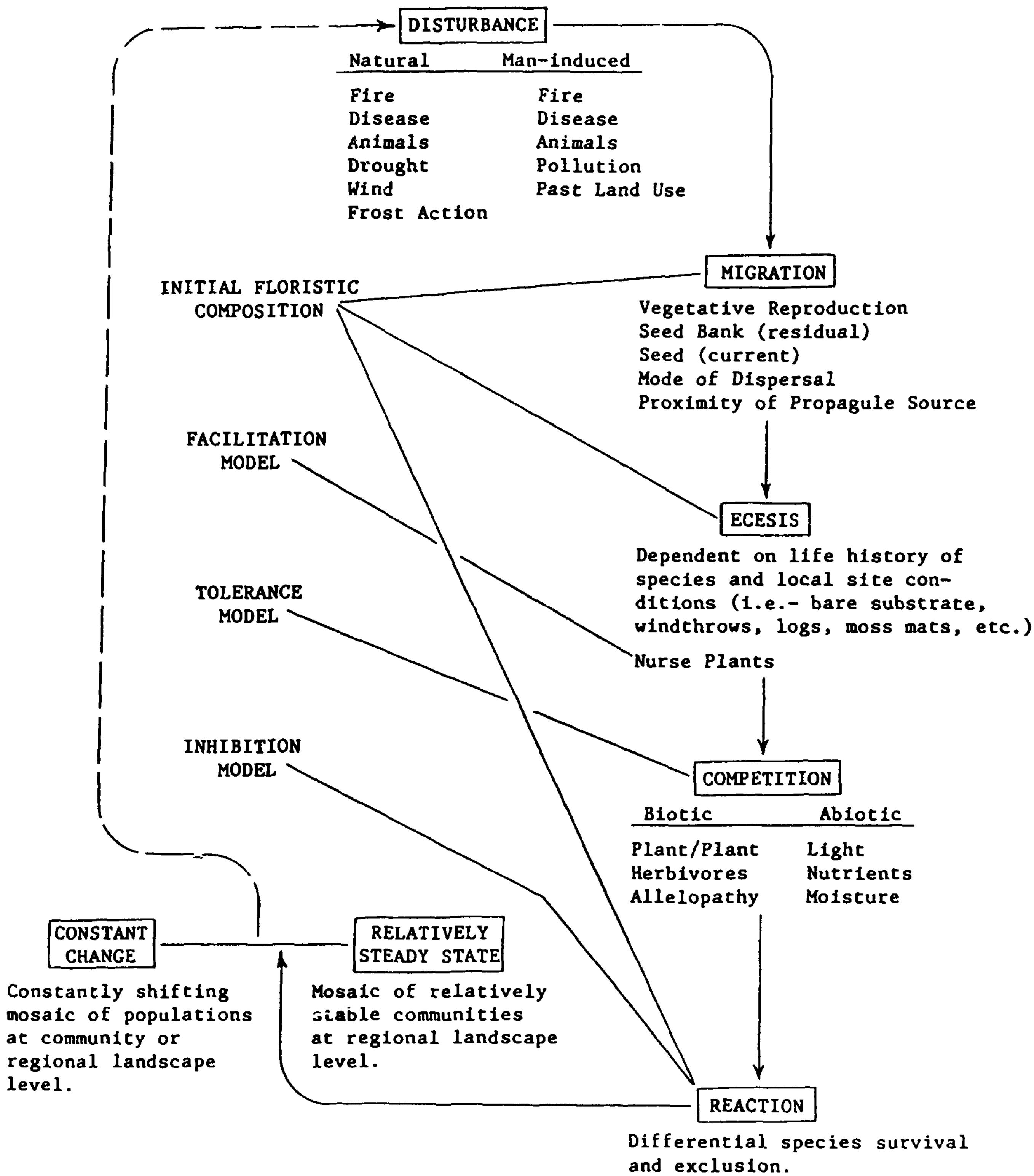


Figure 1. Holistic view of some of the factors and processes involved in vegetation change. Following disturbance a given system may eventually reach a relatively stable state or be in a continuous state of flux (Niering 1987).

be modified by disturbance, often due to hydrologic changes. As Mitsch and Gosselink (1986) indicate, the idea of a regional climax is inappropriate since both allogenic and autogenic factors are operative in wetland change. They further point out that changes in wetlands are often not directional and "...in fact, wetlands in stable environmental regimes seem to be extremely stable, contravening the central idea of succession."

## THE CONCEPT OF PERSISTENCE

It is my opinion, and that of a growing number of other ecologists, that the use of such terms as "vegetation development" or "biotic change" is preferred to "succession," and "relative stability" or "equilibrium state" to "climax." Some ecologists are now finding the concept of persistence an even more relevant paradigm in visualizing ecosystem dynamics (Lewin 1986). This idea of persistence is especially relevant in wetland ecology. In wetland creation the objective is to create a viable persisting system which will exhibit a variety of functional roles. Over decades or centuries one may expect changes in the vegetation structure and composition of the system. Some will be small, others catastrophic, but the wetland system will persist. Therefore, our goal in wetland creation should not always be to duplicate a specific vegetation type but to create a wetland system that is hydrologically sound (Carter 1986) and incorporates the potential for all those future biotic variations that might be expressed under differing hydrologic regimes in that particular site.

## RELEVANCE OF WETLAND DYNAMICS TO WETLAND CREATION

In conclusion, it may be helpful to summarize how those involved in wetland mitigation will find an understanding of wetland dynamics especially relevant.

1. Natural wetlands are characterized by distinctive, usually fluctuating hydrologic regimes.

2. As pulsed systems, they are highly dynamic but can persist as relatively stable entities or be in a constant state of flux.

3. Biotic change in wetlands is usually not directional and generally not predictable since fluctuating water levels, chance, and catastrophe are constantly interacting.

4. Short-term wetland observations concerning vegetation change toward wetter or drier conditions can be misleading, thus dictating the need for long-term observations.

5. Considering the natural ontogeny of wetlands over centuries or millennia, human efforts in the creation of viable, functional wetland ecosystems should be approached with trepidation and humility.

6. Any wetland creation effort must be aimed toward a self-perpetuating system which will permit the potential for all the future biotic variations which might occur in a natural system.

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# LONG-TERM EVALUATION OF WETLAND CREATION PROJECTS

Charlene D'Avanzo
*School of Natural Science*
*Hampshire College*

***ABSTRACT.*** Long-term success of wetland restoration and creation projects may be quite different from short-term success. In this chapter six criteria are used to evaluate the long-term success of more than 100 artificial wetland projects reported in the literature. Results from numerous U.S. Army Corps of Engineers' dredged material stabilization projects demonstrate the importance of long-term monitoring and increasing long-term as well as short-term success. Several studies reviewing wetland creations are also used to demonstrate problems with projects in both the short and long-term.

The long-term evaluation of artificial wetlands is very difficult because wetlands are created for a variety of purposes. We know little about basic aspects of many wetland systems, "succession" in wetlands is less straightforward than previously assumed, and it is difficult to generalize from one wetland type to another. There is a striking range of opinions about the success of wetlands that have been created. On the one hand, the U.S. Army Corps of Engineers' dredged material stabilization program exemplifies artificial wetland projects that appear successful over a decade or more. Several types of criteria including vegetation characteristics, soil chemistry, and animal studies suggest that several dredged material wetlands are becoming similar to reference wetlands with time. But, some wetlands characteristics (soil carbon) may require many years to reach natural levels.

In contrast, a great many other artificial wetland projects are problematic or failures. Reasons for failures include improper hydrology, erosion, herbivory, and invasion by upland plants. Many projects have never been evaluated so their permanence is not known, and a disturbing number of required projects have never been created.

In evaluating projects with regard to persistence (long-term success) of the created wetlands, the following points are especially important: 1) 1-2 years of monitoring is too short; evaluations over as long a period of time as possible (10-20 years) are desirable; 2) vegetation characteristics are useful but do not necessarily indicate function; at a minimum, several parameters should be used (e.g., belowground/aboveground biomass comparisons); 3) chemical/physical aspects of wetland soils are also useful in evaluating trends in created sites; 4) local reference wetlands are critical for comparative purposes; and 5) some wetlands should be created with great caution because they have failed in the past (e.g., high salt marsh in the northeast) or because we know little about these wetland types (e.g., forested wetlands).

## INTRODUCTION: A CHALLENGING TASK

This chapter is a review and evaluation of changes that have occurred over time in wetland creation projects. The results of more than 100 artificial wetland studies are discussed; the sites range from large-acreage federal projects to small private plantings. The main questions addressed are: 1) how have artificial wetlands evolved over time, and 2) what can we learn from these effects concerning the feasibility of creating wetlands with long-term functions?

Evaluating the long-term "success" of artificial wetlands is very difficult for a number of reasons. First, wetlands are created for a wide variety of purposes--some are created as mitigation for destroyed wetlands, some are experimental plantings, and still others are aimed at stabilization of dredged material. Methods of evaluation are also not standardized. Access to publications of the studies differ as well; publications in refereed journals are more accessible while some federal studies, such as those by the U.S. Army Corps of Engineers (USACE), are more difficult to obtain.

A second reason why the long-term

evaluation of wetland creation projects is especially challenging was pointed out by Larson and Loucks (1978) a decade ago. We know little about many basic aspects of ecosystem-level processes in wetlands. For example, a knowledge of wetland seed bank dynamics is important for creation and evaluation of human-made wetlands. However, we are particularly ignorant about this aspect of wetland ecosystems. The most basic of questions--how water level influences seedling recruitment (Keddy and Ellis 1985) and how seed dispersal and on-site hydrology influences plant community composition (Schneider and Sharitz 1986)--are just being addressed for some wetlands. A wetland-creation evaluator who lacks such community/ecosystem information will find it difficult to understand why the outcome of one project differs from another.

A third reason particularly relevant to long-term wetland studies is the great difficulty in predicting vegetation change over time ("succession") in many wetland types. The classical Clementsian view of wetlands developing towards an upland climax is not held today by most wetland ecologists (Niering 1987; Guntenspergen and Stearns 1985). For example, bogs can become more hydric with time and plants typical of low marsh or brackish areas can grow in the high salt marsh zone (Niering 1987; Odum 1988). The salt marsh example is particularly important because these are our best studied wetlands. However, papers are now being published that discuss factors (e.g., flooding, disturbance, and herbivory) influencing the distribution of plants in the high marsh of northeast US coastal marshes (Valiela 1984). Once again, without this kind of information long-term changes in high salt marsh vegetation will be difficult to predict.

A fourth reason why wetland creation projects are challenging to evaluate over the long term, is that wetlands are exceedingly varied, highly dynamic systems. They are dynamic because they exist at the interface between terrestrial and aquatic systems and are unusually sensitive to variations in hydrologic regime (Guntenspergen and Stearns 1985). As a result, it is difficult to generalize from the response of creation projects in one wetland type to creations in different locales and habitats.

We do know more about some wetland types than about others. As an example of this difference, Mitsch (1988) summarizes the state of art of wetland modelling; he points out that freshwater marsh models are "primitive" while coastal marsh models are "well developed". Therefore, generalization about saltmarsh creations may be more accurate than generalizations about freshwater marsh creations.

## DIVERGENT VIEWS ABOUT THE LONG-TERM SUCCESS OF WETLAND CREATIONS

There is a striking range of opinions about the success of wetland creation projects. The reported outcomes of USACE Dredged Material projects are generally positive (e.g., Newling and Landin 1985). Other researchers also conclude from relatively long-term studies that under proper hydrologic regimes created salt marshes appear similar to natural ones (e.g., Seneca et al. 1976).

On the other hand, the success of many other wetland creations and mitigations is less certain. For example, several summaries of wetland restoration projects in California point to problems. Josselyn and Buchholz (1984) concluded from a statewide analysis that most California sites were not carefully monitored after project completion; therefore, long-term success or failure of these creations is not known. Race (1985) says that "...it is debatable whether any sites in San Francisco Bay can be described as completed, active or successful restoration projects at present". Eliot (1985) evaluated permits of 58 projects in San Francisco Bay that required wetland restoration. She states that "...the 58 projects are diverse, frequently unsuccessful, and do not adhere to established mitigation policies. Many projects have not been completed. Of those that have been, many do not resemble the existing remnant marshes in San Francisco Bay".

Difficulties with mitigation projects are not limited to California. In Washington state Kunz et al. (1988) reviewed Section 404 projects and concluded that 1) mitigations resulted in a net wetland loss of 33% in 6 years (1980-1986), 2) some wetlands (forested) were not replicated at all, 3) time lags between project initiation and mitigation completion resulted in a loss of at least 1-3 growing seasons per project, 4) there was no routine procedure for tracking compliance, and 5) 5 of the 35 projects were never restored or negotiated.

Why do these conclusions differ so greatly? The people involved in the USACE Dredged Materials Program partially answer this question. They have a great deal of experience which they can apply to each project, particularly with regard to hydrologic design. For example, Newling (USACE, pers. comm.) states that someone familiar with the project design must be on-site when dredged material is applied to a site because elevation above water is critical to project success. Such experience may be lacking in other creations.

# THE SIX CRITERIA USED FOR WETLAND ASSESSMENT

In this chapter I address wetland creations, as opposed to restoration or mitigation, unless these other activities have taken place. I define wetland creations as artificial wetland habitats established in new locations. Manipulations of already existing wetlands--flooding marshes to enhance wildlife use, for example--are not described here. Terminology is debatable in wetland creation studies. For example, Harvey and Josselyn (1986) criticized Race (1985) for her use of the term "wetland restoration" in describing various experimental plantings in San Francisco Bay.

The projects I discuss differ greatly in 1) age of the human-made wetland when evaluated (14 months to 40 years); 2) use of natural controls for comparisons; 3) use of quantitative methods in contrast to qualitative ones; and 4) reasons for the creations. Nevertheless, the wetland creation projects discussed provide considerable information to address questions concerning change of these artificial wetlands with time.

Although the focus of this chapter is permanence of created wetlands and their evolution with time, most artificial wetlands are too young to provide information for long-term studies. Many of the projects described in this chapter were evaluated 1-2 years after they were created. Exceptions are USACE dredged material projects; some of these have been studied for 14 years.

The criteria used in this chapter to evaluate success and describe how the human-made wetlands change with time are:

1. Comparison of vegetation growth characteristics (for example, biomass or density) in artificial and natural wetlands after two or more growing seasons;
2. Habitat requirements (for example, upland vs wetland) of plants invading the created site;
3. Success of planted species;
4. Comparison of animal species composition and biomass in human-made and natural sites;
5. Chemical analyses of artificial wetland soils compared to natural wetlands; and
6. Evidence of geologic or hydrologic changes with time.

These criteria are typically used in wetland ecosystem studies (e.g., Valiela 1984). In addition, plants are emphasized as wetland indicators because they reflect the hydrologic regime and perform numerous important functions (D'Avanzo 1987).

## COMPARISON OF VEGETATION GROWTH CHARACTERISTICS IN HUMAN-MADE AND NATURAL WETLANDS

Using vegetation criteria, USACE scientists have generally judged successful marine wetland creations on dredged materials. But these studies also note the importance of long-term monitoring. For example, Hardisky (1978) found that in Buttermilk Sound, Georgia, aerial biomass of saltwater cordgrass, Spartina alterniflora, planted in dredged spoil was 1.3-5.5 times less after four growing seasons than that of cordgrass in natural sites. Of the 16 comparisons of aboveground biomass of various plants listed in this study, in 13 cases the biomass was greater in natural saltmarshes. Belowground biomass for Buttermilk Sound S. alterniflora was also 2.1-12.4 times less than that of comparison marshes. Hardisky expressed concern about erosion, herbivory, and competition between saltmarsh and invading plants. By 1982 Newling and Landing (1985) were more positive about this site because aboveground biomass was more similar to that in reference marshes. Belowground biomass still lagged behind.

In contrast, in a different dredged spoil stabilization project in North Carolina, aboveground S. alterniflora production measured in the third through fifth growing seasons was within the range of that seen in similar natural marshes; belowground production exceeded natural controls (Hardisky 1978).

At the Bolivar Peninsula dredged materials site in Texas the marsh grasses, Spartina alterniflora and Spartina patens, dominated plots after 3 years although erosion was noted there (Webb et al. 1986). Newling and Landin (1985) concluded from preliminary analysis of this site after 4 years that stem height and aboveground biomass equaled or exceeded reference locales while root biomass was less. In addition, at the Apalachicola Bay salt marsh site, Newling et al. (1983) monitored stem density, height, occurrence and flowering in 8 quadrats 6 years after the site was planted with S. alterniflora and S. patens; these parameters were similar to those in reference marshes.

Not all Corps salt marsh projects have been entirely successful. Stedman Island in Aransas Bay, Texas, was almost entirely vegetated after two years but after 39 months S. alterniflora at low elevations died (Landin and Webb 1986). The reason for the die-off is not known, but this study shows the importance of long term monitoring.

Some freshwater marshes created within the Corps dredged materials program are also judged successful over a relatively short period of time when vegetation criteria were used. Windmill Point on the James River, Virginia, is a freshwater tidal marsh established in 1974-5. Emergent plants similar to those in comparison marshes were observed in 1978-82 (Newling and Landin 1985). Another freshwater intertidal locale, Miller Sands on the Columbia River in Oregon, was planted in 1976. Vegetation development has been slower here than at other Army Corps sites and some plantings failed. However, vegetation began to invade bare areas after several years. Since freshwater tidal marshes have only been studied in the last decade or so, experience and information which could help explain the results here are limited.

Other projects in which vegetation was used to evaluate the long-term success of created salt marshes show mixed results. In two artificial Spartina foliosa marshes in San Francisco Bay, plant density in experimental plots was less than a third of that in nearby natural stands, but the site was only evaluated after two growing seasons (Morris et al. 1978). Plantings in a salt marsh mitigation for a marina in Bourne, Massachusetts failed because the marsh grass was planted too low in the intertidal zone and because the grasses were eaten by waterfowl (Reimold and Cobler 1986). Josselyn and Buchholz (1984) analyzed 3 wetland restoration projects in Marin County, California; plantings failed in 2 sites because proper elevation was difficult to achieve and contaminated dredged spoil used to raise elevation may have hindered plant growth.

Shisler and Charette (1984) compared eight artificial salt marshes to eight adjacent natural marshes in New Jersey. Overall live biomass after 2-6 years was similar in created sites and natural marshes and, not surprisingly, total biomass (including dead litter) was significantly lower in the human-made marshes. However, density and number of reproductive grass heads in the artificial wetlands were also lower than in controls. These vegetation differences, invasion by plants not characteristic of salt marshes, and significantly different soil chemical parameters (described below) led Shisler and Charette to recommend no further construction of high marsh habitat in New Jersey.

Restoration of areas previously vegetated by marine plants appears less problematic. Thorhaug (1979) planted the seagrass Thalassia in Biscayne Bay, Florida in areas that had been denuded by thermal effluent. After four years, she measured similar grass densities in planted areas compared to controls; for these planted seagrasses, flowering and fruiting compared well with controls. It is important to note that these were sites that had previously supported Thalassia and, therefore, the success of revegetation after thermal emissions ceased was promising.

The vegetation characteristics described above--above and belowground biomass, plant density, and number of reproductive stalks--are among the most commonly used quantitative measures of plant growth. Using these characteristics as measures of success, it is difficult to make long-term generalizations about wetland studies. In New Jersey for example, only low S. alterniflora has been successfully established and S. patens exhibited very limited success; therefore, one cannot predict replacement of low marsh by high marsh, a change that can occur in natural marsh ontogeny. We can say that growth of plants in the artificial habitats is sometimes different from that in controls even after 4-6 years. It is difficult to determine temporal trends, however, since many sites were not analyzed over time. In several dredged material sites that have been evaluated over time, vegetation becomes more similar to reference sites. This is not so in the California examples. Therefore, it is impossible from many existing descriptions to determine whether these created wetlands are becoming more like the natural controls as they age.

What generalizations about wetland creation have been drawn by others from vegetation studies in artificial wetlands? Again, opinions greatly differ. On one hand, Zedler et al. (1982) conclude: "Regardless of the techniques used, the examples are too few, and their period of existence too short to provide an instructional guide for marsh restoration projects in California. At present restoration must be viewed as experimental". In contrast, the Corps appears more confident about the information base. Landin and Webb (1986) state that: "The Corps has strived for development of viable wetland sites and will continue to do so. When problems have arisen on sites, or failure noted ...lessons were learned ... and these mistakes were not repeated on later sites".

## COMPARISON OF ANIMAL SPECIES COMPOSITION AND BIOMASS IN ARTIFICIAL AND NATURAL WETLANDS

While we emphasize vegetation in this chapter, it is instructive to evaluate animal responses in created wetlands. One set of studies again demonstrates the value of long term analyses. In a North Carolina dredged material site, Cammen (1976a) found significantly more macroinvertebrates and 10 fold greater biomass in natural plots compared to those in the 2 year old human-made marsh. In addition, in the natural marsh, isopods, polychaetes, and mussels were the dominant fauna while amphipods and flies dominated the artificial plots. In one sampling location, less than 40% overall faunal similarity was seen in the natural/created comparison and in another site the similarity was less than 10% after three growing seasons. Sacco et al. (1988) studied the macrofauna in this marsh 15 years after it was created. The macrofauna had greatly changed and was mainly composed oligochaetes (56%) and polychaetes (36%). Therefore, Sacco et al. concluded that the macrofauna in the human-initiated marsh began to resemble natural marshes within 15 years, although fauna in reference sites were not listed in this abstract.

In a different comparison of North Carolina dredged spoil restoration, Cammen (1976b) also found significantly lower animal density and biomass as well as different animal populations in several year old created systems. In this case, insect larvae dominated the created wetland while polychaetes accounted for most of the biomass in the natural marsh. In contrast to Cammen's findings, in the New Jersey mitigation sites evaluated by Shisler and Charette (1984), many species of macroinvertebrates were common to natural and artificial marshes and populations were highly variable in each.

## HABITAT REQUIREMENTS OF INVADING PLANTS

The persistence of obligate wetland plants with time--either planted or naturally colonizing--and their successful dominance over other vegetation, is one good measure of creation failure or success. Data on species changes of wetland versus nonwetland plants over time indicate mixed success of creation projects.

Kruczynski and Huffman (1978) studied marsh and dune vegetation on dredged material in Apalachicola Bay, Florida. One island supported no plant growth after 17 months because of erosion. Dikes stabilized another island where 42 plants--many upland indicators such as morning glory (Ipomoea sp.) and cudweed (Gifola germanica)--were already growing alongside planted Spartina after 14 months. Shisler and Charette (1984) describe plant species characteristic of upland/marsh ecotones in numerous artificial marsh projects in New Jersey. In Creekside Park, a San Francisco Bay restoration site, upland species and bare ground occupied as much of the marsh surface area as marsh vegetation after eight years. High marsh in particular was not vegetated due to high salt concentrations (Josselyn and Buchholz 1984).

On 40 Florida coastal islands of various ages composed of dredged material studied by Lewis and Lewis (1978), exotic upland plants were common invaders, while these plants were unusual on natural islands; "the predominance of the exotic Australian pine and Brazilian pepper in the later seral stages is unique to dredged material islands in Florida. The maritime forest climax is rare ..." Birds may have influenced plant invasion and success on these islands.

Invasion by upland plants into artificial wetlands was not seen in many studies. However, development of non-wetland flora was not an unusual occurrence and is cause for concern (Odum 1988). In addition, many artificial wetlands were observed only after 2 or 3 growing seasons, which may be insufficient time for establishment and growth of upland vegetation or to determine if wetland flora will persist.

## SUCCESS OF PLANTED VEGETATION

Particular types of vegetation are planted in artificial wetlands to temporarily stabilize soil, provide wildlife habitat, or for aesthetic reasons. Disappearance of these plants over time is not unusual (Hardisky 1978; Shisler and Charette 1984; Dial and Deis 1986; Odum 1988). Certainly, plants in artificial wetlands, as in natural ones, will likely change with time as, for example, seeds in the soil or imported seeds germinate. If these newly observed plants are obligate wetland plants, we may, by definition, call the creation site a wetland. However, it is much more difficult to decide whether the new wetland is a success if unanticipated plants invade a project. What if freshwater marsh plants grow in a saltmarsh project? Is the creation a failure? The answer to this question largely depends on the specific functions the artificial wetland is designed to serve and these must be outlined in detail in the management plan. In any case, it is useful to document unanticipated results.

Examples of unplanned vegetation communities in artificial wetlands are common. Hardisky (1978) noted after four growing seasons an influx of fresh and brackish water plants overtopping planted spikegrass (Distichlis spicata) in a Georgia estuary dredged material site. Hardisky predicted that the salt tolerant D. spicata would be outcompeted. The growth of freshwater plants in this location indicated a complete inability to predict the hydrology of the area. Similarly, freshwater wetland plants such as the royal fern (Osmunda regalis) and a rush (Juncus sp.) dominated the high marsh in a West Florida dredged material project where Spartina patens had originally been planted. In the New Jersey artificial marshes, Spartina patens was planted in some locations but Spartina alterniflora was dominant during subsequent samplings (Shisler and Charette 1984). Spartina foliosa was planted in a 95 acre (38.4 ha) dredged material site in San Francisco Bay; here, as in other locations in California where S. foliosa has been planted, Salicornia has invaded the area (Race 1985). Dial and Deis (1986) reviewed 10 mitigation or restoration projects in Tampa Bay, Florida. The survival of Spartina alterniflora ranged from 10-93% and the number of plants per square meter ranged from 0 to 230. Dial and Deis (1986) attribute plant deaths to erosion, competition by upland plants, and poor planting techniques. Finally, Savage (1978) photographed the same mangrove plantings in Tampa Bay, Florida over a six year period; Rhizophora and Laguncularia did not survive while Avicennia did.

Odum (1988) points out that invasion by unwanted plants is common in freshwater artificial wetlands. Typha spp. often crowd out more valuable planted species, leading to the "cattailization of America".

Other factors influencing the success of plantings of created wetlands include predictions of hydrologic conditions and proximity to seed source. High water levels and lack of control of water level resulted in death of trees planted on the shore of Missouri River reservoirs (Hoffman 1978). Eastern cottonwood (Populus deltoides) and green ash (Fraxinus pennsylvanica) did not survive inundation, while broadleaf cattail (Typha latifolia) and white willow (Salix alba) did. Cattle grazing also influenced vegetation success on the banks of these dams. Reimold and Cobler (1986) evaluated five mitigation projects in the northeast U.S.; they rated one freshwater site after two growing seasons as "marginally successful" because banks were too steep and water too deep for emergent vegetation. Two other freshwater mitigations rated "ineffective" by Reimold and Cobler were only seen after one year (D'Avanzo 1987). Gilbert et al. (1981) studied a 49-acre tract in Florida that has been mined for phosphate and noted invasion by 50 wetland plant species after 3 years. However, plantings had failed because the hydrology of the site had been incorrectly predicted. Gilbert et al. (1981) concluded that species potentially invading the approximately 27,000 acres in Central Florida used for phosphate mining were site-specific; invading types depend on source material and type of habitats close to the restoration. In the case studied, unmined wetlands supporting a diverse native flora were adjacent to the mitigation project.

Race (1985) reviewed 15 experimental plantings in San Francisco Bay. She concluded that many problems--high soil salinities, incorrect slope and tidal elevations, erosion and sedimentation, and poor water circulation--accounted for numerous failures of the plantings. For example, in the Bay Bridge site, 10% of the Spartina foliosa and 20% of the Distichlis spicata transplants survived one year; Salicornia transplanting was more successful. S. foliosa spread well from plugs at the Marin County Day School location after two years, but the stated objective of the project--erosion control--was not met. All S. foliosa experimental plantings in the Anza Pacifica lagoon failed within 2-3 years; the mitigation site was replanted and, again, after three years only remnants of the planted plugs remained. In three USACE erosion control projects, neither seedlings, sprigs, nor plugs survived longer than eight months (Race 1985); survival of marsh plugs was good only in unexposed areas of marsh and creeks. Experimental plantings of cordgrass seedlings in Muzzi Marsh prior to mitigation were dead after one year. The 125 acre (50.6 ha) Muzzi Marsh project is becoming naturally colonized by Salicornia and Spartina.

The highly experimental nature of marsh creation is clear from Race's critical review of these projects. (See Harvey and Josselyn, 1986 for a critique of this review and Race, 1986 for a reply). Since saltmarsh restoration is a new technology and one with a relatively poor science base, failure of experimental plantings is not surprising. However, it is disturbing when projects that are largely unvegetated or that support exotic vegetation are called successful restorations (Race 1985).

## CHEMICAL ANALYSES OF SOILS IN CREATED AND NATURAL WETLANDS

Little data exist on sediment characteristics of human-made wetlands or of comparisons between these sites and natural controls (Race and Christie 1982), although this data base is growing. Several studies do show that nitrogen, phosphorous, and organic matter increase with age of the created site (Reimold et al. 1978, Lindau and Hossner 1981, Craft et al. 1988a). While organic carbon at various depths was considerably less in human-made marshes in

North Carolina, Cammen et al. (1974) estimated that organic content of soils in these creation projects would reach reference concentrations in 4-26 years. Studies by Craft et al. (1988b) with natural isotopes support this trend since marsh plants were the main source of organic carbon in both natural and transplanted marshes. After 2 years, organic matter concentrations, total nitrogen, and ammonium-nitrogen levels in experimental marsh soils from Texas dredged spoil projects were on average 2-3 times lower than those in natural marshes (Lindau and Hossner 1981). Concentrations of these parameters increased with time and Lindau and Hossner concluded that, assuming a linear rate of increase, concentrations would be equal to those in surrounding marshes in 2-5 years.

Despite such predictions, Race and Christie (1982) are cautious in their analysis of these findings; "no man-made marsh to date has shown the stabilization of physical and chemical properties in the range of values for natural marshes". Their caution is supported in the findings of Craft et al. (1988a) who compared natural and planted soil in 5 sites; they concluded that organic matter pools develop in 15-30 years but development of soil C, N, and P pools take much longer.

In some cases, the substrate in the created wetland differs greatly from that in genuine wetlands. Shisler and Charette (1984) found that sand was the substrate most often used in eight artificial marshes studied and this resulted in distinct edaphic differences. Artificial marsh sediment was lower in organic matter, nitrogen, phosphorous and salinity when compared to nearby reference marshes. Only pH was the same.

Chemical/physical analyses of artificial wetland soils are particularly useful indicators of project progress and success with regard to changes with time. It is possible to predict trends (increasing organic carbon concentration, for example) and to determine rates of change of these parameters. The few studies in which this approach was used show that created sites become more like natural ones with time. An important question for mitigation projects is: how much time? The time scale of these projects is several years and sediment in genuine wetlands has developed during hundreds and thousands of years.

### EVIDENCE OF GEOLOGIC OR HYDROLOGIC CHANGES WITH TIME IN ARTIFICIAL WETLANDS

Much of this information has been described above but it deserves reemphasis because the geologic/hydrologic setting is so critical in wetlands. Clearly, dramatic geologic or hydrologic changes--including sediment erosion or deposition, or groundwater seeps--will alter creation projects as planned.

Some creations, such as the Panacea Island project in Florida (Kruczynski and Huffman 1978), have entirely eroded away. Waves killed planted mangroves in a Tampa Bay creation (Savage 1978). Wave erosion and sediment inundation was also a problem in some New Jersey mitigations (Shisler and Charette 1984). In a freshwater bank stabilization project, high water killed numerous planted floodplain trees (Hoffman 1978). Finally, Gilbert et al. (1981) noted that plantings failed in a phosphate mine revegetation project because the hydrology of the site was poorly understood.

Some of these events could have easily been prevented. Dikes can be better constructed and creations should be not attempted in areas where erosive forces may negate the project. However, storm damage is impossible to predict in many locations, including the coast and floodplains of rivers. Therefore, it is not surprising that some creations fail.

## CONCLUSION

What conclusions can be drawn concerning the long-term evaluation of wetland creation projects discussed in this chapter? Using six criteria as measures of success, there is a striking contrast in the 2-15 year success of different projects. On one hand, for a decade or more the U.S. Army Corps of Engineers has evaluated a large number of wetlands created with dredged materials. When vegetation parameters are used, many of these projects become structurally similar to reference sites with time. In addition, one 15-year old animal study showed a similar trend. Several evaluations of soil chemistry also indicate that these wetlands become more like natural ones with time. USACE researchers evaluate their experiments and use this information in new projects; a large data base about similar types of projects is communicated within the program.

It is important to recognize that even the "old" USACE artificial wetlands are not identical to reference wetlands; for example, soil carbon and belowground plant biomass are developing slowly. Therefore, when an artificial wetland is built as a mitigation for a lost wetland, decades may pass before the created project assumes the structure and function of the lost habitat. During this time, the important functions that the destroyed wetland may have served (Larson and Neill 1987) may be lost to society.

In contrast to these USACE projects, many other artificial wetlands--mitigation projects and experimental plantings--are judged problematic or partial failures in studies of up to several years. Reasons for failures include contamination of soils, herbivory, erosion, and inappropriate hydrologic regime. In addition, many created wetlands have never been evaluated and, therefore, their success in not known. Studies also indicate that a small but disturbing number of required projects were never even initiated.

Many creation projects fail because of improper hydrology. Basic to the entire concept of wetland creation is the existence of a functional hydrologic regime appropriate for the establishment and development of the specific wetland species. For example, water level depth, seed bank potential, and sloping marginal contours are crucial to the development of emergent aquatic plants (Niering 1987). Some types of artificial wetlands do appear stable after several years; perhaps the hydrology of these habitats is less challenging to predict than in other locales. For example, the establishment of low Spartina alterniflora salt marsh has met with considerable success while the creation of high Spartina patens salt marsh has been problematic (Shisler and Charette 1984). Most high marsh sites are adjacent to upland and therefore the hydrology of the high marsh is more unpredictable than that of the low marsh and more difficult to reproduce.

Some created wetlands systems will remain relatively stable over time while others can be expected to change. Hydrology is an important factor determining wetland community changes with time. The basic goal is to create persistent functional wetland systems. In some situations this may be more important than creation of specific wetland types because the present structure of a wetland may be a momentary expression of the wetland of the future.

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# REGIONAL ASPECTS OF WETLANDS RESTORATION AND ENHANCEMENT IN THE URBAN WATERFRONT ENVIRONMENT

**John R. Clark**
*Rosenstiel School of Marine and Atmospheric Science*
*University of Miami*

***ABSTRACT.*** In urban settings, wetland resources are typically degraded and often seriously dysfunctional. Loss of wetland function in this manner reduces the productivity of the larger aquatic ecosystems of which the wetlands are a component. Therefore, in urban settings a high priority must be given to restoration and enhancement of aquatic ecosystems and to their component wetlands. Success in system-wide restoration requires formulation of a regional strategy with goals, objectives, methodologies, and predesignated restoration sites. Such strategies must be locally generated and cannot be substituted by existing one-agency programs. All levels of government and private interests must be involved. Moreover, the existing system of site-by-site permit review must be altered to ensure that permit decisions are oriented toward the regional restoration strategy. It is particularly important to recognize that the developers' resources will be the main source of restoration project funds through voluntary or mitigative restoration and enhancement. Therefore, mitigation has to be given a role at the front end of the review process and not held until the end as a "last resort".

## INTRODUCTION

The urban setting presents distinctive problems for waterfront development as well as special opportunities for restoration and enhancement. For several reasons mitigation has the potential to become a positive tool for restoration and enhancement rather than just an obstacle to developers (Wessel and Hershman, in press). Currently, the limited waterfront property that exists in most urban areas is being aggressively sought for residential and commercial development. The pressures are great, front-foot prices are astronomical, investment funds are abundant, and profits are assured, providing that permits can be obtained with reasonable effort. This pressure has resulted in renewal projects for much of the old, degraded, urban waterfront area in coastal cities (Figure 1). For example, the buildout cost of renewal projects now underway or proposed for the New Jersey side of the Hudson River opposite New York City is estimated at $10 to $12 billion.

In urban waterfront settings, there are virtually no original or unaltered wetlands or intertidal flats left. Wilderness is not found here. Most of the urban shoreline edge has been "hardened" and dredged or otherwise altered, changing its ecological character to the detriment of fish and wildlife. The result is an overall reduction in biological diversity and carrying capacity for desirable species within the adjacent estuary, river, or lake. This habitat needs to be repaired as much as to be protected. Much of the urban wetland we try to protect is so damaged that to be worth saving it should be repaired. Therefore, in urban settings, restoration and rehabilitation should be given maximum attention.

It was predicted in 1980 that restoration would reach the top of the wetland agenda during the decade of the 1980's (Clark and McCreary 1980). This has certainly occurred for urban aquatic ecosystems but in most regions it has happened de facto , not as the result of policy decisions or program commitments (one exception is the California State Coastal Program). Because funding possibilities are so limited in the urban setting, rehabilitation should be primarily focused on biological needs, such as restoring habitat for endangered or commercially valuable species or enhancing critical processes of the wider wetland ecosystem (Clark 1979). As put by Batha and Pendleton (1987): "Lack of suitable enhancement sites at reasonable cost and conflicts among agencies as to what type of habitats are of greatest importance to the Bay system greatly concern all people interested in the future of San Francisco Bay.... Rapid urbanization will make the possibility of adding wetlands to the Bay increasingly difficult in the future".

One example of the multiobjective approach

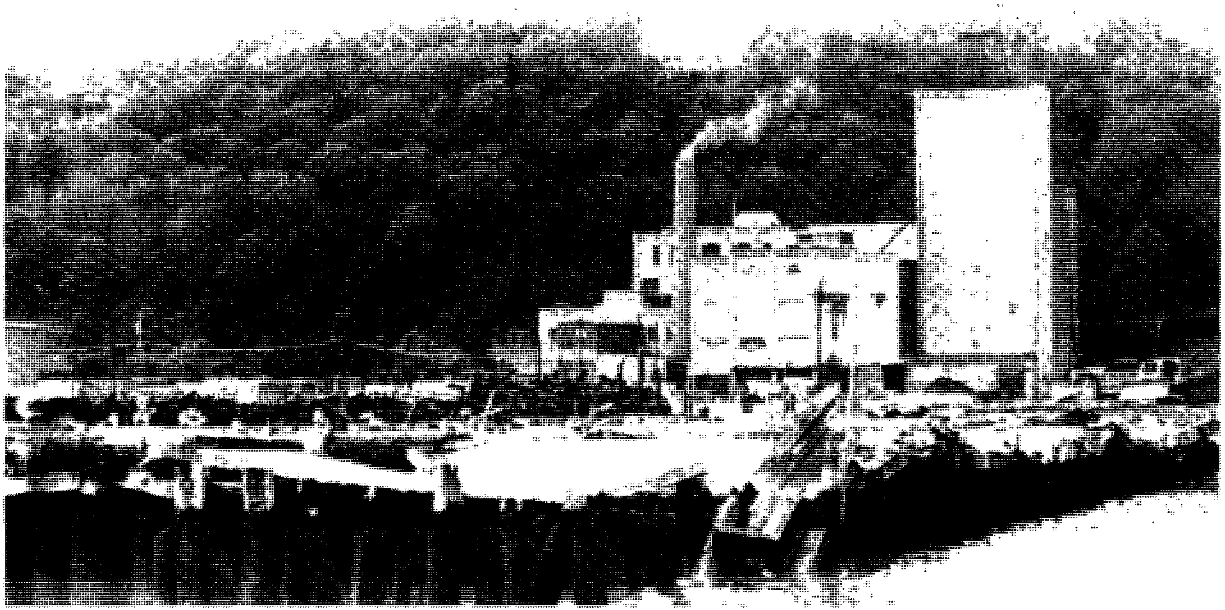

Figure 1. Typical waterfront scene on the Hudson River in Manhattan. Original wetlands and tideflats were replaced with piers and channels which are now deteriorated and dysfunctional. Some interests want to retain these piers, others want them removed, and still others want ecological rehabilitation in combination with residential development.

that can be used in an urban situation is the Pt. Liberte canal side residential project in Jersey City, N.J. (see following section: "Case Study Port Liberte"). Here the development site itself was small, but peripheral areas and edges were used in a voluntary program of multiple enhancements (Figure 2) to: rehabilitate and reroute a seriously degraded stream, rehabilitate a degraded tideflat/ slough system, enhance the beach-dune system, create a least tern nesting site, build an artificial reef, enhance a small peninsula owned by Liberty State Park, and protect the state-designated Caven Point Natural Area (tideflats and shallow waters) adjacent to the site from boater damage.

It is unfortunate that aquatic habitat restoration has not been given the same priority as water quality restoration which has received great attention and lavish budgets in the past 15 years. Direct appropriations for physical habitat repair and ecosystem restoration by either Federal or state governments have been minuscule, regardless of how compelling the need may have been (Clark 1985). Progress in habitat restoration has for the most part, been left

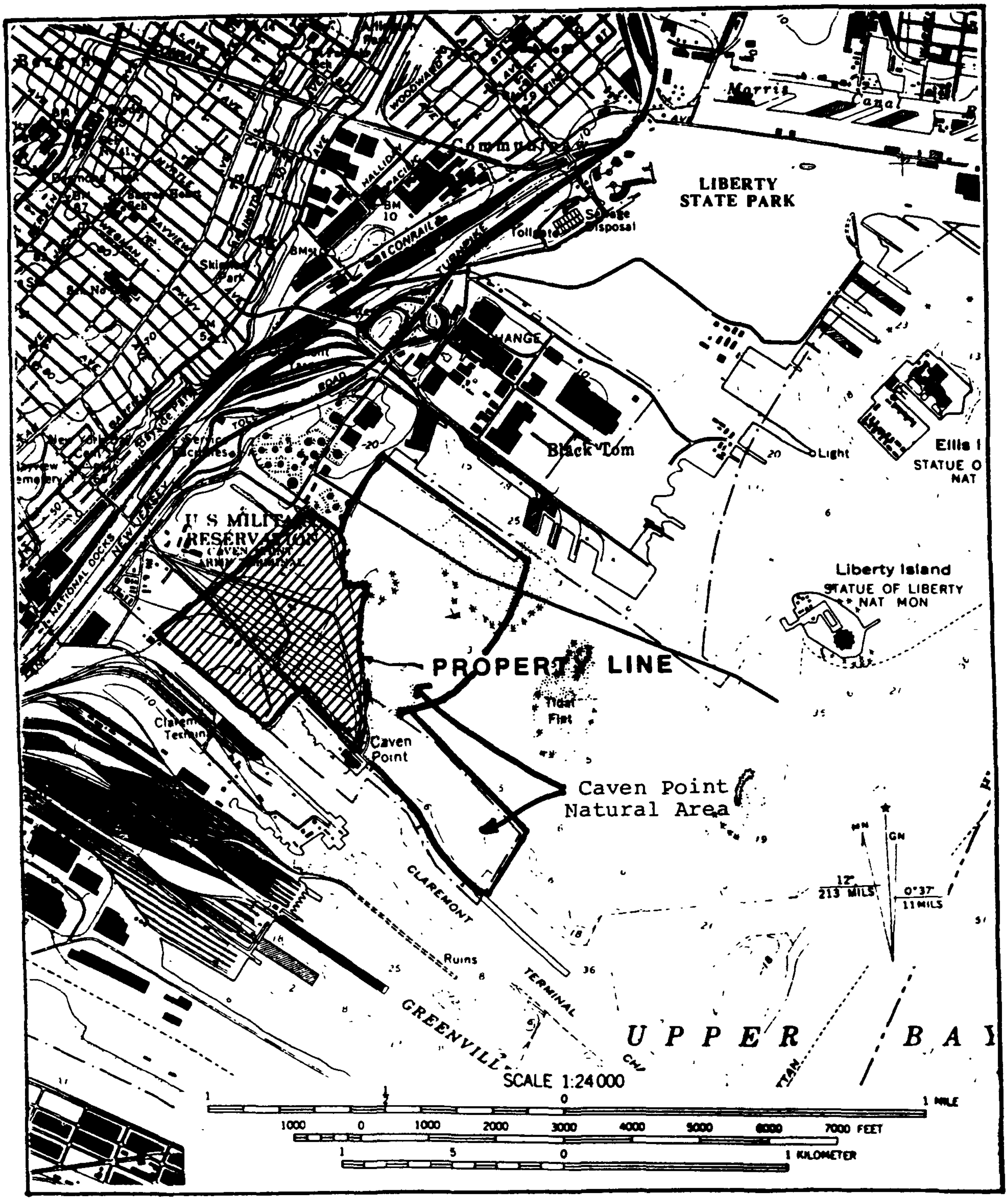


Figure 2. Jersey City, N.J., waterfront now in active redevelopment from industrial to residential/commercial. Shaded section is the site of the new Port Liberte project which is occupying an abandoned military site.

to casual and secondary mechanisms. The most promising of these mechanisms is mitigation in exchange for development permits, whereby physical habitat restoration is, in effect, exacted from developers by regulators as a quid pro quo for obtaining waterfront development permits. But this approach has been less than successful because the mitigation process under most permit programs has been poorly organized and ad hoc. Since long term future goals have not been established for particular ecosystems or regions, nor guidelines formulated for developers, mitigation has been a case-by-case, uncoordinated activity. Often this seems to have been deliberate, because regulatory agencies may want to relegate mitigation to a "last resort" basis. This may be commendable in rural areas where more natural conditions exist, but in urban settings mitigation may often have to be the "first resort" where no other mechanisms are available for repair of damaged aquatic habitats.

A mitigation goal of "no net loss of habitat value", often advocated for rural settings is not sufficient for highly damaged urban aquatic ecosystems. Here the goal should be "a net gain in habitat value" if we are to regain the losses of the past, reach higher levels of biological productivity, and accomplish recovery of depleted populations of economically valuable or endangered species. This goal could be stated in another way, specifically as a policy "to achieve net positive cumulative impacts". This approach to ecosystem recovery through strategic, rather than reactive mitigation has promise for certain urban aquatic ecosystems where a basis for cooperation among regulators, developers, scientists, and environmentalists can be found (Clark 1985).

It is far too easy to drift into an attitude, or approach, where only potential negative impacts are addressed. I believe we should try hard to prevent future losses of wetland, but we also should work to regain lost functions. To be workable, the restoration approach must address the total individual wetlands ecosystem (lake, river, estuary, marsh, etc.); that is, the whole aquatic system of which the wetland is a part. We should recognize that certain functions are being lost in an aquatic system, see which are dependent upon wetlands, establish priorities for the functions of greatest value (e.g., bird habitat, flood storage, productivity) and enhance these functions. This would reverse the serious decline of productivity and diversity in aquatic habitats in the urban setting.

It is fair to say that most mitigation consultants find the typical permit-by-permit approach of regulatory agencies ineffective in advancing long-term goals for aquatic ecosystem conservation and a deterrent to strategic system restoration. Further, individual permit reviews should be evaluated wherever and whenever possible through a regional strategy for restoration. I recommend that goals and targets should be determined in advance according to a regional strategy and used to guide subsequent permit actions involving restoration and enhancement. For example, Sorensen (1982) concludes that "...the relative scarcity and abundance of the resource needs to be determined on a region-wide basis in order to set priorities on the types and locations of habitats that should be provided in a restoration site plan".

The ideas expressed in this chapter are particularly applicable to the urban settings of coastal cities and their surroundings. But the principal recommendations involving regional strategies, goal-setting, ecosystem focus, and predetermination of restoration needs and sites could apply to less urbanized seacoast and freshwater areas.

## THE NEED FOR ADVANCED CRITERIA

If urban developers (whether public agencies or private corporations) are to cooperate in restoration of aquatic habitats through either mitigation or voluntary enhancement, they must have some guidance. They should know what is expected of them in the context of the regional ecosystem in which the project is located. If voluntary enhancement is to be encouraged, they should know what specific opportunities exist and what public interests they can best serve. Moreover,they should know this information at the time they are planning their projects, not after the application has been submitted and the Section 10 or 404 Public Notice has been circulated by the Army Corps of Engineers (COE).

In the mitigation process, the COE usually defers to the U.S. Fish and Wildlife (FWS) to assess mitigation requirements and expects to receive FWS advice after the developer's permit is submitted (COE 1985) and the developer is already committed to a certain plan. If the COE does not agree with FWS or other commentators, including EPA and the National Marine Fisheries Service (NMFS), a prolonged and expensive delay will often result (months or even years). For example, Zagata (1985) states, "The mitigation requirement in 404 of the Clean Water Act has been a source of controversy between the regulating agencies and permit applicants. The need to mitigate is considered at the end, rather than the beginning, of the permit process, after other alternatives have been examined. Thus, industry frequently perceives mitigation as an additional source of delay and money...an add-on-cost since it is considered after completion of the proposed project's normal budgeting and planning process". All of which may be welcome if you're only trying to stop a project but not if you're trying to promote restoration of urban aquatic ecosystems.

In order to succeed, effective restorative mitigation must be a cooperative venture between developer and agencies. As of now, the developers' opinion of mitigation is typically one of frustration (Wilmar 1986):

> "The Corps usually recommends that the applicant embark upon a series of negotiations with the various commenting agencies. This is generally a frustrating exercise because there are few rules, and commenting agencies have broad discretion to interpret those standards that do exist. Moreover, the applicant has usually already obtained approvals from the local and state agencies, each of which has extracted concessions as the price of project approval. Thus, the unsophisticated, generous, or inexperienced applicant often has no more to give, and the federal agencies have little other incentive to reach an agreement."

By the time the application has been submitted, positions have hardened and options have been closed for both the developer and the regulator. Aware of this situation, EPA and other principal agencies including state agencies will often meet with the developer in "pre-application" conferences that FWS mitigation policy presumably encourages (FWS 1981). This can be beneficial if various agency staff can come to agreement among themselves and give unambiguous advice to the developer (Is high marsh lower priority than low marsh? Are bird breeding islands a beneficial substitute for open water surface, water column, and bottom? Are piers over bare bottom beneficial or detrimental? Should mudflats be converted to marshland? Are ducks more important than fish?). However, all too often an agency's staff has not had a chance to come to consensus in advance on the issues of habitat option preferences. The developer is too often left to gamble on which mitigation approach might be best to get him through the permit process. It is a major problem for the permit process that a formal method for prior consensus on regional mitigation priorities does not exist. It is also a major problem that current mitigation manuals or guidebooks on mitigation methods and preferences are not available to development planners to consult throughout the siting and design process.

What can an individual EPA or other agency permit reviewer do to improve this situation in a region where no organized mitigation policies and programs are in place? The answer is to work to clarify and reach consensus among agency colleagues on mitigation procedures and priorities, and to assist in conveying the results to the applicant at the earliest possible time. An appreciation of the urgent necessity for restoring urban wetland-related ecosystems using mitigation is, of course, the precursor to agreement on mitigation targets. While FWS and COE are the main Federal agency actors in early permit skirmishes, EPA has a strong influence because of the agency's ultimate "veto" power.

The advantages of advance criteria and early coordination in project planning are stated by Dial et al. (1985): "To be most effective in preserving habitat, mitigation activities should begin during the planning phase of a project. It is usually only at this phase that the avoidance or minimization of the impacts is possible, and mitigation in the literal sense of the word occurs".

## THE ADVANTAGE OF THE REGIONAL STRATEGY

A major challenge to EPA and other agencies is to make the fundamental shift from a site-by-site focus to a regional focus for urban areas. Because permit actions are typically confined to a project site, often there may be little knowledge or concern about the relationship between that site and the regional ecosystem incorporating the project site. Ecosystem thinking is engendered by the regional approach. One can't think of each individual wetland as a unit of landscape in isolation, but rather in terms of the whole system.

A major advantage of taking the regional ecosystem view by thinking beyond the immediate project site to consider the whole, is that most wetland functions that we value involve a related aquatic system that is larger than the affected wetland itself. The wetland unit often depends on the larger aquatic system to actually realize the potential of a particular wetland function. For example, detrital output is a value only if there is a living community beyond the wetland to utilize it. Likewise, if a wetland is to serve as a nursery for fish it must be accessible to an adjacent healthy, functioning, major aquatic system which depends upon many components other than wetlands. For example, a snook nursery area needs to have a shallow intertidal area with mangrove edge and an admixture of fresh water and, outside, a productive feeding and cryptic habitat of seagrass beds. After this period (1/2 year or so) the snook move into deeper waters and utilize a variety of habitats in enclosed waters of estuaries and around channels, where good water quality becomes important. Obviously, we need to be concerned about more than acres of wetlands (mangrove) if we want to improve the snook's lot (now greatly depleted). We want to reverse the degradation of the whole aquatic system and achieve a positive direction in various permit review and mitigation activities. Consequently, in restoring or creating wetland units in mitigation, we have to decide what is the optimum balance of, say, high wetlands, low wetlands, flats, channels, and open shallow waters (Clark 1986b).

When the potential for mitigation or voluntary enhancement arises, the question follows of what specific restoration projects should be recommended. With private developers, the question is most often fielded by a consultant; with public projects, a staff professional usually provides advice. Interaction of these professionals with regulatory agency personnel is most often the key to efficiency in subsequent review of the permit and in approval of the mitigation/restoration program. This is all that would be necessary in a perfect world characterized by mutuality, omniscience, and altruism. However, in the real world of permitting, the process is typically an adversarial one, each permit is handled de nouveau, advance goals are absent, and agency reviewers are often unsympathetic to development and reluctant to commit to specifics and foreclose their post-submittal options. Thus, the official pre-application conference (as advocated, for example, by FWS mitigation guidelines, Fed. Reg., Jan. 23, 1981, Vol. 46, No. 15, p. 7644 et seq.) may fall short of developer needs and may discourage restoration initiatives. This confirms the strong need for directive guidelines to make the process predictable to developers and to make available to their environmental experts advance mitigation criteria for use at early planning stages. This can only be accomplished effectively in a regional context.

The shift from the reactive to the strategic approach would bring a shift from "supply-side" to "demand-side" thinking about wetlands. That is, assessing the condition of a wetlands system begs the strategic question "What are the societal demands for natural goods and services from this system and how well are they being met?". This replaces the reactive question "What natural goods and services does this wetland supply?".

Effectiveness in aquatic habitat restoration requires understanding the regional ecosystem, its present condition (how far degraded), and what values are most important and should be given priority for rehabilitation (plant productivity? bird habitat? nursery area?). Given this, one can formulate goals and advance criteria for permit review and mitigation and even reverse the trend of negative cumulative impacts and bring about a positive cumulative impact sequence.

## REGIONAL ORGANIZATION

It is within the purview of the EPA or other agency reviewers to consider each wetland unit as part of a greater ecological and hydrologic system when dealing with restoration and reversal of cumulative impacts. Thinking discriminately is important, including considering the variety of configurations, functions, and social needs that restoration projects can meet. From the ecological engineering point of view, given the money, one can do almost anything to a wetland. It can be regraded, reshaped, rewatered or replanted. The substrate can be changed, the elevation, topography, or the supply of water (Clark 1986a).

But beyond the technical issues, there are judgmental questions to be answered: What wetland design would yield the highest socioeconomic benefit, considering regional needs for natural goods and services? If waterfowl habitat is critical, then a relatively shallow open water area would be most appropriate (Figure 3). If shorebird habitat, shoreline stabilization, or run-off water purification are the priority needs, then different designs are indicated. The strategic approach to mitigative restoration requires that someone other than the project developer or permit reviewer--preferably a regional entity--select the regional priorities for aquatic ecosystem outputs of natural goods and services. Once that is accomplished, an environmental professional can convert these priorities to functional criteria and engineers can convert the criteria to design specifications and construction (Clark 1986a).

Figure 3. Degraded streambed on the Port Liberte site scheduled for rehabilitation to enhance its value to waterfowl, shorebirds, and nursery size fishes and to remove high concentrations of toxics in the streambed.

Because of the variety of public interest questions involved in mitigative restoration, individual agency permit reviewers would benefit from advance formulation of regional goals and restoration priorities by a recognized entity charged with balancing the variety of private and public interests. Where regional entities have been established to deal with aquatic habitats and permits and have formulated guidelines and criteria, the results seem to have been helpful.

Federal/state programs that can be used to explore regional possibilities include the following:

1. EPA's authority for "advance identification" or "predesignation" of wetlands (under Sect. 404(c) or Sect. 230.80 of the Guidelines) which enables EPA to list those that are off limits to dredging and filling in a particular region (e.g. the Hackensack Meadows). The procedures for advance identification provide for input from a variety of interests, scientific evaluation of wetlands values, and a plan for priority protection of critical habitats. But the program may or may not deal effectively with whole ecosystems or with restoration needs (Studt 1987).

2. The COE's long-term management strategy (LTMS) for dredging activities on a regional basis strongly encourages and assists Districts in developing LTMS's within their boundaries (Klesh 1987). Districts with LTMS's in place or in planning include St. Paul, Rock Island, Seattle, and Portland.

3. States' authority under the Federal Coastal Zone Management Act (1980 Amendments) to do regional Special Area Management Plans (SAMP's), whereby all aspects can be considered in a regional planning context. SAMP's can effectively establish regional strategies for aquatic

habitat restoration, including restoration criteria, identification of mitigation sites, preparation of guidelines, and mechanisms for incorporating mitigation into a restoration master plan. Federal agencies must be consistent with approved state SAMP's (Studt 1987). A major example of a successful SAMP is that for Rhode Island's salt pond region (Olsen and Lee 1985) whereby strong guidelines for development and aquatic system restoration in the salt ponds were formulated with the participation of a wide spectrum of agencies and environmental and private interests. The main example of the difficulty of the SAMP approach is Gray's Harbor, Washington, in which Federal and state agencies and the local planning entity and port authority have spent more than 8 years trying to agree to a plan.

4. "Area wide" advance Environmental Impact Statements developed by the COE, and often advocated by FWS, provide an opportunity to review the condition and restoration needs for regional ecosystems. These need to be set up for wide consensus, public interest balancing, formulation of policy, and implementation of positive programs.

5. Use of the Estuarine Reserves program, authorized by the Federal Coastal Zone Management Act to organize regional aquatic ecosystem conservation programs. Examples of strong local estuarine reserve programs which have enhanced restoration and provided an advance framework for permit decisions include Apalachicola Bay (Florida) and Tijuana Estuary and Elkhorn Slough (California) National Estuarine Reserves (Clark and McCreary 1987).

6. State-organized advance designation of mitigation sites. This approach, currently operating in California and proposed by New Jersey, is especially applicable to the urban setting where on-site mitigation opportunities are limited (however, they do imply advance acceptance of the idea of offsite mitigation, which is not viewed favorably by some agencies). Such programs are an excellent way to pinpoint the need for restoration and to take definitive steps to establish priorities for restorative mitigation.

To the extent possible, regional needs and opportunities for restoration should be included in any initiatives under the above programs.

Locally organized programs designed for specific regional aquatic ecosystems have been successful in many coastal urban areas. Although not usually designed specifically for restorations, these locally organized programs can be most helpful in generating a consensus on restoration needs and guiding regulatory agencies toward restoration priorities in permit decisions involving mitigation and voluntary enhancement. Examples of such programs in urban coastal areas are:

1. The Bay Conservation and Development Commission (BCDC), the original regional organization for aquatic ecosystem conservation, was founded in 1965. All development around the shoreline of San Francisco Bay must be permitted by BCDC which has worked to find broad consensus on aquatic ecosystem conservation and to formulate mitigation guidelines. A major restoration mitigation goal is to require opening of diked wetlands in compensation for any filling allowed.

2. The Environmental Enhancement Plan for Baltimore Harbor (1982) by the Regional Planning Council for the Baltimore Metropolitan Area (a Maryland state body) broke a 10-year deadlock over fill, dredging, and dredge spoil (dredged material) disposal when it was modified to be acceptable to Federal agencies (by eliminating a mitigation bank). The Plan includes rehabilitation of aquatic habitats and creation of wetlands. Five sites were selected in advance for mitigation activity. This approach made mitigation more rational and expedited the permit process.

3. The Tampa Bay Regional Planning Council initiated aquatic habitat management planning action that resulted in a cooperative agreement with FWS to, among other things, identify mitigation options and select mitigation sites. This action has resulted in enhanced cooperation among various interests and has expedited permit approvals.

4. The Ports of San Pedro and Los Angeles jointly developed the "2020 Plan" for port expansion which includes specific mitigation commitments according to a Memorandum of Understanding signed by the interested agencies. Mitigation requirements will be met by off-site restoration (there being extreme limits on available mitigation sites in the Los Angeles harbor area). Specifically, as a first goal the entire Bataquitos Estuary ecosystem will be restored to a prescribed level of function.

5. The Bataquitos Lagoon restoration project is a regional effort, organized cooperatively with several Federal and state agencies and local institutions with a goal to restore the entire aquatic ecosystem of the lagoon (ca. 1,000 acres) by off-site, out-of-kind (mostly) mitigation. Included is sediment removal,

building of least tern nesting sites, beach nourishment, inlet stability, creation of freshwater marsh, etc. This project, funded as mitigation for dredge-and-fill by the Port of Los Angeles, is seen as the first in a series of restorations under a long-term cooperative integrated regional plan (Marcus 1987).

6. Fraser River Estuary Management Programs (British Columbia, Canada) initiated in 1977, resulted in a plan in 1982 and 1985 for the joint management and restoration of the estuary by a network of national and provincial government authorities. The plan was preceded by a thorough inventory, consensusing, goal setting, and criteria formulation process. The management plan makes decision making predictable. Under the coordinated Project Review System, developers get a 30-day response (the interagency committee meets bi-weekly). The North Fraser Harbour component has a mitigation bank with preselected littoral sites for restoration and a system to intercalibrate relative values of different wetland types and other shallow aquatic habitats (Williams and Colquhoun 1987).

7. The Biscayne Bay Management Project (Florida) has integrated a variety of authorities and actions toward a master plan approach to water quality and aquatic habitat restoration and conservation. While management is less centralized than examples above, the integrated consensus formation and networking have enhanced restoration and made development constraints more predictable.

## REGIONAL GOALS AND MITIGATION TARGETS

Any regional strategy for aquatic habitat restoration requires formulation of goals, often followed by objectives, guidelines, and criteria for project evaluation. The process of goal setting should incorporate the policies of agencies and the views of the full spectrum of private and public interests involved. Even when completed, the strategy will most likely be advisory and not a substitute for existing agency authorities and prerogatives.

The following is recommended as a conceptual approach to the goal setting process (Josselyn and Buchholz 1984, quoted in Quamman 1986):

> "The government agencies involved in managing and regulating natural resources need to identify restoration goals which state the habitats and functions deemed to be important within each ecoregion. This will result in improved project coordination within an ecoregion, and also allow for identification of the cumulative effects of piecemeal alterations in the region. The initial step in identifying restoration goals involves determining the types and area of the different habitats present, as well as their rates of losses and gains. This determination, coupled with knowledge about the importance of each habitat to the ecoregion's key species, will provide the information needed to decide which habitat types should be restored or replaced."

An example of Regional Restoration Goals generated by the California Coastal Commission is the following for the South Region of the California Coast (Calif. Coastal Comm. 1987):

> "The predominant restoration goal for this region should emphasize the creation of open circulation, low intertidal habitat interspersed with salt marsh patches to enhance shorebird, diving duck, and marsh and wading bird populations. The open circulation pattern will enhance local fish and invertebrate populations and keep mosquitos and flood control activities relatively easy. The salt marsh areas should be sufficient in size to maintain endangered species populations."

Such goals provide a good starting point for the technical realization of restoration but obviously need to be extended with detailed criteria.

If you are fortunate enough to be reviewing permits for an aquatic ecosystem that is covered by a regional strategy with goals and criteria for restorative mitigation where previous analytic steps have been taken, you have only to match the development project with identified-in-advance restoration targets and procedures. If not, you may nevertheless be able to analyze the regional ecosystem involved and identify targets that would be acceptable to your colleagues in the other agencies, environmentalists, and the developer. One major issue is to evaluate the mitigation or voluntary restoration in the context of the needs of the wider ecosystem. Most wetlands do not exist in isolation; they are coupled to wider aquatic ecosystems (Figure 4). Another major issue is to recommend mitigation targets that have high priority in terms of your perception of regional ecosystem needs.

This approach is different from the familiar acre-for-acre compensation requirements because of its urban orientation. Urban aquatic systems are always in need of repair. These needs can be diagnosed and specific treatments prescribed that will be of much greater value than formula acre-for-acre replacement of a particular marsh, mudflat, or beach habitat type. For example, ducks may be more in need of protected shallow water area than of emergent marsh, or terns more in need of sandy nesting islands than mudflats. Critical habitat needs such as these can be identified in most urban aquatic ecosystems. In another chapter of this volume, Erwin suggests giving priority to defining mitigation goals specifically in terms of fish and wildlife targets and in fulfilling those goals, allowing the maximum flexibility and creativity.

Trying to restore an existing wetland to its original, pristine condition may not always produce the most appropriate result in terms of meeting the region's critical need for wetland output. For example, creating a coastal high marsh area of sea daisy and saltwort, although a close replication of the original wetland, may be of far less value than a replacement low marsh of mixed cordgrass and mangrove with open channels, which would both provide a nursery area for fishes and an export of detritus to the estuary. Often there is a current regional demand caused by shortages of particular types of wetland function that are recognized for a particular region (Clark 1986b). Whether the shortage has occurred because of wetlands conversion or wetland dysfunction, the demand can be at least partially provided through repair of dysfunctional ecosystem units in many circumstances (Figure 5).

Any regional strategy can be organized to respond to "cumulative impacts" and to provide "offsets" for any environmental damage in degraded ecosystems (as for air quality "non-attainment" areas). Under a regional strategy, a priority goal would be to reverse the accumulation of negative impacts, and begin a trend of positive cumulative impacts for the regional ecosystem. The regional authority would determine a baseline condition, or threshold level, for attainment by examining historical trends of resource losses for the ecosystem. Future restorative mitigation would have an overall target to return the system, via positive cumulative impacts, to an earlier designated level of productivity (e.g., for the Chesapeake Bay, return to the status of the year 1950 seems to be favored).

## MULTIPLE IMPACT PROJECTS

In urban waterfront projects, several different impact types can often be identified; some positive and some negative. In this situation, the balance of net benefits and losses must be determined in some fashion based on qualitative and quantitative factors. If no predetermined scheme is available to convert "apples to oranges", the process may have to be more judgmental than analytical. In the previously cited official FWS mitigation policy (p. 765f2) it is stated that: "... the net biological impact of a project proposal is the difference in predicted habitat value between the future with the action and the future without the action". In effect this encourages the developer to present an actual "balance sheet" in support of his application (including voluntary enhancements) which shows for each of the important functional categories the extent to which the project will benefit or harm the ecosystem in the "without project" and "with project" scenarios. Table 1 illustrates a very simplified example of a summary sheet.

Sophistications that can easily be introduced into such comparisons include FWS "resource categories", HEP analysis, and relative value calibrations.

This approach encourages the developer (with his consultant's advice) to incorporate a variety of voluntary restorative enhancements into project design in the early planning stages. However, ambiguity is introduced by the FWS interest in holding to itself the determination of "...whether these positive effects can be applied towards mitigation" (FWS mitigation policy, p. 7652). If such interpretation is actually delayed until permit application is submitted, no improvement in predictability is achieved and developer-supported restorative mitigation is frustrated. Where restorative mitigation will be in the offing, it behooves EPA and other agency reviewers to provide secure advice to developers as early in the pre-application process as possible.

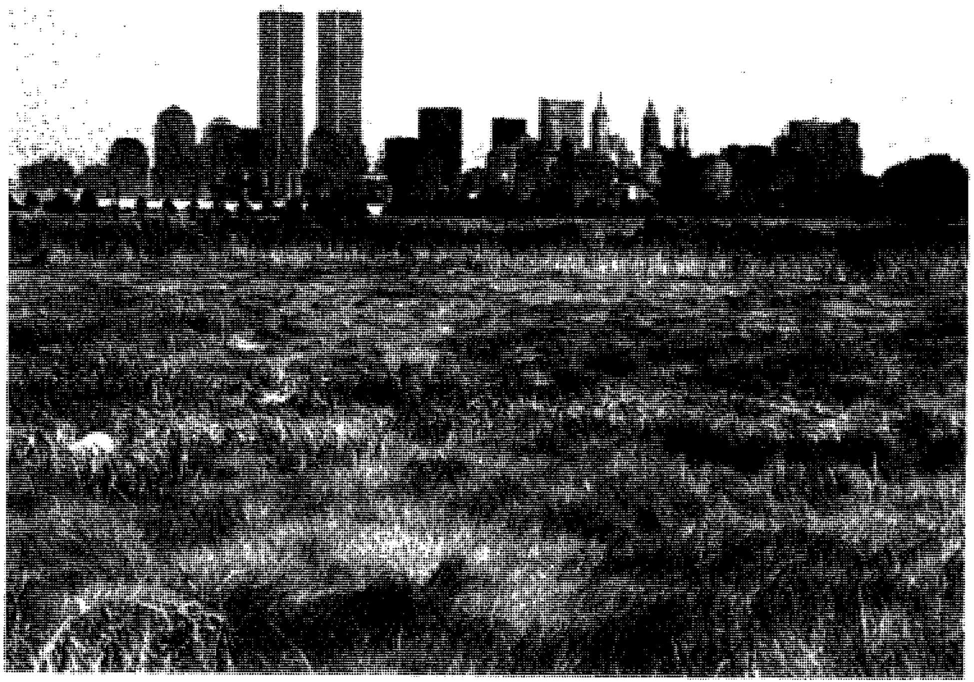

Figure 4. This Spartina patens marsh on the Port Liberte site appears isolated but it is strongly linked to the lower Hudson Estuary through runoff drainage, tide action, detrital outflow, animal movements, and other factors

Figure 5. Repair of this shallow, polluted, marsh/tideflat/slough is part of the Port Liberte enhancement program.

Table 1. A very simplified example of a summary sheet that could be used to review the possible impacts of a proposed project.

| Category | Without Project | With Project | Net Impact | Comments |
|---|---|---|---|---|
| Channel circulation | Restricted, stagnation, eutrophic | Free flow non-stagnant, non-eutrophic, improved access, fewer mosquitos | Highly positive | Depth of 4' specified; range of 3-5' would be acceptable |
| Macrophytes | Unimpeded insolation | Piers, boardwalks will shadow 3-1/2 acres | Moderately negative | Plank spacing of 1-1/4" will reduce shading effect |

## MITIGATION BANKS AND ALTERNATIVES

In the urban setting it is most difficult to avoid going off site with mitigation where it is required of a development. Waterfront is so scarce and valuable that land parcels for development are small and use is intensive. Therefore, land available for mitigation is at a premium. On the other hand, waterfront redevelopment creates extensive benefits through value added to the land, taxes, jobs, and particularly, through ridding the waterfront of the blight of decaying warehouses, collapsing docks, and health and security nuisances. Most communities will vigorously support waterfront renewal. This must be strongly considered by COE in its public interest review.

These two factors, motivation for intensive use of waterfront parcels and the limited options for onsite mitigation, create strong pressure to find offsite solutions for mitigation demands, often through some type of "mitigation bank". One solu- tion is a mitigation bank whereby developers are "taxed" for impacts and the proceeds "deposited" in a habitat creation/restoration account similar to the "impact fees" for infrastructure often charged to dryland developers. A second solution is a different kind of bank whereby areas in need of habitat restoration or suitable for habitat creation are "banked" so as to be available in the future for mitigation requirements levied against developers.

A third solution is a regional cooperative restoration plan, whereby mitigation for various projects is done at predesignated sites. It would be as though, at Bataquitos Lagoon for example, several developers had participated sequentially in the restoration project. The major requirement is advance designation of sites for restoration as the COE does now for dredge spoil (dredged material) disposal areas. Designation can be done by a regional body (e.g., North Fraser River), a state (e.g., California coast, or New Jersey's proposed advance site program), a Federal agency, or a special agency like the California Conservancy (McCreary and Zentner 1983). This approach avoids the appearance of a developer "buying" a permit, as in the first solution (which is not looked on favorably by most agencies; e.g., the Baltimore Harbor plan was rejected by the COE for this reason).

# CASE STUDY PORT LIBERTE

This case study describes aspects of an innovative residential project in Jersey City, N.J. along the shores of the Hudson River. A 125-acre parcel of previously filled land (by the U.S. Army in the early 1940's) was excavated to provide 2 linear miles of canals for waterside housing (Figure 6). The developer engaged a panel of experts to prepare a series of enhancements (to be paid for by the developer) in advance of formal permit review.

Port Liberte, bounded by the Caven Point Natural Area and Liberty State Park is a canal side residential marine community currently under construction with 1690 condominium units, commercial space and marina. Caven Point Natural Area represents one of the few remaining remnants of the natural estuary with a Spartina salt marsh and tidal mudflat (Burger and Clark 1987). The genesis of the Port Liberte project was and continues to be one of sound environmental planning whereby appropriate geological and biological expertise guided the development, architectural design, and construction schedule of the project and the monitoring programs. With the acquisition of the permits, major construction began in 1986 but careful monitoring of water quality, fish populations (Figure 7) and avian use (the three critical resources on the site) continues and will continue during the project. This is one of a few projects to involve a year of monitoring prior to permitting, with continued monitoring during buildout. Monitoring data obtained before construction was used to physically design the marina, channels, canals, and boardwalks as well as the timing of particular construction schedules. One notable and unusual aspect of the Port Liberte project was the cooperative nature of the interactions between project personnel, government personnel, scientists, and environmentalists, rather than the usual more adversarial approach (Burger and Clark 1987).

That the complex project received its New Jersey permit in less than 1 1/2 years is owed to the collaborative spirit in which the project evolved. Another important factor was that, due to confidence in the process, the state permitting authority was willing to extensively "condition" the permit rather than wait until the multitude of details were settled and the COE was agreeable. By this means, the project could get underway and the issues could be worked out simultaneously, requiring an extended in-process dialogue with state and federal agencies (still ongoing) and continuing ecological baseline and monitoring studies. Also, full use was made of the opportunity for pre-application conferences and informal dialogue with state and Federal agency personnel (Burger and Clark 1987).

The Port Liberte Restoration Design Panel, an interdisciplinary group of ecological experts, (academics and consultants) was formed to review Port Liberte development plans and to provide advice on ecological enhancement. At this point no specific mitigation requirements had been mandated, but permit review authorities did expect a good and sufficient enhancement effort which was strongly supported by the developer, the Port Liberte Partners. Consequently, the Panel was encouraged to brainstorm freely and to formulate an optimum variety of ecological enhancements for the project.

The panel was concerned with using the opportunity to fulfill current ecological demands. That is, rather than simply planning to supply so many acres of habitat, the panel wanted to meet responsible local demand for ecological goods and services. For example, it was recognized that the endangered Least Tern needed safe nesting sites and that the profusion of aquatic birds using the littoral zone of the project area needed both an adjacent source of fresh to slightly brackish water and continued access to low cover on the beach berms at high tide, as well as protection from disturbance. A second priority goal was to see that adversely impacted aquatic areas were rehabilitated. While accomplishing the above, the panel recognized that many constraints were operating and attempted to stay within the limits of practicality imposed by permit conditions and project requirements.

The Port Liberte Restoration Design Panel met in September, 1985 to develop criteria for ecosystem enhancements, including restoration, rehabilitation, and creation of aquatic subsystems. The enhancement concepts had been reviewed in advance by the State of New Jersey (Department of Environmental Protection, Division of Coastal Resources) and conditions had been imposed. Consequently, the Design Panel was simultaneously considering the developer's proposals, the state's reactions and requests, and the individual ideas of panel members.

The mandate was specifically to advise the developer on restoration and enhancement of natural systems within and adjacent to the project area, particularly in regard to the following:

1. Rehabilitation and rerouting of Caven Creek, a drainage channel that transects the

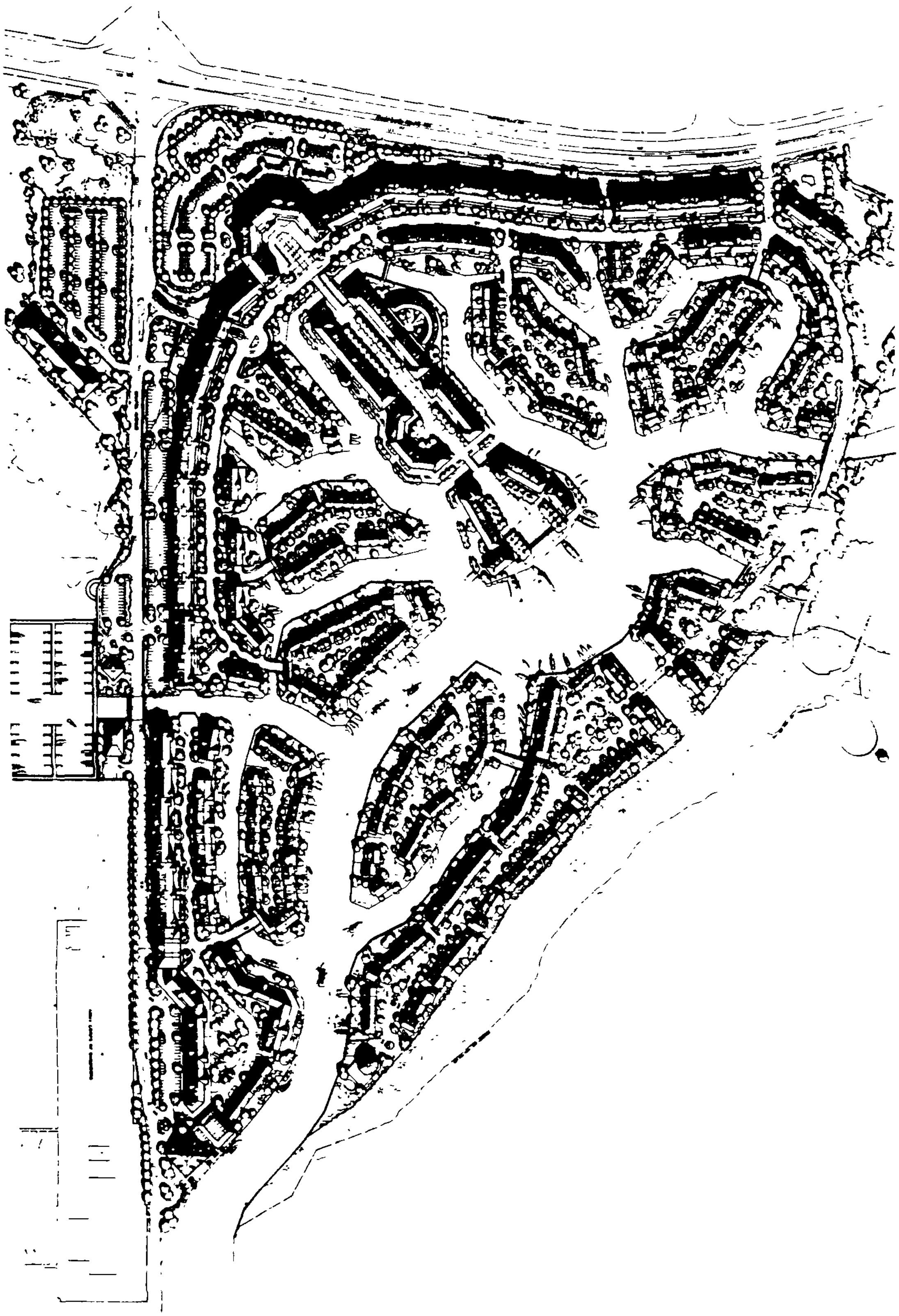

Figure 6. General plan for the Port Liberte waterfront community. The artificial canal system is open to tidal flow on the north, south, and at the main boat entrance at the southeast. The canals shallow from the central trunk to the laterals. Deadends have been virtually eliminated.

Figure 7. Biological baseline and monitoring activities include seining in the shallow waters of the east beach at Port Liberte along with offshore trawls, benthic and water quality samples, and intensive bird censusing.

property near its northern boundary along with ecological improvements of the Caven Point Peninsula.

2. Rehabilitation of the North Slough, a tidal embayment lying west of Caven Peninsula that has been adversely affected by pollution.

3. Enhancement and maintenance of the Spartina-beach-dune system that fronts the east side of the project along Caven Cove on the Hudson Estuary (Figure 8).

4. Creation of a special nesting habitat for the endangered (New Jersey state list) Least Tern.

5. General ecological enhancement of Caven Point Peninsula with considerations for public access and education.

The Panel's charge was to generate recommendations with sufficient detail to enable project planners to draw detailed plans and write specifications for the work (Figure 9). After receiving its mandate, the six-person panel worked with full independence, generating some recommendations that neither the state nor the developer might have favored, but which the panel was obliged to offer by virture of its knowledge or the principles involved. While it is still too early to determine the panel's success, all recommendations were accepted and acted upon by developers and regulators.

# SUMMARY

In dense urban settings, restoration is a priority goal for mitigation or voluntary enhancement of aquatic habitats. Therefore the needs of regional ecosystems must be considered, not just project sites or single wetland units. In expanding urban areas a combination of protection, set-aside, and restoration may be required. Because strategies for aquatic ecosystem restoration are planning programs, they conflict strongly with the ad hoc nature of regulatory programs. Adjustments are necessary to enable permit evaluations to respond to the goals of regional restoration strategies. Effective restorative mitigation depends upon cooperation from private and public development entities; this means that unambiguous advice can be given to developers in project planning phases.

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Figure 8. Restoration of the east beach is a major enhancement activity at Port Liberte. The beach is screened and protected from landside disturbance by a buffer zone of Phragmites.

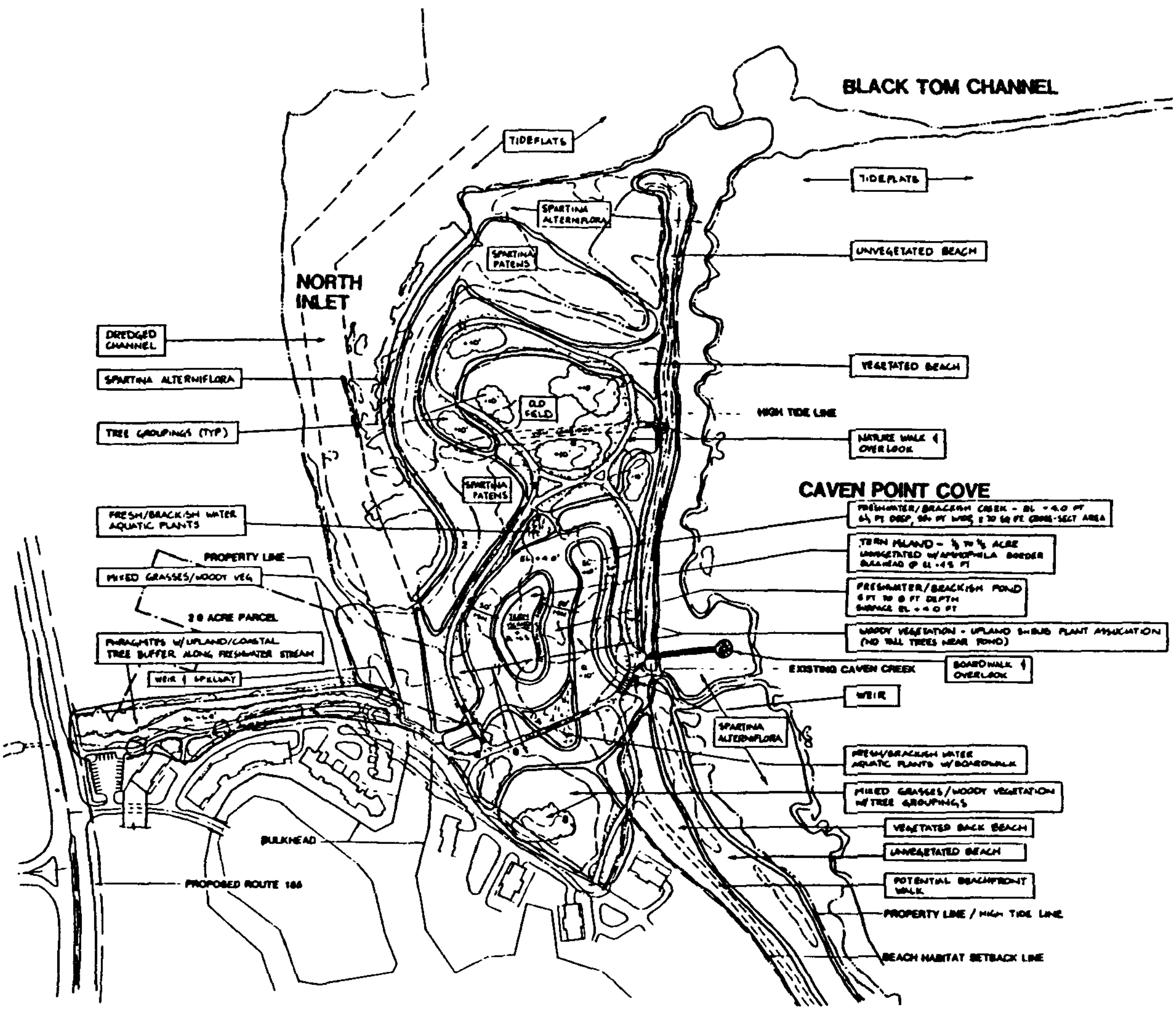


Figure 9. General enhancement plan for the natural areas lying east and north of the Port Liberte project site.

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# WATERFOWL MANAGEMENT TECHNIQUES FOR WETLAND ENHANCEMENT, RESTORATION AND CREATION USEFUL IN MITIGATION PROCEDURES

**Milton W. Weller**
***Caesar Kleberg Professor in Wildlife Ecology***
***Department of Wildlife & Fisheries Sciences***
***Texas A & M University***

***ABSTRACT.*** Waterfowl and other wetland wildlife managers have long been involved in wetland restoration and enhancement, and have developed functional techniques for management of certain wetland types in various geographic regions. These procedures can serve other wetland managers in many useful ways, and are worthy of experimentation for other purposes. Most use natural processes to tap natural seed banks, modify cover-water ratios, or control weeds via water level control and herbivores. Wetland types where procedures have been standardized include those dominated by palustrine persistent emergents, moist-soil nonpersistent emergents, estuarine emergents, and forested palustrine communities.

This chapter presents some general concepts based on a selection of the extensive literature designed to facilitate adaptation of these strategies to the special situations of restoring, enhancing or creating wetlands to meet mitigation requirements. The procedures described also can be used to enhance various wetland functions such as water quality, shoreline protection, and esthetic values.

Major information gaps include: long-term ecological effects of management processes; methods for speeding natural events that aid in wetland restoration; and lack of quantitative information on other groups of wildlife such as fish, herptiles, and even nongame birds and mammals.

## INTRODUCTION

Mitigation efforts requiring enhancement of established wetlands, restoration of former wetlands, or the creation of new wetlands where none existed, often are viewed as new efforts that are untested and uncertain. In fact, wildlife managers and some fisheries managers have been involved in such efforts for many years. Local wildlife or fisheries managers often are the best source of wetland restoration techniques that have been tried and work in that region. Most of the habitat management techniques are based on natural processes in wetland systems, and thus also influence other wetland values and functions. However, few of these practices have been subjected to long-term experimental testing and evaluation. Much of this material has been published but it is not available in a single document that covers all wetland types and their regional variations.

This chapter brings together some generalizations, a selection of the extensive literature, and a few examples of wetland types and procedures that have been standardized in certain areas. Such efforts have emphasized waterfowl and muskrats and occasionally other furbearers; very little work has dealt with other groups although some work indicates that successful efforts for game species also may favor nongame species. These procedures can be used equally well to enhance other wetland functions, such as reducing turbidity, protecting shorelines from erosion, and esthetic values. Thus, a review of the backgrounds of this management for waterfowl will facilitate consideration of all available strategies to the special situations of restoring, enhancing or creating wetlands to meet mitigation requirements.

## DEFINITIONS OF MANAGEMENT STRATEGIES AND MANIPULATIONS

Although a fairly complex and somewhat inconsistent terminology has evolved among wetland managers and consultants, wildlife managers generally include a variety of situations and problems under the terms "habitat development" and "management" (e.g., Sanderson and Bellrose 1969, Atlantic Flyway Council 1972). However, there have been several typical patterns: Restoration of drained wetlands has been common where there was an opportunity to reclaim a major wetland of high wildlife value that has been degraded. The usual situation involves a failed drainage project where land values have declined, so that federal or state agencies can purchase the land and attempt restoration. Numerous National Wildlife Refuges (NWR) such as Tule Lake NWR in California and Aggasiz Lake NWR in Minnesota fall into this category (Laycock 1965). Still older examples are available in the European literature (Fog 1980).

Enhancement of wetlands involves an attempt to improve the wildlife values of a wetland that has not been drastically perturbed, but one that managers believe could be producing wildlife at a higher level more of the time. Periodic manipulations of water levels to enhance nesting conditions or modify plant succession rates would be typical examples.

If we define creation of wetlands as establishment of wetland communities and functions where none existed, this has been a less common practice among wildlife managers. However, this is partly a matter of terminology as procedures have not been categorized in relation to the nature and status of the wetland. The typical pattern has been the conversion of terrestrial communities to wetlands via identification of a natural drainage or basin that has had some history of moist-soil vegetation resulting from periodically wetter years. This conversion is usually done by creating an impoundment or diverting water to provide more regular flooding and encourage wetland plants and associated game species. Large impoundments created for other purposes such as water supply or flood control also may result in wetland development at the margins or upper reaches of the pool. Additionally, mining operations such as gravel removal may result in suitable wildlife habitats and considerable information is available (Svedarsky and Crawford 1982). The reverse of this, the conversion of aquatic areas to wetland, has been less common but has been accomplished by diking to keep out water and reduce continual deep flooding--as has been common at refuges and other wildlife management areas along coastlines of large lakes or oceans.

## GOALS AND OBJECTIVES

Most conservation agencies have long-range planing processes for management areas that involve 3-to 10-year plans, often with annual updates. By their legal charge (e.g., migratory bird treaty or Federal-Aid funding) or by policies of guiding groups such as commissions, wetland managers in charge of specific areas or regions usually attempt to maximize wildlife attractiveness and wildlife production. This target could be in conflict with other wetland values and functions, but this is not always the case.

Philosophically, many of the goals of wildlife managers overlap with those of other wetland managers: There is a desire to preserve natural landscape units and functional values. Managers differ, however, in whether they prefer to use artificial methods that may give more immediate results, versus the use of more natural processes that tend to take longer but are less expensive and longer lasting (Weller 1978). Benefit-cost ratio strongly influences the choice of strategy as some functional but very expensive techniques such as hand transplants can be more easily justified in mitigation procedures than in conservation efforts for wildlife. Short-term goals often have been the driving force in habitat management of wetlands for wildlife: 1) increased production of game for hunting via creation of more and better nesting sites, increased food supplies, resting and roosting condition, or reduced predation; 2) improved conditions for hunters in pursuit of game, such as cover patches or blind sites; or 3) improved access to wetland areas for hunting by means of roads and boat channels.

Many wetland wildlife managers cherish the rich natural values and aesthetic aspects of the natural system. They expound a natural management philosophy as a code of ethics (Errington 1957), and are dedicated to preserving a naturally functioning ecosytem in perpetuity (Weller 1978, 1987) and maintaining or adding diversity (Sanderson 1974, Mathisen 1985). Others place first priority on maximal production of the targeted game species, but not intentionally in opposition to other natural values and functions. Ideally, these approaches should both be incorporated into a unified plan that involves other wetland functions as well. The consideration of multiple interests and approaches has been enhanced by the use of public hearings for local residents, laypersons and experts so that greater unity of goals is possible.

## REVIEW OF PRODUCTION, SUCCESSION AND VEGETATION STRUCTURE

Research biologists working with marsh and other wetland wildlife have long recognized the importance of natural ecological processes such as seed germination, plant growth and production, succession, flooding, and water quality in regulating the plant community that ultimately dictates the diversity and populations of wildlife. As a result, there have been numerous vegetation studies oriented toward understanding habitats for waterfowl, including: vegetation community, structure and dynamics (Dane 1959, Kadlec 1962, Weller and Spatcher 1965, Weller and Fredrickson 1974); germination and plant growth (Weller 1975, Beule 1979); effects of drawdowns or dewatering (Kadlec 1962, and others); hydroperiod and other water-driven vegetation patterns (Meeks 1969, Knighton 1985); wetland wildlife responses to changes in structure and availability of vegetation (Weller and Fredrickson 1974, Ortega et al. 1976); influence of vegetation on predation rates (Keith 1961, Duebbert and Lokemoen 1976); and competition between wildlife species (Weller and Spatcher 1965).

Much of this work has been done on inland freshwater marshes, but there has been some excellent work on interior saline (Bolen 1964, Christiansen and Low 1970) or alkaline wetlands (Stewart and Kantrud 1972). Tidal regime, turbidity and salinity influences on plant growth and survival in coastal marshes have been the subject of numerous wildlife-oriented plant succession studies (Chabreck 1972, Palmisano 1972, and others), and have provided a basis for sound management. Some studies by botanists and plant ecologists have preceded and supplemented these studies by wildlife biologists, but their research questions often were directed toward different goals. There are many opportunities to improve upon this foundation with management applications in mind, but the effectiveness of such studies will depend upon the questions asked.

## PRECONSTRUCTION CONSIDERATIONS

### GEOMORPHOLOGY, LANDSCAPE, PATCH SIZE AND PATTERNS

It has become increasingly apparent that waterfowl and other migratory birds, and some wetland fish, amphibians, reptiles and mammals, do not satisfy all their needs in one wetland. This is particularly true of the breeding period when very specific requirements for foods or nest sites may exist in comparison to post-breeding activities such as migration or wintering. Thus, wetland diversity and density may figure prominently in satisfying these needs, a consideration that may not be met with the restoration or creation of only one wetland when a complex may be necessary. Wetland complexes have been recognized as important by many workers (Swanson et al. 1979, Weller 1981) and data presented by Brown and Dinsmore (1986) suggest that complexes increase species richness over solitary wetlands of similar size. General studies of wetland density in Prairie Pothole habitats, where water cycles influence wetland numbers from year to year, show general correlations between wetlands and waterfowl abundance, as one would expect (Sugden 1978, Leitch and Kaminski 1985). The diversity of wetland types also is deemed vital as the loss of small wetlands in drought years has a particularly great impact on certain species (Evans and Black 1956). Patterns of vegetation (cover-water ratios or cover-cover interspersion patterns) also influence bird use and are important designs for management of wetlands intended to enhance bird use (Weller and Spatcher 1965, Patterson 1976, Kaminski and Prince 1984).

Larger wetlands are known to provide greater numbers of habitats, and therefore are more likely to attract greater number of species (i.e., species richness) (Brown & Dinsmore 1986). There is a tendency to acquire and restore large units for these reasons, but it is also recognized that small areas also may provide specialized habitats for certain species, and management for those may require size considerations (Evans and Black 1956).

Configuration (e.g., length of shoreline in relation to area of the wetland) seems to be an important influence on numbers of territorial species that an area can support, but there are little substantiating data (Mack and Flake 1980, Kaminski and Prince 1984). Some workers have suggested that other vegetation patterns are more influential than shoreline length (Patterson 1976). Managers often successfully create artificial wetlands with complex configurations to provide isolation for breeding pairs. Contiguity between wetlands is especially important to fish (e.g., Herke 1978) and some other vertebrates, and one obvious conclusion is that it provides habitat diversity that meets various needs throughout life.

## PRECONSTRUCTION DESIGNING FOR WATER DEPTH

Preconstruction planning involving detailed contour mapping of prospective sites is essential (Verry 1985). Site observations during natural flooding periods also are useful because contour maps may not provide the precision essential in water level regulation. For example, large-scale contour intervals are unusual on construction maps, when the ultimate precision required for water level control may be a matter of centimeters.

Contouring with earth-moving equipment is commonplace, and should be used to create water depths associated with the desired plant community. Islands, bays and other structural features can be created during construction if soil character and shoreline protection are considered. Where such work is done on areas with a rich seed bank, soil should be moved off-site and returned as topsoil both for the merits of its organic content and as a seed bank. This will reduce invasions by exotics where they are an issue and the necessity of seeding with cultivated varieties that result in low natural diversity.

## REGULATING RUNOFF-EVAPORATION RATIO AND FLOW-THROUGH RATES

Rainfall-evaporation patterns and watershed-wetland size ratios are of special importance in impoundment site selection (Verry 1985). Special considerations are necessary where uplands have been modified by land-use practices. Farming may increase the mean annual silt load and eutrophication, and intensive grazing on the waterway slopes can increase peak surges of water entering the wetland during storm events, washing out vegetation and water control structures. Urban development may increase runoff due to parking lots, roadways and roofs. In wetland restoration or enhancement projects, water control structures must be carefully engineered to handle these added burdens. Additionally, up-slope protection can be achieved through water diversions to streams, grass plantings to absorb more rainfall, or smaller impoundments that serve as catch basins for both water and silt.

These solutions also are relevant where wetlands are created from terrestrial sites, in which case site selection is extremely crucial and requires knowledge of the slope, area, and rainfall data of the watershed (Verry 1985). Storm events always seem to exceed runoff projections and are particularly damaging in the early stages of wetland development. In coastal areas, tidal action and wind fetch are important influences that must be considered, and considerable work has been done on shoreline protection.

## CONTROLLING EROSION AND TURBIDITY

In any wetland management program, modified water levels, exposed banks and unvegetated bottom are vulnerable to wave and current action. Decreased wetland productivity may result from erosion of shorelines, elimination of vegetation, and increased water turbidity. Most wildlife managers have dealt less successfully with these problems than have other wetland designers, due in part to factors of need and cost. Importing firmer soil, gravel or rock may be necessary, and prepared rip-rap can be used in extreme cases of erosion. Several steps can be taken to prevent erosion: 1) exposing the shoreline by dewatering until vegetation has become established, and 2) delaying flooding until the bottom has been stabilized with emergent and preferably submergent vegetation. These measures will reduce turbidity that may prevent vegetation establishment when reflooding occurs.

## CONSIDERING SPECIAL WILDLIFE NEEDS

Waterfowl and other wildlife are highly selective in their choice of habitat: it must supply vegetation cover, nesting sites, protection from predators, reduced disturbance and food supplies. On a worldwide basis, systems have been developed to manage for these needs (e.g., Scott 1982). In recent years, it has become clear that habitat quality is very important, and providing a place to live must also include nutritional food at the proper time of the reproductive cycle (Fredrickson 1985). Work on invertebrates of wetlands still is inadequate but several workers have demonstrated how patterns vary and how wildlife seem to respond (Voigts 1976, Swanson et al. 1979), which managers more and more take into account in their management strategies (Whitman 1976, Reid 1985).

# PROCEDURES BY PROCESS AND PROXIMATE OBJECTIVE

## MANAGING THE SEED BANK

Although the longevity and abundance of seeds of wetland plants has been known at least since the 1930's (Billington 1938), and early marsh managers advised location and utilization of sites with a natural seed bank (Addy and MacNamara 1948, Crail 1955, Singleton 1951), managers have varied in their utilization of this general principle. Seeding of Japanese millet or use of native millets (Echinochloa crus-galli) and smartweeds (Polygonum spp.) for seed sources were widespread among National Wildlife Refuges in the 1940's and 1950's (Linduska 1964). Planting of millets, smartweeds, and agricultural crops was used to feed large numbers of migrant and wintering waterfowl in preference to less predictable processes that capitalized on natural sources (Givens and Atkeson 1957). More recently, moist-soil management and other types of strategies that use natural seed banks have been viewed more positively by a generation of managers who favor natural diversity and minimal expenditures on machinery and manpower. Management of both water depth and hydroperiod is the major strategy employed (see for example studies by Fredrickson and Taylor 1982) and the techniques are now more widely recognized and appreciated.

Another aspect of seed banks generally recognized by wetland ecologists but unknown to many others is the importance of preserving the seed bank in a newly created wetland. Dams and levees often are built with borrowed soil taken from the water side to create some deep-water sites or to facilitate installation of water control structures. When basin shape is modified by scraping, a barren substrate may be created (Kelting and Penfound 1950) that must be reseeded or await the natural processes of seed transport, germination and local seed production. Marsh hay cut at seeding times (as occurs with seeding of wildflowers on highway right-of-ways) may be a good seed source, but I know of no experiments in wetlands to demonstrate this.

Despite their common longevity, seed banks may be limited in diversity or even non-existent in situations of long inundation where wetland emergents have not existed for many years; aquatic plants or long-lived terrestrial plant seeds may survive, but species of value to the wetland restoration may not occur (Pederson and van der Valk 1984). Where available, use of soil from local wetlands may be useful in resolving this problem.

## MANAGING PLANT SUCCESSION THROUGH WATER LEVEL MANIPULATION

Because it has long been recognized that hydroperiod and water depth dictate plant species composition, density, and growth, waterfowl managers have studied the availability and germination characteristics of seed banks (Crail 1955), the physical and physiological requirements of the seed for germination, germination rates and rates of growth, tuber production, plant productivity, and plant life-history strategies (Weller 1975, Beule 1979) that influence wetland succession (Dane 1959).

To provide the water conditions that induce germination seed and plant growth, most wetlands created or modified for wildlife make provisions for complete dewatering via control structures (Atlantic Flyway Council 1972). The latter is a vital consideration if any influence over plant community is desired, and the engineer should be alerted to the need for total dewatering. Subsequent modifications of dike height must consider water control structures and the potential of dam failure or erosion. Strategies for achieving the desired goals will be discussed under examples of several wetland types that have been commonly and successfully managed.

Although the terminology of succession may not be very useful in many wetlands (Weller and Spatcher 1965, van der Valk 1981), manipulations involve dewatering to return the plant community to mudflat annuals and seeding perennials that are characteristic of more shallow marsh (Bednarik 1963, Linde 1969, and others). Plant growth rates or germination also can be influenced by extreme flooding or drying, by enhancing nutrients with fire or fertilizers, and by weed control.

## MODIFYING WATER DEPTH AFTER WETLAND FORMATION

The most common method of deepening a natural or created wetland for waterfowl has been to install a dam or dike to impound more water, and to incorporate a water-control structure that limits the pressure on the dam and allows dewatering. Increasing water depths in basins that do not have an adequate supply can best be accomplished most economically by gravity flow systems such as stream diversions and up-slope reservoirs. A more reliable but expensive alternative is a well and pump, but this is a perpetual expense, and may be a source of disagreement among different user groups.

Modifying shallow wetlands to create open pools and deeper water can be done by dewatering and a bulldozer, by drag-line removal of basin substrate, or by blasting with dynamite (Strohmeyer and Fredrickson 1967) or ammonium nitrate fertilizer charged with a more volatile explosive (Mathiak 1965).

## REGULATING VEGETATION VIA HERBIVORES AND FIRE

Wetlands, especially those dominated by persistent, perennial emergent plants, are renowned for their attractiveness to native muskrats (Ondatra zibethicus) and the introduced nutria (Myocaster coypu). Overpopulations resulting in "eat-outs" are well documented in northern and midwestern marshes (Errington et al. 1963), and dramatic population changes also exist in eastern brackish marshes (Dozier 1947), and southern deltaic and chenier marshes (Lynch et al. 1947, O'Neil 1949, Palmisano 1972). Muskrat populations in particular expand rapidly because of their high reproductive potential and adaptability to new food resources. Ultimately, the area is denuded and populations of other wildlife are drastically impacted (Weller and Spatcher 1965). Managers often are unprepared for this event and may lack methods for control because of harvest regulations. In large areas, control may be impossible due to size and logistics of trapping. The resultant open water may persist for many years unless dewatering is used to induce revegetation.

Beavers (Castor canadensis) likewise can impact on willows (Salix spp.), cottonwood (Populus deltoides) and other highly palatable plants, whether the plant are used only for food or for lodges and dams as well (Beard 1953). Flooding by beavers of other terrestrial or wetland vegetation often is regarded as serious by managers not only because of plant mortality but because water level stability within a wetland may not be conducive to maximal community diversity and productivity of many wetland species.

Another group of herbivorous animals are fish such as the introduced common carp (Cyprinus carpio), and more recently, white amur or grass carp (Ctenopharyngodon idella). Whereas sterile hybrids of grass carp are being used to reduce the chances of reproduction in the wild, the common carp reproduces readily and is spread by fishermen. It also moves upstream into shallow wetlands. Invading carp can be extremely serious because of their direct consumption of submergent plants and invertebrates, and indirectly because of the turbid waters they induce which reduces light penetration and therefore plant production (Robel 1961).

Livestock such as cattle, sheep and goats can be useful management tools, but such grazing may be difficult to regulate because of public pressure for grazing rights or due to our lack of understanding of the carrying capacity of wetlands under variable and often uncontrollable conditions. Grazing exposes tubers then utilized by grubbing geese such as snow geese (Anser caerulescens) in both southern and eastern coastal marshes (Glazener 1946), but can also can eliminate favored duck food plants (Whyte and Silvy 1981). Grazing in northern areas is generally regarded as detrimental to nesting waterfowl (Kirsch 1969), but obviously can be beneficial to species like upland sandpipers (Bartramia longicauda) that prefer short vegetation. Fencing is the simple tool used by managers all over the world to change the character of overgrazed wetlands (Fog 1980), but better management may require regulation of the grazing level and not merely total exclusion.

Fire has been used by farmers and ranchers for years to increase forage and hay crops, but it can be devastating to nesting ducks and other birds (Cartwright 1942). The response of wintering geese to fire has resulted in a policy of periodic burning on refuges to reduce vegetation and expose tubers for grubbing geese (Lynch 1941). Fire also has been used in northern marshes with peat bottoms to create deep water openings; however, control of the fire is often difficult (Linde 1985). Considerable work has been done recently to explore the role of fire in marsh succession (Smith 1985a, 1985b), and clearly much more of this type of work is needed in all vegetation types (Kantrud 1986).

## SEEDING AND TRANSPLANTING

Both seeding and transplanting were used extensively in the 1940's for marsh edge plants, and sometimes for emergent plants along the shallow water's edge (Linduska 1964). Planting Japanese millet and other seeds available from farm suppliers and wildlife nurseries is still widely done on small areas, especially by private landowners, but is less widespread as an operational procedure on refuges and waterfowl management areas because of cost. Upland farming is more common because equipment is available or sharecropping is a cost-effective way to produce wildlife foods while appeasing local farmers over local land lost to agriculture (Givens and Akeson 1957). Planting in wetland areas used for waterfowl hunting may involve legal issues because of "baiting" laws, and must be done in counsel with local wildlife officers.

Planting natural rootstocks or runners and other plant parts has been used with cattail (Bedish 1967) and other perennials, but is labor-intensive and of questionable success--not just because of plant growth potential but because of losses due to their attractiveness to muskrats and other herbivores. Erosion on wave-swept shores is an equally serious problem, and floating boards have been used to protect as well as facilitate wetland establishment and survival.

## CONTROLLING WEEDS

Part of maintaining a wetland that is attractive to wildlife requires a balance of open water and vegetation. Because nesting birds and migratory waterfowl are especially influenced by these conditions, considerable effort goes into creating suitable habitat. In addition to the control of succession and cover-water ratios through water-level management (Weller 1978) or fire (Kantrud 1986), more direct (artificial) and immediate methods have been utilized such as chemical sprays (Martin et al. 1957, Beule 1979); mechanical destruction by roller or cutting (in or out of water) (Nelson and Dietz 1966, Linde 1969); and grazing (Kirsch 1969).

# EXAMPLES OF COMMONLY MANAGED WETLAND TYPES BY OBJECTIVE

## PALUSTRINE PERSISTENT EMERGENT WETLANDS

For nesting waterfowl and other marsh wildlife, most managers prefer sturdy water level control structures and a reliable source of water for use in modifying water depths to control plants for nest sites (birds) and food sources (muskrats as well as birds). A diversity of plants of various life forms is preferred to serve various animals. Marginal nonpersistent emergent plants produce large seed crops; deeper water persistent emergents are excellent for nest sites and provide tuberous bases useful to herbivores; and submergent plants often provide food directly or serve as substrates for invertebrates.

Water depths dictate dynamic vegetation patterns in wetlands subject to seasonal and annual variation in water supply. These may vary from lake-like aquatic conditions to near-terrestrial vegetation due to hydrologic perturbations. Wildlife respond directly and vary greatly in species richness and population abundance (Weller and Spatcher 1965).

Examples of plant succession following drawdowns to re-establish vegetation were provided by Kadlec (1962), Harris and Marshall (1963), and Weller and Fredrickson (1974). Subsequent changes in vegetation due to the influence of water level and muskrats (Errington et al. 1963, Weller and Fredrickson 1974) and common carp (Robel 1961) demonstrate that: 1) the natural short-term water dymamics of midwestern wetlands must be dealt with in restoration projects, and 2) the inherent adaptability of wetland plants provides them with great powers of recovery and repair.

A well-established technique to reestablish vegetation after it has been eliminated by high water or muskrat "eat-out" is to dewater ("drawdown") the area by use of a water control structure or pumping. Germination from the natural seed bank (van der Valk and Davis 1978) provides most of the source of plants but enhanced production of persistent plants via tubers and rhizomes also results (Weller 1975). Re-establishment may result in excessively dense vegetation not suitable for the intended wildlife, whereupon the natural herbivores may move in and create suitable openings.

Modification of this pattern occurs with various methods of creating artificial openings described elsewhere, and these may be useful in intensive management or restoration projects where time is vital. The drawdown-revegetation cycle is commonly practiced by conservation agencies in many midwestern states (Linde 1969), and in situations where time is less important relative to costs. This method seems to simulate natural processes and events without lasting damage. Even fish populations of those areas seem responsive and pioneering.

## MOIST-SOIL IMPOUNDMENTS FOR NONPERSISTENT EMERGENTS

Migratory waterfowl feed less on high protein animal foods in fall and winter and instead use seeds or foliage. Seed production is especially enhanced by creating or maintaining shallow water areas where nonpersistent emergents such as millets, smartweeds, spikerushes (Eleocharis spp.) and other marsh edge plants germinate and produce seed (Fredrickson and Taylor 1982). This requires mud flat conditions, typical of any marsh drawdown, except that such wetlands are normally not breeding marshes for waterfowl (although they may be suitable for some rails and songbirds). Drawdowns are performed early in the year to allow sufficient drying so that annual seeds will be produced. Because of the climatic regime in southerly areas, both spring and late summer crops may be produced where water is available and levels can be controlled. The usual procedure is to construct low dams or dikes to impound water equipped with a simple structure for water level control. In rice areas, low-level terraces that are opened and closed by machinery work quite well, but the intended crop of annuals must determine the structure design and water depth.

Areas flooded in spring and dewatered gradually create mudflat conditions attractive to migrant shorebirds and ducks (e.g., green-winged teal, Anas crecca), but also induce germination from the seed bank (Fredrickson and Taylor 1982, Rundel and Fredrickson 1981). Too rapid drying produces more terrestrial species (Harris and Marshall 1963), so soil conditions and water level regulation are extremely important. The retention of some moisture on the flat is essential to ensure full maturity of seeds and the germination of late maturing plants like smartweeds. Here, as in any drawdown, a thunderstorm can produce flooding and the loss of a year's crop. Typically, such areas are reflooded in the fall prior to the arrival of waterfowl and other migrants. Flooding to make food available to migrant waterfowl involves regulation of the water control structure (except in cases of high rainfall and flow-through rates) to maintain depths of 6 to 18 inches so that birds can swim but still dabble and tip up for food. Dabbling ducks like green-winged and blue-winged teal (A. discors), mallards (Anas platyrhynchos) and pintails (A. acuta) find ideal food and water conditions in such situations. Deeper areas may be utilized by shallow divers like the ring-necked duck (Aythya collaris) (Fredrickson and Taylor 1982),

Undesirable plants, particularly willow and cattail can be extremely troublesome as they outcompete annuals and eliminate openings favored by ducks. The capability to dry out the area, or to flood it to excessive depths, may allow control of some nuisance species (Fredrickson and Taylor 1982).

## TIDAL ESTUARINE (BRACKISH AND SALT) WETLANDS

Many of the processes that occur in fresh marshes also occur in brackish marshes, and can be influenced by muskrats or nutria populations. However, sites under a tidal regime usually cannot be dewatered for revegetation, and serious marsh loss can occur (as considered elsewhere by other authors in this volume). Herbivore control is one of the most important and effective methods of preventing this loss as it is in freshwater wetlands lacking water source and level control. Such marshes also may serve as nesting and feeding areas for waterbirds, although no long-term studies seem available.

The usual management strategy for attracting breeding, migrant and wintering waterfowl has been to build freshwater impoundments as catch basins that exclude salt water. This approach developed in part from the adaptation of rice impoundments for use by waterfowl along the eastern U.S. coast (MacNamara 1949). It is still commonplace on many coastal refuges, but is now strongly discouraged by the National Marine Fisheries Services to ensure free access of marine organisms such as finfish and shellfish to brackish and fresh tidal marshes that are vital for feeding, breeding and nursery areas. Hence, weirs are often used in place of dikes, and these semi-impoundments reduce turbidity but may not affect salinity markedly (Chabreck and Hoffpauir 1962, Chabreck et al. 1979). In this way, submergent vegetation attractive to waterfowl and also to marine organisms that frequent these shallow areas is enhanced. There has been intensive study of this type of impoundment on fish and shrimp populations in Louisiana (Herke 1978). Undoubtedly there are changes in the species composition and diversity of benthic invertebrate populations caused by this more continuous flooding of areas that once were periodic mudflats. Impounding areas for private waterfowl hunting areas has been legally challenged by federal agencies on the east coast, and this practice may demand extensive evaluation before it is allowed to continue. Nevertheless, it is widely regarded as the best way to enhance waterfowl habitat in saline coastal areas. In South Carolina coastal impoundments, brackish rather than fresh water has been used in the management of such areas (DeVoe and Baughman 1986). Waterfowl capitalize on brackish food species like widgeongrass or musk grass. Dewatering by the use of dikes and water-control structures can also be used to produce the mudflat plant, Sesuvisum (Swiderek et al. 1988) which has small but highly palatable seeds. Waterfowl response in these situations has been impressive, but the species composition may shift. Additionally, such areas may be attractive to shorebirds at low water stages.

Burning has previously been mentioned as a tool for seasonally opening up vegetation for geese, but this more commonly occurs in higher marshes that are only periodically flooded.

### GREEN-TREE IMPOUNDMENTS (FORESTED PALUSTRINE WETLANDS)

The natural winter flooding of flood plain oxbows, sloughs and backwaters, especially in the southeastern United States, provides superb wintering habitat for mallards and other ducks that eat acorns and other large tree seeds and fruits (Allen 1980). Additionally, beaver ponds have been important to waterfowl, but tree mortality results from such water stabilization (Beard 1953). Flooding is erratic and dependent on the timing and the rate of rainfall. Moreover, flooding that occurs during the growing season may kill trees that are not tolerant to prolonged inundation at that time. To enhance the reliability of water and food supplies for migrants, low level impoundments have been used with water control structures to flood mast-producing trees during the dormant season (Cowardin 1965, Schnick et al. 1982, Mitchell and Newling 1986). Typically, a stream is diverted to fill the area, and some flood prevention plan often is necessary. Some areas use low level dikes that will withstand overflowing water but, as in any wetland impoundment, the potential for complete drawdown is essential. If a water control structure is not used, the impounding dam may be cut with a front-end scoop, and then repaired after the drying has occurred.

To take advantage of natural seed crops, site selection for impoundments is crucial and must include those mast producing species such as willow oak (Quercus Phellos ) and water oak (Q. nigra) that tolerate prolonged flooding, but also produce acorns of a size suitable for ducks (Allen 1980). Depending upon the forest species composition and flood duration, some tree mortality may occur due to the reduced drainage capacity of the area. However, these openings are attractive to waterfowl and will produce moist-soil annual seed crops if the areas are naturally or artificially exposed during late summer and early fall. Some managers are creating openings by clear-cutting small patches of less desirable species with the intent of combining the moist-soil management technique with the mast production of the green-tree impoundment strategy (Harrison and Chabreck 1988).

## CONCLUSION

Waterfowl and other wetland wildlife managers have been involved in wetland enhancement and modification for many years, and have developed a series of techniques that are fairly standard for management of various wetland types and geographic regions. These can serve other wetland managers in many useful ways, and are worthy of exploration and experimentation. Some of these techniques could result in highly significant cost reduction where time is available for the use of natural processes. However, because of the Gleasonian nature of succession in many wetlands (van der Valk 1981), plant communities are difficult to predict and the desired or original ecotype may not develop; therefore some range in specifications is essential.

Understanding natural patterns and processes of wetlands is a vital first step to proper and lasting restoration, enhancement or creation. Additionally, one must tap the expertise of the many disciplines that can contribute to such wetland preservation processes. As long-term evolutionary products of extremely dynamic systems, wetland plants and animals are quickly responsive to the availability of resources in newly created and enhanced areas. But we must not become over-confident that we can "create" a normally functioning and naturally diverse system. In most situations, we can provide the environmental needs to allow dominant wetland plants and animals to succeed, and the product will satisfy many if not most viewers. We cannot, however, expect to replace the complex and diverse natural systems that are a product of many centuries of evolution and randomness, and we should not let the ease of creating the structure and simple features of a wetland for mitigation lead us to accept unnecessary and perhaps unsatisfactory substitutes.

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# WETLAND AND WATERBODY RESTORATION AND CREATION ASSOCIATED WITH MINING

Robert P. Brooks
*School of Forest Resources*
*Forest Resources Laboratory*
*Pennsylvania State University*

***ABSTRACT.*** A review of published and unpublished reports was combined with personal experience to produce a summary of the strategies and techniques used to facilitate the establishment of wetlands and waterbodies during mine reclamation. Although the emphasis is on coal, phosphate, and sand and gravel operations, the methods are relevant to other types of mining and mitigation activities. Practical suggestions are emphasized in lieu of either extensive justification or historical review of wetlands mitigation on mined lands.

The following key points should receive attention during planning and mitigation processes:

* Develop site specific objectives that are related to regional wetland trends. Check for potential conflicts among the proposed objectives.
* Wetland mitigation plans should be integrated with mining operations and reclamation at the beginning of any project.
* Designs for wetlands should mimic natural systems and provide flexibility for unforeseen events.
* Ensure that basin morphometry and control of the hydrologic regime are properly addressed before considering other aspects of a project.
* Mandatory monitoring (a minimum of three years is recommended) should be identified as a known cost. Rely on standard methods whenever possible.

Well-designed studies that use comparative approaches (e.g., pre- vs. post-mining, natural vs. restored systems) are needed to increase the database on wetland restoration technology. Meanwhile, regional success criteria for different classes of wetlands need to be developed by consensus agreement among professionals. The rationale for a particular mitigation strategy must have a sound, scientific basis if the needs of mining industries are to be balanced against the necessity of wetland protection.

## OVERVIEW

The protection of wetlands is an issue of national concern. Of primary concern is how to mitigate for wetland losses. Few cost-effective opportunities exist to restore and create wetlands, thereby helping to reverse the trend in wetlands loss and perhaps create an increase. Surface mining, which historically has had substantial negative impacts upon the landscape, may offer some realistic and inexpensive mitigation options, if mitigation plans are integrated into mine reclamation plans at an early stage. To help guide those who make day-to-day decisions about wetland mitigation, this review provides a summary of the methods used to create and restore wetlands and waterbodies during mine reclamation. The recommendations presented at the end of this review can serve as a checklist to help ensure that constructed wetland systems function properly.

This review focuses on surface mining for coal, phosphate, and sand and gravel. It must be recognized that mining of these materials will continue in the U.S. into the foreseeable future. Coal is an essential component of electrical energy production, the fertilizer and chemical industries depend heavily on phosphate rock, and the construction industry requires continued access to sand and gravel reserves. Therefore, mitigation decisions should be based on consensus agreement among knowledgeable individuals who are familiar with both mining operations and wetland trends in the particular physiographic region in question.

The principles pertaining to these three extractable materials will, of course, have a bearing on other types of mining and severe landscape disturbances (e.g., placer mining; hydraulic mining and in-stream dredge mining; open pit mining and sand mining for metal ores, limestone and other rocks; peat extraction). Important literature on wetland mitigation from other types of mining is cited where it is relevant to the discussion. The extraction of peat differs markedly from mineral mining, and is beyond the scope of this review. Readers are referred to the following publications regarding peatland values, impacts and mitigation (Carpenter and Farmer 1981, Minnesota Department of Natural Resources 1981, Damman and French 1987).

The impacts of surface mining activities on wetlands and waterbodies have been well-documented (Darnell 1976, Cardamone et al. 1984). They differ depending on the material extracted, the methods used, and regional differences in topography, geology, soils, and climate. Even if it is assumed that reclamation is performed according to current regulations, mining will have significant effects upon the environment. In addition to the direct removal and filling of wetlands, the removal of soil and overburden severely alters local topography. This in turn disrupts local and regional groundwater and surface water flow patterns. Mining activities typically result in a decrease in groundwater tables and an increase in surface water runoff, both of which significantly affect the restoration and creation of aquatic systems. The removal of vegetation and disturbance of land surfaces increases sedimentation rates, with resultant increases in water turbidity. Access roads cause erosion in steep terrain, and can block the flow of water in areas of low relief, resulting in the formation of ponds. Exposed coal mine spoils readily oxidize, causing pollution problems such as acidic mine drainage. There are increases in the formation and deposition of materials, such as iron, manganese, aluminum, and sulfur, sometimes in amounts toxic to biota. Tailings from metal mines also can produce biologically-toxic discharges. Sedimentation rather than metal toxicity is a major problem associated with phosphate and sand and gravel mining.

In summary, habitat loss, chronic environmental stress, and toxic levels of pollution can occur during the mining process, especially if reclamation practices are poorly implemented (Darnell 1976). Any efforts to encourage wetland and waterbody creation on mined lands, whether to mitigate for losses attributable directly to mining, or as a means of increasing wetland area, should be cognizant of mining impacts on surficial and groundwater hydrology as outlined above.

Ten years have passed since the Surface Mining Control and Reclamation Act of 1977 (SMCRA, P.L. 95-87) was enacted. This federal act, coupled with the appropriate state statutes, has halted many of the past environmental abuses associated with surface mining, particularly with respect to the mining of coal. Although viewed as among the most encompassing and detailed pieces of environmental legislation, the Act often relies on vague notions, such as "higher and better uses" to guide decision-makers about reclamation strategies (Wyngaard 1985). Thus, the overall success of this law must be tempered by an examination of the relatively sterile landscapes that are often created under the guise of reclamation. Wetlands and waterbodies are allowed under existing regulations, but provisions are strict, and anything but encouraging. Decades of pre-SMCRA experience with polluted waters have resulted in cautious approaches to managing water on mined lands. Permanent impoundments are allowed under SMCRA guidelines, but "are prohibited unless authorized by the regulatory authority" (Sec. 816.49a). Thus, unless variances are sought, it is often viewed as less expensive to remove an impoundment or wet depression rather than to develop plans to leave it in place (Grandt 1981).

The Experimental Practices section of SMCRA (Sec. 711) produces the same result. Virtually any innovative reclamation technique can be tried if the operator is willing to justify the practice to state and federal regulatory authorities (Thompson 1984). This additional effort is often perceived as adding expense to a project, but overall costs may actually be reduced if permanent wetlands or waterbodies are left in place (Fowler and Turner 1981). The net result of these regulatory stumbling blocks has been to discourage the intentional creation of wetlands on surface mined lands (e.g., Gleich 1985) unless they are either demanded by an informed landowner, or based on in-kind replacement of a wetland that has been lost or degraded during mining. The vast majority of wetlands and waterbodies on mined lands exist not because of astute planning, but by accident.

Mining and related activities have disturbed less than 0.2% of the land mass of the U.S. (Schaller and Sutton 1978), yet in mining regions, disturbances can exceed 20% of a given land area (e.g., coal mining in Clearfield County, Pennsylvania; phosphate mining in Polk County, Florida). Coal reserves occupy large areas in selected regions of the U.S. (Fig. 1). Phosphate deposits, although large in area, occur only in a few regions. Wetland mitigation

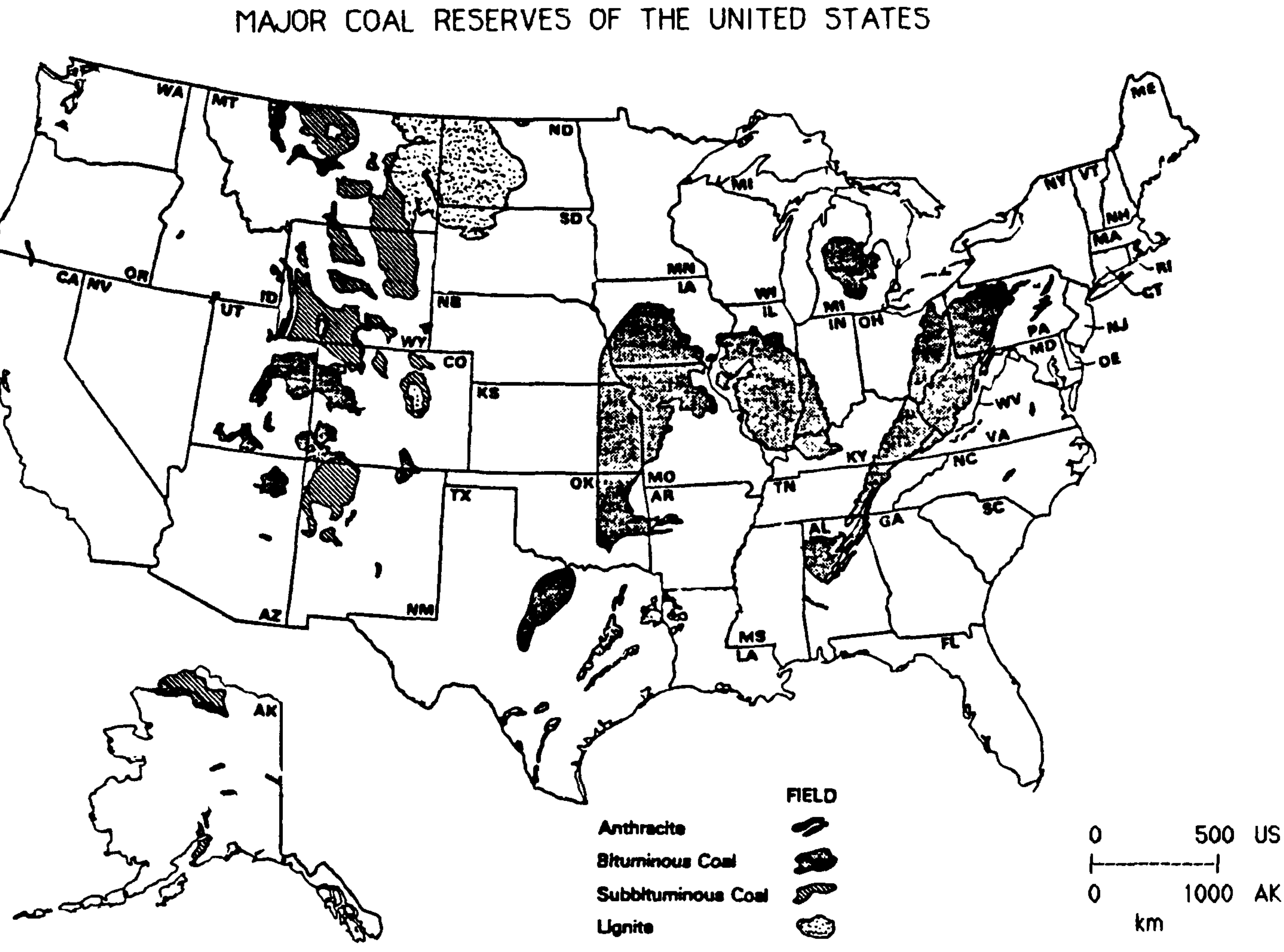


Figure 1. Major coal reserves of the continental United States and Alaska (modified from Energy Information Service 1984).

issues related to phosphate mining occur primarily in Florida (Fig. 2). Sand and gravel deposits are dispersed throughout the U.S.

Mining activity has not always resulted in a net decrease in wetlands. The gain in open-water, palustrine wetlands nationwide during the 1950's to the 1970's (Frayer et al. 1983) is apparent in land use surveys of mined lands. Brooks and Hill (1987) reported that mined lands in Pennsylvania supported 18% more palustrine wetlands than unmined lands, primarily because of a 270% gain in permanent, open water wetlands in the glaciated coal region of the state. Conversely, Hayes et al. (1984) observed a reduction in the number of impoundments, particularly shallow, vegetated waterbodies, following passage of SMCRA in 1977. Palustrine vegetated wetlands are often converted to open-water wetlands, which may result in a significant change in regional wetland types (Tiner and Finn 1986, Brooks and Hill 1987).

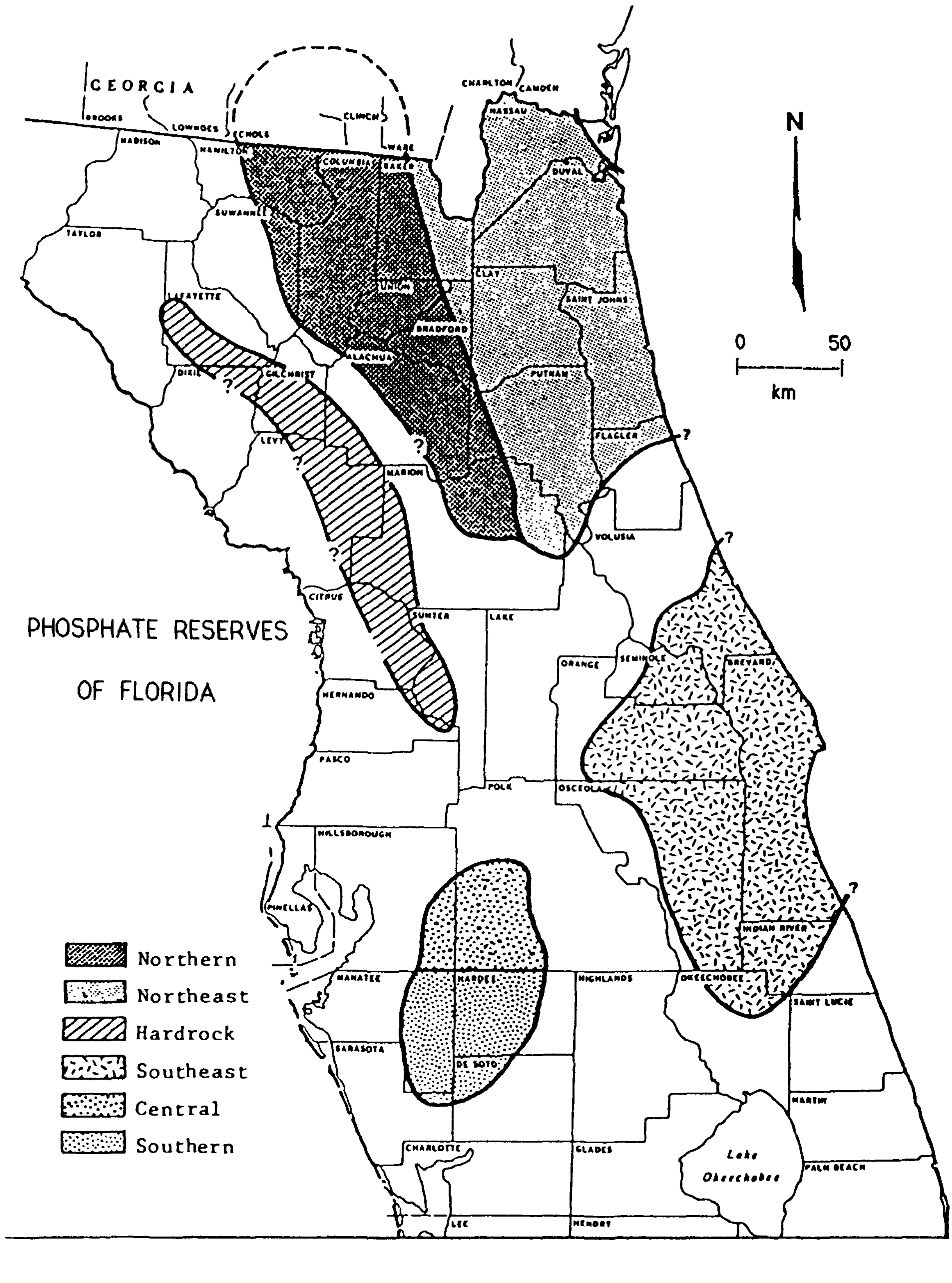


Figure 2. Major phosphate reserves of Florida (modified from Florida Defenders of the Environment 1984).

Before examining specifically how wetlands and waterbodies have been restored and created on mined lands, it is useful to discuss the characteristics and functions of volunteer wetlands, which are much more abundant than those purposefully designed. As mining practices differ, so do the types of aquatic environments left behind. The following will profile the inadvertent creation of aquatic environments by past mining and reclamation practices.

## SURFACE MINING FOR COAL

Based on a survey of the literature, the following types of wetlands (listed approximately in order of declining numerical abundance) are commonly found on coal-mined lands: 1) sediment basins; 2) shallow wet depressions and emergent marshes; 3) moss-dominated springs and seeps; 4) final-cut and other deep lakes; 5) intermittent streams; and 6) slurry ponds and other coal refuse disposal areas.

During surface mine reclamation for coal, wetlands and waterbodies are created intentionally for erosion and sedimentation control as sediment basins. Basin size is determined by the anticipated runoff for a mine site and thus, is a function of the area of land disturbed. Sediment basins are usually <0.5 ha in size (Brooks and Hill 1987); often only 0.1 ha (Fowler and Turner 1981). They are geometrically shaped (i.e., circular, oval, rectangular), and have steep slopes (usually >30°), and flat bottoms. Volunteer palustrine wetlands also occur as a function of local changes in hydrology following reclamation. These include moss-dominated springs and seeps, persistent and non-persistent emergent marshes, and shallow wet depressions (similar to the prairie potholes of the northcentral U.S. (Cole 1986).

Before the advent of reclamation legislation, final-cut lakes were left inadvertently when the final excavation was not back-filled. Characteristics of these lacustrine waterbodies vary considerably, but they are often linear in shape, large (1-50 ha), deep (2-30 m), and have poorly developed littoral zones (Jones et al 1985a, Hill 1986). Other deep water bodies are formed after pits are excavated in regions with water tables near the surface. Lakes of varying shape and size have formed in this manner in glaciated regions of Pennsylvania (Brooks and Hill 1987), and several midwestern states (Jones et al. 1985b, Klimstra and Nawrot 1982); 6,000 ha of these lakes exist in Illinois (Coss et al. 1985) and 3,600 ha in Ohio (Glesne and Suprenant 1979) (Fig. 1).

After coal is processed, coal fines and associated particles are discharged into basins known as slurry ponds. The usual reclamation procedure for these typically acidic disposal areas is to cover them with at least 1.3 m of topsoil. However, a variety of vascular hydrophytes will colonize slurry ponds, thus establishing emergent wetlands (Nawrot 1985) (Fig. 3).

Although a discussion of streams and rivers is beyond the scope of this review, intermittent streams containing emergent vegetation are also fairly common, and therefore, constitute another wetland type. Relocation and restoration of major streams is discussed in another chapter of this document (see Jensen and Platts).

A variety of ecological functions and economic uses have been documented for the types of wetlands listed above, including wildlife and fisheries habitat, agricultural and recreational activities, sediment retention, treatment of acidic mine drainage, and public water supplies.

Sediment basins provide for uses beyond their intended purpose. They provide habitat for a variety of vertebrate taxa, including birds (Burley and Hopkins 1984, Sponsler et al. 1984, Brooks et al. 1985a), mammals (Brooks et al 1985a), and herpetofauna (Fowler and Turner 1981, Brooks et al. 1985a). A diverse macroinvertebrate community also has been identified with sediment basins (Hepp 1987).

Mine lakes are known to produce excellent fisheries (Jones et al. 1985b, Mannz 1985), in part due to adequate primary production (Brenner et al. 1985) and macroinvertebrate production (Jones et al. 1985a). They can serve as foci for recreational activities such as fishing, boating, and waterfowl hunting (Klimstra et al. 1985). Other uses, particularly in the Midwest, include lake-side housing and community open spaces, crop irrigation and livestock watering, and water supplies for homes, fire protection, and industrial purposes (Glazier et al. 1981).

Vegetated wetlands dominated by either vascular or non-vascular species can effectively sequester some of the constituent of mine drainage. Observations on the removal of metals by naturally occurring Sphagnum moss (e.g., Wieder and Lang 1986) has led to further investigations of how mosses, algae and macrophytes with their associated bacteria, can be used to ameliorate the effects of mine drainage (see Girts and Kleinmann 1986 for a review).

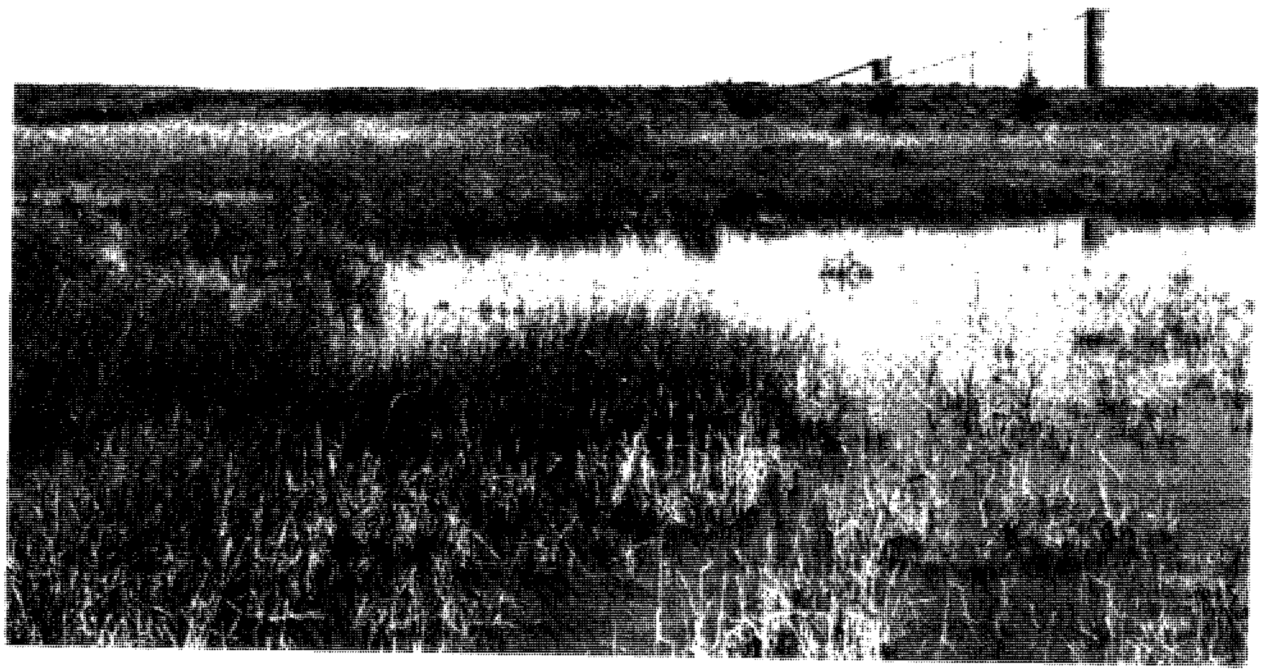

Figure 3. Seasonally inundated zone of a wetland created on coal slurry in Indiana showing four years of growth. (Courtesy of Jack Nawrot, Cooperative Wildlife Research Laboratory, Southern Illinois University.)

## SURFACE MINING FOR PHOSPHATE

Primary phosphate deposits in the U.S. occur in Florida, Tennessee, South Carolina, and the Phosphoria Formation of Montana, Wyoming, Idaho and Utah. However, surface mining activities affecting wetlands occur almost exclusively in Florida, where wetlands typically comprise 8-17% of the landscape area (Florida Defenders of the Environment 1984) (Fig. 2). The principal focus of reclamation in Florida has been on mitigating for wetland losses. Substantial progress in developing restoration and creation technology has been made through the combined efforts of the phosphate industry and state regulatory agencies. Florida provides an example of how regulatory pressures can accelerate a desired technology if the pressures are firmly and reasonably applied.

Reclamation of phosphate mines in Florida was voluntary until 1975, when the Department of Natural Resources developed regulations (Florida Administrative Code Section 16C-16, 16C-17) in response to legislation (Florida Statute 211.32, 370.021). Due to extraordinary residential and commercial development, there have been increasing efforts to push reclamation technology toward the goal of replicating original wetland conditions as a provision of mining. Public pressure combined with a flat topography suitable for wetland establishment and awareness of wetland functions and values has led to sophisticated efforts to restore and create complex wetland systems.

Historically, the removal of phosphate ore by draglines produced mounds of sand tailings interspersed among waterbodies and clay settling ponds. Many of these waterbodies were used by wintering waterfowl that were attracted by volunteering hydrophytes (e.g., Najas spp.). Gradual filling of these waterbodies with clay produced a successional trend from submergent species, to emergents (e.g., cattail, Typha spp.), and finally to shrubs (e.g., willow, Salix spp.) (Clewell 1981). Wildlife use diminished during this process (King et al. 1980). After 1975, reclamation required regrading of the sand tailings, and planting them to pasture. Depressions left from the removal of phosphate ore fill with water, producing a mosaic of pastures and lakes. Marion and O'Meara (1983) reported that the reclamation laws had produced both positive and negative effects on wildlife. One of the positive impacts, was an increase in wetland edge following reclamation.

Boody (1983) studied 12 reclaimed lakes, 6 classified as deep, and six that were considered shallow. Deep lakes had a mean area or 59 $\pm$113 ha (range = 2-287 ha) with depths of 3-5 m. Shallow lakes had a mean area of 9 $\pm$ 17 ha (range = 2-30 ha) with depths of 2-3 m. The pH was typically 5-7, but ranged from 4.2-9.3. Most reclaimed lakes supported fewer species of fish (mean = 10 $\pm$ 6 species, range = 4-22) than the 4 natural lakes that were studied (mean = 18 $\pm$ 2 species, range = 16-20). Of the 29 fish species collected, 27 were native and 2 were introduced (Brice and Boody 1983).

Recent reclamation plans have included littoral zones and periodically flooded areas as part of the lake ecosystem. Freshwater emergent marshes have been successfully established, and to a lesser extent, forested wetlands have been created (Haynes 1984).

The clay settling ponds, which usually occupy >50% of a mine site, continue to pose problems and are perceived negatively by the public. Waste clays from the mining process are suspended in a slurry and pumped into settling ponds. Attention has been focused on de-watering these ponds as rapidly as possible; typically within 10 years. Although the ponds support fewer plant species than natural wetlands, site management in conjunction with planned species introductions can create a heterogeneous mix of wetland vegetation and open water (Robertson 1983). Montalbano et al. (1978) discussed the value of clay settling ponds as wintering habitat for waterfowl (7 species reported), and suggested that water level manipulation would help create high interspersion of emergents and open water. Haynes (1984) believes that these settling ponds may have substantial positive values, and thus should be manipulated and managed as productive wetlands. The settling ponds are large (81-405 ha) and are currently increasing at a rate of 1,000 ha/yr beyond the 30,000+ ha already present. Several authors advocate a drainage basin approach for mitigating wetland losses in the phosphate region, so that areas beyond the individual mining unit are considered in the planning process (Breedlove and Dennis 1983), although Fletcher (1986) believes that the current knowledge is only suitable for restoration of small drainage basins.

## SURFACE MINING FOR SAND AND GRAVEL

Sand and gravel is defined as unconsolidated mineral and rock particles. Generally the particles have been transported by water, and therefore, many deposits still occur in and around waterbodies. Inland deposits are typically classified as fluvial, glacial or alluvial depending on their origin.

Sand and gravel is vital to the construction industry. Excavation is the chief method of removal, and 18% of the lands disturbed by mining are for sand and gravel. Sand and gravel operations are regulated primarily through state laws. Demand continues to increase, with deposits near urban areas in highest demand. More excavation can be expected in nearly every state in the U.S. (National Research Council 1980). Concurrently, opportunities for restoration and creation of wetlands on reclaimed sand and gravel sites will also increase.

Although waterbodies that remain following sand and gravel mining have been used for a variety of purposes, reclamation plans have often lacked advanced planning and imagination (McRae 1986). Fishing, boating, and wildlife observation commonly take place in water-filled sand and gravel pits in both the U.S. and Great Britain (Koopman 1982, McRae 1986, respectively).

Lomax (1982) found that reclaimed lakes in the southern coastal plain of New Jersey were colonized first by emergents (e.g., Typha spp., Cyperus spp., Juncus spp., Scirpus spp.), and then by woody vegetation such as black willow (Salix nigra), red maple (Acer rubrum), and black tupelo (Nyssa sylvatica). Occasionally, bog-like communities developed in pits <1 ha in area. Lomax recorded use by 194 species of vertebrates over a 16-year period. Gallagher (1982) found that the Delta Ponds of Eugene, Oregon became completely revegetated through volunteer colonization. Species found included cattail, pondweed (Potamageton spp.), willow, and alder (Alnus spp.). Birds (78 species), mammals, and fish were observed using the 65-ha area.

Street (1982) reported on the gravel-pits of Great Britain. Pits ranged in size from 1-100 ha, and were 3-30 m deep. Most had steep sides and flat bottoms. A restoration project was initiated at the gravel-pit complex of the A.R.C. Wildfowl Centre in Great Britain in 1972, and has developed into a highly productive 37-ha wetland system. Waterfowl density within the managed site ranged between 2.4 to 38.7 birds/ha, whereas avian density on unmanaged gravel pits did not exceed 2.8 birds/ha. By manipulating basin morphometry, plant communities, and the availability of organic matter, both vertebrate and invertebrate numbers and diversity were increased.

## RECOMMENDATIONS FOR RESTORATION AND CREATION WETLANDS AND WATERBODIES ON MINED LANDS

There have been recent efforts to stimulate the restoration and creation of wetlands on mined lands (e.g., Klimstra and Nawrot 1982, Brooks 1984, Brenner 1986, Brooks 1986, Haynes 1986, McRae 1986). Sufficient recommendations exist to provide guidance for wetland mitigation on mined lands. Due to procedural and regional differences in mining coal, phosphate, and sand and gravel, the recommendations will be discussed under separate headings below.

One cannot incorporate all possible mitigation into a single wetland project. It is best to work within clearly stated objectives that are tied to specific wetland functions. Only then can the wetland be designed optimally with respect to the desired objectives. There may be conflicts among objectives which should be resolved in the planning process (e.g., public water supply vs. ecological productivity, recreational fishery vs. habitat for diverse amphibian community). Whenever possible, pre-mining conditions and regional reference wetlands should be used as guides to how a wetland ought to be created or restored.

### WETLANDS AND WATERBODIES ON COAL MINED LANDS

#### Basin Morphometry

**Area--**

The area covered by a wetland or waterbody is constrained both by objective and site location. Peltz and Maughan (1978) suggested that several ponds of small size (0.25-1.0 ha) were preferred to a few large ones with regard to fish production; 0.1 ha being the minimum recommended size. Sandusky (1978) found that some species of waterfowl (e.g., blue-winged teal, Anas discors) nested on ponds as small as 0.04-0.2 ha. Hudson (1983) recommended pond areas >0.5 ha for waterfowl production in stock ponds, as did Allaire (1979) for wildlife in general. Based on an inventory of 35 existing wetlands on mined lands in Pennsylvania, Hill (1986) recommended areas of 1-3 ha to maximize wildlife diversity. For natural habitats, bird species richness has been found to increase with wetland area, but to level off for areas >4 ha (Williams 1985). As sediment ponds are typically less than 0.5 ha in area, a slight increase in pond size, while still maintaining a diversity of sizes, would seem to meet multiple objectives.

Mine lakes can be as large as the remaining mined pit or depression. Lakes exceeding 10 ha are not uncommon (Jones et al. 1985a). Glazier et al. (1981), Nelson (1982), and Doxtater (1985) provide scenarios for planning multiple-uses of large, deep-water lakes.

### Depth–

The need for water permanence will determine the appropriate depth of a given wetland or waterbody. Again, project objectives coupled with mining operations will influence the eventual depth characteristics of the wetland. It is important to remember that deep water lakes will tend to be either mesotrophic or oligotrophic, whereas shallow waterbodies and vegetated wetlands usually have higher primary productivity, tending toward eutrophic conditions.

To enhance year round survival for fish, Peltz and Maughan (1978) recommended depths of 2-3 m for ponds with groundwater sources, and >5 m for ponds supplied by surface runoff alone. Although water depth in excess of 3 m may be desirable for fish survival, retention of flood waters, as a water supply reservoir, and for some recreational activities, most investigators have stressed the need for construction of an extensive littoral zone. Many species of sport fish require depths of 0.5-2.0 m for spawning (Peltz and Maughan 1978, Leedy 1981). Some submergent hydrophytes grow better in depths >0.5 m (e.g., Potomageton spp., Chara spp.). The regulatory guidelines of SMCRA require stability of water levels in impoundments, but this may not be feasible or desirable for many wetlands. Colonization by emergent hydrophytes requires fluctuating water levels. Cole (1986) found that water volume, and hence depth, varied by >40% in five ponds on mined land in Illinois. These changes in water level exposed the littoral zone much like the wetlands of the Prairie Pothole region further west. Fluctuating water depths of <0.5 m are recommended to promote the growth of emergent hydrophytes, which in turn encourage macroinvertebrate production in the littoral zone.

### Slope–

Whereas a shelf 1 m in depth may benefit aquatic species such as fish, other species benefit from slopes that grade gently from upland to wetland. A wetland basin that has a variety of slopes, ranging from <5° to almost 90° will benefit a diversity of wildlife species and provide visual variety. The majority of the shoreline should have gentle slopes. Amphibians, reptiles, and some fishes require gentle slopes, typically <15°. Sand and mud flats used by foraging shorebirds should have slopes of <5°. Access areas for swimming and boating also require gently sloping terrain. Some species will benefit from steeply sloped or overhung banks, including burrow-dwelling muskrats (Ondatra zibethicus, Brooks and Dodge 1986), belted kingfisher (Cerle alcyon, Brooks and Davis 1987), swallows, cliff-nesting raptors, and some fishes.

### Shape–

The shorelines of wetlands and waterbodies should be convoluted to produce an irregular shape (Brooks 1984). Basins with a high shoreline development index (i.e., length of shoreline divided by the circumference of a circle of equal area, Wetzel 1975) provide more edge for wildlife, and reduce wind and wave action on larger waterbodies (Coss et al. 1985). Coves, peninsulas, and islands contribute substantially to shoreline development (Leedy and Franklin 1981, Brooks 1984). Islands ( >3 m in diameter, Emerick 1985) and even large rocks (0.5-1.5 m in diameter, O'Leary et al. 1984) provide nesting and resting places for many species of waterfowl and shorebirds. Irregularities in basin shape tend to disperse water flows thus helping to maximize retention time in the basin if flood control or water treatment are desirable characteristics of the wetland.

### Soils--

It is important to consider both hydric soils within a wetland and the soils of adjacent uplands. Proper management of upland soils will protect aquatic systems from unnecessary sediment, chemical, and thermal pollution (Rogowski 1978, Leedy 1981).

### Upland Soils--

During reclamation of mined land it is preferable to have topsoil cover the overburden to protect and conserve the available water and provide a better medium for plant growth. Vegetated topsoil will reduce evaporation, allow more infiltration into groundwater supplies, produce temporary ponds in depressions, and reduce peak infiltration rates that lead to abnormal fluctuations in the water table and droughty surface conditions (Rogowski 1978). The ability of a soil to retain water is dependent on its texture (i.e., sand is more droughty than clay), depth, the content of organic matter, and the distribution of pore size (Schaller and Sutton 1978). Thus, a careful study of soil conditions will enhance the probability of successful restoration and creation of wetlands, and the reclamation of upland areas.

Sediment yields from exposed soils are typically highest in the first 6 months after regrading, and are halved in subsequent 6-month periods as the site progressively revegetates (Schaller and Sutton 1978). Silts and sediments that enter waterbodies tend to reduce light transmission (and hence, photosynthesis), raise water temperature, and cover sensitive organisms (Leedy 1981). Thus, it is important to revegetate exposed soils as rapidly as possible to avoid interfering with wetland establishment.

Based on the reclamation literature for upland portions of mined sites, several recommendations can be made to protect aquatic systems from upland runoff. Exposed soils must be seeded, fertilized, and mulched as soon as possible. Rafaill and Vogel (1978) recommended 60 lbs/acre (67 kg/ha) of nitrogen and 100 lbs/acre (112 kg/ha) of phosphorus, but no potassium for reclaiming mined land in Appalachia. In acidic areas, soil should be limed to a pH of at least 5.5. Use of high quality seeds is advised (i.e., high germination and purity percentages, McGee and Harper 1986). Seeds and fertilizer should be applied first, followed by an appropriate mulch to avoid perching seeds above the ground's surface (Schaller and Sutton 1978). Straw and hay were suggested as the best mulch to use, particularly if applied by a mulch blower that cuts, shreds, and evenly spreads the material. Estimated costs for purchase and application of straw were $100-200/ton (909 kg) with an application rate of 1-2 tons/acre (2,245-4,490 kg/ha), whereas nets and mats may cost > $1,500/acre ($3,700/ha), especially on steep slopes (Mining and Reclamation Council of America and Hess and Fisher Engineers 1985). Advice for selecting the appropriate plant species, and seeding, fertilizing, and liming rates for a given soil type are generally available from mining agencies (e.g., Office of Surface Mining, U.S. Bureau of Mines, state mining agencies) and county offices of the Soil Conservation Service.

Vegetative buffers should be installed around wetland basins. Although recommendations for buffer widths range from 1-300 m, vegetated strips as narrow as 15-20 m can remove 50-75% of the sediments (Barfield and Albrecht 1982). Whenever appropriate for a given region, buffers should include shrub and forested zones. Gilliam (1985) studied unmined agricultural areas in North Carolina and found that wooded buffers about 100 m wide removed >50% of the sediment, including much of the nitrogen and phosphorus. In addition to serving a water quality function, vegetative buffers can act as travel corridors and refugia for wildlife, thereby reducing the isolation of the wetland. If desired, wetland edges can be shaded by planting properly oriented tree species that will grow to a height of twice the distance to the water (Leedy 1981).

In severe cases of upland runoff, structural diversions may be necessary to divert sediment-laden waters. Diversion ditches, concave depressions, and sediment traps are some of the techniques available. Mining agencies, the Soil Conservation Service, or experienced consultants can provide the expertise needed to design these systems.

### Hydric Soils--

Hydric soils, or those previously saturated, usually must be constructed, unless soil is available from a wetland scheduled to be altered or removed. Routine cleaning of roadside ditches or other wet depressions can also act as a source of hydric soil, although pollutants such as road salt, oil, or lead may be present in substantial quantities. Hydric soils should be stockpiled, preferably for less than one month, and then spread to the desired thickness in newly constructed basins. These soils typically have a relatively high organic matter content, and often act as a seed source or seed bank. Longer storage periods will result in desiccation of plant materials, and possibly re-oxidation of metals and other potentially damaging materials.

When existing hydric soils are not available, they can be constructed by using a relatively fertile topsoil. Good plant survivorship and seed germination rates have been obtained by mixing about 30% (by volume) livestock manure in with the topsoil to act as a source or organic matter and nitrogen (Brooks, unpublished). Small quantities of superphosphate were added to the soil around each planted propagule. Chemical fertilizers have been recommended as an additive to ponds and lakes designed for fish production; 12-12-12 or 8-8-2 (nitrogen-phosphorous-potassium; Glesne and Surprenant 1979, Leedy 1981, respectively). Leedy (1981) suggested that no more than 200kg/ha of 8-8-2 fertilizer be added at one time, although application rates for infertile waters might exceed 1,500 kg/ha/yr.

Whenever possible, soil tests should be made to provide more accurate estimates of fertilizer and lime additions for both hydric, and adjacent upland soils depending on the plant species desired and the intended use of the wetland or waterbody. Basins constructed on mined lands often contain acidic soils. Assuming that a circumneutral pH is desired (although some wetland plants require acidic or alkaline conditions), the pH of the bottom soils should be raised to about 6.5 using lime (Peltz and Maughan 1978). If the pH of the soil is less than 5.5, then at least 1,000 kg/ha of lime is probably needed (Leedy 1981). Slurry ponds with acidic soils require more alkaline additions to promote growth of hydrophytes; >20,000 kg/ha of limestone (Nawrot 1985). Warburton et al. (1985) reported improved growth rates for bulrushes (Scirpus spp.) with addition of slow-release fertilizer tablets (22-8-2) to each propagule. If acidophilic plants occur naturally on the site or their presence is a desired objective of reclamation, then it may not be necessary to adjust pH. The presence of certain species of moss and algae in springs and seeps is a good indicator of waters with low pH and usually low concentrations of nutrients (Brooks, unpublished).

Basins constructed below the water table rarely need to be sealed, whereas perched wetlands need a water-conserving layer of material on the bottom and sides of the basin. Clay is commonly used in this manner and should be compacted to a thickness of about 30 cm (Soil Conservation Service 1979). Bentonite, and synthetic membranes can also serve as sealants. Specifications for a specific soil type and climate are generally available from county offices of the Soil Conservation Service or mining agencies.

## Vegetation

Studies of existing wetlands have shown that a diversity of hydrophytes will volunteer over time. Cattail (Typha latifolia) is by far the most successful vascular hydrophyte on mined lands. Cattail, soft rush (Juncus effusus), and woolgrass (Scirpus cyperinus) were the first invaders of four wetland basins in central Pennsylvania; all were present within 1-1.5 years of regrading (Hepp 1987). Twelve species of vascular plants had volunteered on one site after 6 years. Fowler et al. (1985) found that cattail, soft rush, and spike rush (Eleocharis obtusa) rapidly invaded sediment ponds in Tennessee; 10 species were eventually present. Coss et al. (1985) found 14 species of vascular hydrophytes growing in four lake complexes in Illinois. The lake with the greatest hydrophyte diversity had 7 species.

After volunteer macrophytes were observed on slurry ponds in southern Illinois (e.g., reedgrass (Phragmites australis), a planting program was started in that has led to revegetation of more than 200 ha of wetlands on 12 sites (Nawrot 1985). Investigators found that perennial rootstocks of hardstem bulrush (Scirpus acutus), three-square (S. americana), and prairie cordgrass (Spartina pectinata) were more dependable than seed because sub-surface conditions were more amenable to plant establishment than surface conditions. Rootstocks were collected at a rate of 75-100 propagules/man-hour, and hand-planted with bars and shovels. Collection of propagules in early spring is preferred over autumn collection. Spacing was on 0.3-1.5 m centers, and each propagule was planted in 5-13 cm of soil, depending on the species. They recommended a water-level control structure to assure adequate control over seasonally variable water levels. Plants collected locally under similar conditions had better survival rates than commercially available stock. Whenever possible, local planting stock should be used.

We have constructed smaller wetlands, designed specifically for treating acidic mine drainage (Brooks, unpublished). Cattail rhizomes were collected from existing sediment basins at a rate of 50-100/man-hour, and planted at a rate >100/man-hour. Multi-stemmed clumps of sedges (Carex gyandra) and soft rush (20-cm dia. plugs) were also collected. Both were planted on 0.5-1.0 m centers. We had 75-80% survival of these plants after one year. Costs for constructing wetlands designed to treat mine drainage are slightly less than $10/m^2$ ($1/ft$^2$) (Girts and Kleinmann 1986, Rightnour, pers. comm.), including all planting and basin construction costs.

There are several ways to enhance the proliferation of aquatic vegetation if a decision is made to encourage volunteer colonization. The morphometry of the basin, as previously discussed, must be suitable with respect to depth and slope. The desired zones of vegetation can be controlled by manipulating morphometric variables. Emergent species will colonize the littoral zone up to about 1 m in depth. Shrubs will be restricted to very shallow or seasonally flooded zones. By creating topographic diversity within a site, there will be more opportunities for a variety of species to successfully colonize. Mitigated wetlands that have hydrologic connections with natural wetlands or other mitigated sites will be more likely to receive plant propagules, either through wind, water, or animal dispersal.

## Fauna

Diverse vertebrate and invertebrate communities have been found in wetlands and waterbodies on coal surface mines. Brooks et al. (1985a) reported that 125 vertebrate species were observed on 35 wetlands studied in western Pennsylvania (86 birds, 19 mammals, 11 reptiles, and 9 amphibians). The mean number of vertebrates per wetland was 23 $\pm$ 12 (1 SE), with a range of 7-60 species/wetland (Hill 1986). Hepp (1987), in a more intensive study on four wetlands in the same region, reported use by 90 vertebrate species (64 birds, 15 mammals, 3 reptiles, and 8 amphibians) and more than 39 invertebrate taxa. O'Leary et al. (1984) observed 76 avian species, including 18 species of waterfowl, and 10 mammalian species on 47 wetlands in southwestern Illinois. Also in Illinois, Coss et al. (1985) studied four mined lake complexes and found 89 vertebrate species. In nine sediment ponds in Tennessee, Fowler et al. (1985) reported use by 61 invertebrate taxa, 6 fish species, and 12 amphibian species. Jones et al. (1985a), in a study of 33 mine lakes in Illinois and Missouri, identified almost 200 invertebrate taxa and 33 fish species. Nineteen species of fish were collected from one 86-ha mine lake in Illinois (Jones et al. 1985b).

With the exception of fish species and some invertebrate taxa (e.g., Mollusca), most species voluntarily colonize surface mine wetlands. Some invertebrates can be introduced by water birds as larvae attached to feet and feathers. Fish are also introduced by local anglers. If wetlands are hydrologically connected with other reclaimed or natural systems, the opportunities for rapid colonization are greatly improved. If wetlands are juxtaposed to a variety of upland habitats that provide shelter and travel corridors, colonization rates and numbers probably will be greater. Hepp (1987) reported rapid colonization rates (within 3 years of final grading) for both invertebrate (e.g., dipterans, coleopterans, hemipterans) and vertebrate (e.g., amphibians, some small mammals, and many birds) species, followed by a period of stabilization in community structure. Pentecost and Stupka (1979) found that common amphibian species invaded sediment ponds within one month of formation; founder populations were located 100 m away.

Artificial structures and substrates can be introduced to supplement existing shelter, such as nest boxes for cavity nesters and artificial reefs for fish and invertebrates. As with flora, wetlands designed with specific objectives will provide suitable habitat for the desired species, whether fish, waterfowl, or a diversity of faunal groups.

## WETLANDS AND WATERBODIES ON PHOSPHATE MINED LANDS

### Basin Morphometry

The same parameters discussed for coal mined lands are equally important for phosphate areas (e.g., area, depth, slope, shape). A major difference exists for the Florida landscape, however, because of its low relief. To accommodate the sheet flow of water over flat lands and to match the adaptions of plant species to subtle changes in elevation, the slopes of basin banks and bottoms need to be carefully established. In addition, hydroperiod variations between wet and dry seasons must be considered in project design. Wetland systems must be capable of storing large quantities of water during the wet season. This can be accomplished by designing wetlands of sufficient size. During the dry season, when the water table drops below the land surface, there must be enough deep depressions to harbor aquatic organisms, such as fish, amphibians, and invertebrates (King et al. 1985). Depressions should be at least 2 m below the high water marks to maintain aquatic habitat during droughts (King et al. 1985). Reduced slopes (<3%) will allow the development of wide soil moisture zones. This will provide a wider tolerance zone for many species of wetland vegetation and compensate for environmental disturbances, such as drought, fluctuating water tables, and fire. Conversely, steeper slopes result in narrow moisture zones that leave little room for error in predicting the eventual composition of the floral community.

### Soils

Soils of the central phosphate region in Florida are typically circumneutral and quite fertile due to the abundance of phosphorus and calcium, although potassium may be limiting (Clewell 1981). Phosphate deposits further north may be more acidic and less fertile. Soils being prepared for the establishment of wetlands are usually regraded to the proper elevation and conformation using the sand tailings. Additional overburden, if available, can then be added up to a depth of 30 cm (Erwin 1985). Numerous studies have shown that the addition of wetland topsoil (i.e., mulch, organic muck) from natural wetlands scheduled for mining greatly enhances the chances for successful reclamation (Clewell 1981, Dunn and Best 1983, Erwin 1985). "Topsoiling" or "mulching" can provide a variety of propagules (e.g., seeds, roots, rhizomes) from native plant species that result in a more natural vegetative community at the exclusion of weed species.

### Vegetation

Wetland restoration efforts in the Florida phosphate region have focused on the establishment of three major types of wetland communities: open water, emergent marshes, and forested wetlands. Open water areas are primarily a function of water depth and need not be discussed further. The two types of vegetative communities will be discussed separately. The techniques developed have been influenced by regulations that require rapid revegetation (within one year) and the creation of a self-sustaining community.

### Emergent Marshes--

Techniques used to establish herbaceous hydrophytes include: 1) transplanting from natural wetlands; 2) application of hydric topsoil from natural wetlands; and 3) reliance on voluntary establishment. Florida allows licensed individuals to remove native species from natural wetlands for the purpose of mitigation. In addition, plants from wetlands scheduled for mining can be transplanted to newly prepared sites. However, the availability of plants from natural wetlands may not always match the timing of mitigation projects.

For the Agrico Swamp project in central Florida (restoration of 61 ha of wetland on a 148 ha project site) Erwin (1985) and Erwin and Best (1985) reported that the application of wetland topsoils resulted in the establishment of 41 plant species in a restored marsh, whereas overburden alone resulted in the establishment of only 26 species. The common species present included, cattail (Typha latifolia), pickerelweed (Pontederia cordata), rushes (Scirpus californicus), dog fennel (Eupatorium capillifolum), and arrowhead (Sagittaria lanceolata). The topsoil areas contained both perennial and annual species, whereas the overburden areas contained primarily annuals. The rapid establishment of late-successional species, such as many perennials, either through "topsoiling" or transplanting may help to eliminate undesirable species such as cattail (Erwin and Best 1985).

Volunteer plants contribute substantially to restoration efforts in Florida. Certain factors can increase the role of volunteers. When natural communities are proximal to restored sites, the likelihood of propagule dispersal is enhanced. Hydrologic connections with streams can also distribute the seeds and propagules of desirable species. Self-sustaining seed banks with their inherent benefits can become established within 3 years if artificial planting is done (Erwin 1985), and within 4-5 years if based solely on volunteer species (Dunn and Best 1983).

Restoration of emergent marshes in Florida is further enhanced if good quality planting stock is used and if specific site preparation and planting methods are properly applied (Haynes 1984). Several long-term monitoring studies of wetland mitigation projects are underway in Florida (e.g., Erwin 1985) which should help determine how closely created match natural conditions.

### Forested Wetlands--

The slow growth of woody species prevents rapid assessment of the success of creating forested wetlands, but there are indications that the techniques applied in Florida will be successful. As part of the 61 ha of wetlands created on the Agrico Swamp project site, 66,000 tree seedlings were planted. Twelve species were represented. The most abundant species included, cypress (Taxodium distichum), Florida red maple (Acer floridium), loblolly bay (Gordonia lasianthus), black gum (Nyssa sylvatica), sweetgum (Liquidambar styraciflua), and Carolina ash (Fraxinus carolinia). Seedlings were planted on about 2-m centers by hand in the summer and fall of 1982. Survivorship was 72% in 1982, 77% in 1983, 72% in 1984, and dropped to 58% in 1985 following a drought (Erwin 1985). Growth of some species was apparently enhanced when water levels during the wet season did not exceed 20 cm (Best and Erwin 1984).

Gilbert et al. (1980) reported on the success of planting 10,400 seedlings representing 16 species. After the first year, survival was 85% for cypress and green ash (Fraxinus pennsylvanica), 72% for sweetgum, and 62% for red maple (Acer rubrum).

Clewell (1981, 1983) also had tree seedling survival in excess of 70% while creating a riverine forested wetland in central Florida. Mechanical planting of potted, nursery-grown seedlings increased efficiency and enhanced survival, but may not be feasible, depending upon the substrate. Direct seeding may also be possible, but germination and survival rates are lower. Clewell (1983) suggested that enclaves of saplings could be established through transplanting to provide shade for shade-tolerant species. A combination of seedlings, saplings, topsoil, and natural colonization were recommended.

## Fauna

Studies of faunal communities on reclaimed phosphate mines have been less common than studies of vegetation. Erwin (1985) reported that 56-62 taxa of macroinvertebrates were collected seasonally in open water, submergent, and emergent wetland communities for an annual total of 107 taxa. A total of 83 bird species were recorded on the same 148 ha site. Use of clay settling ponds by waterfowl and shorebirds has also been reported (Montalbano et al. 1978). King et al. (1985) provide extensive recommendations for enhancing fish and wildlife habitat on both wetland and upland mine sites in the phosphate region. To maximize fish and wildlife diversity, they suggest the creation of heterogeneous physical and vegetative habitats among a diversity of aquatic systems.

## WETLANDS AND WATERBODIES ON SAND AND GRAVEL MINES

As many of the recommendations discussed for coal and phosphate mining apply to sand and gravel, only those techniques that differ will be included in this section. Mining of mineral sands for rare metals (e.g., rutile, zircon) is a unique type of sand mining. Although most prevalent in Australian coastal zones, the wetland restoration techniques developed by this industry also warrant inclusion in this section (e.g., Brooks 1987, 1988).

### Basin Morphometry

Most authors recommend increasing the area of wetland basins, and having a heterogeneous shoreline. Slopes with a horizontal to vertical ratio as gentle as 10:1 or 20:1 are recommended to increase the zone widths of plant communities (Street 1982, Crawford and Rossiter 1982). Water-level control devices are encouraged to allow optimal management of vegetation.

### Soils

The addition of topsoil to pit floors was recommended where plant colonization is desired (Crawford and Rossiter 1982). Leaving some areas bare will meet the foraging requirements of wading birds and shorebirds (Lomax 1982), and the spawning needs of fish (Herricks 1982). The bare zones should have a variety of particle sizes as substrate to meet the specific needs of various species. Compaction of bottom material is an effective means to discourage volunteer plant species. In newly reclaimed sites, organic matter is often lacking, so straw or hay can be added as food and substrate for both plants and invertebrates; 1 kg/m$^2$ of straw was suggested by Street (1982). Nutrients are often lacking as well, so fertilizing may be necessary. Stabilization of upland banks and surrounds is also emphasized to reduce erosion and sedimentation (Branch 1985).

Brooks (1987, 1988) identified three major factors that enhanced the recovery of both herbaceous and woody vegetation after mining for mineral sands. First, basin morphometry must be reclaimed properly to provide suitable drainage patterns and water-level control. Second, the use of drains before and after mining under saturated conditions facilitated the establishment of seedlings by avoiding excessive drying or flooding. Drains were removed once the plants adapted to the variable water regime. Third, careful manipulation of existing topsoil enhanced the survival of propagules of native species. A "double-stripping" method was used. The upper 20-25 cm was removed and stockpiled in large lumps. A second layer that was 10-15 cm deep was stockpiled separately. Topsoil layers were returned in their original order after mining. Storage time was usually 1-3 months. This additional care later reduced planting costs during reclamation. Other recommendations for enhancing restoration of vegetation and fauna were similar to those discussed for coal and phosphate.

## CONCLUSIONS AND RESEARCH NEEDS

There are examples throughout the U.S. and other countries of innovative approaches to successful restoration and creation of wetlands during mine reclamation, however, specific guidance applicable to different physiographic regions is still needed. The recommendations presented in this chapter should provide the basis on which to build a mitigation plan for a specific project. We are still in a rapid learning phase in restoration technology, and thus, must be open to new ideas and willing to experiment with innovative methods.

Managers need to move away from easily constructed geometric shapes and must attempt to create landforms that mimic natural systems. Overly engineered designs with specifications that are difficult to meet are not appropriate given the nature of biological systems and the current level of understanding in restoration technology. Designs and plans must be flexible to allow room for error and unpredictable events. Regulatory reform may be necessary to allow this flexibility to occur.

One way to ensure that the proper information is collected is to require mandatory monitoring programs of all wetland mitigation projects. It is suggested that a 3-year monitoring period be part of the known costs to a permittee before a project gets underway (e.g., Brooks and Hughes 1987). Short-term monitoring of individual sites coupled with a few long-term research projects will enhance our ability to predict the outcome of mitigation policies. As there is some scientific evidence for the stabilization of emergent marsh systems after 3 years (e.g., Erwin 1985, Hepp 1987), a 3-year period will allow evaluation of the project's success after three growing seasons. Also, some annual variability in climatic and growing conditions can be assessed during this time period. Finally, a modest 3-year monitoring plan does not put an unbearable economic burden on the permittee.

Long-term studies should seek to improve our predictive capabilities regarding the seasonal, annual, and successional variation inherent in most wetland systems. How do fluctuating water levels influence the composition and abundance of floral and faunal communities? What is an acceptable load of pollutants for a wetland to absorb before significant changes are observed in food webs and the health of individual organisms?

A number of studies have used comparative approaches to gain insight into how to replicate the functions of natural wetlands. Pre-mining and post-mining studies are valuable, as are comparisons between natural and restored systems, the latter being quite scarce (e.g., Brooks and Hughes 1987, Brooks 1988). Land managers need to establish their mitigation policies in the context of what changes are occurring in wetland types throughout a given physiographic region, not just on a particular mine site. In some regions (e.g., glaciated) wetland restoration has a greater chance for success because of inherent water and soil characteristics. Thus, what may work well for one area, may fail in another.

Based on this survey of the literature, it appears that the techniques appropriate to restoration and creation of simple open water and emergent marsh wetlands are fairly well established. The success of shrub and forested wetland projects, because of their slower rates of succession, has been more difficult to assess, and therefore, needs more attention. Questions remain with regard to plant materials: Are the proper propagules available? What is the best mix of native and exotic species to use? How do we balance the variable success of different planting methods against economic realities? How adept are we at predicting the successional outcome of a newly restored wetland system?

Success criteria for wetland mitigation need to be established. I do not believe, however, that satisfactory criteria can be developed on a national scale. Criteria necessarily vary with the type of wetland being established (e.g., tidal mud flats vs. freshwater emergent marshes vs. evergreen forested swamps). They also vary with the differential pressures placed on wetland resources within a region. For some wetland types, we may not yet know how to characterize their hydrology or biotic diversity, let alone satisfactorily replicate them.

At the current level of knowledge, it is ludicrous to demand 100% replication of species richness and abundance for all projects, but what are the minimum standards for replacing equivalent functions? Allowances must be made for variable growth patterns among floral species and for seasonally and annually fluctuating hydrologic regimes. Naturally occurring changes in wetland characteristics are commonplace. How will these changes be assessed, and then applied to a mitigation project? As with many environmental regulations, success criteria must evolve incrementally as new information becomes available. In time, a broad criterion such as "establish locally-occurring plant species" will be replaced by quantitative specifications for designated species arranged in suitable patterns on the landscape.

An interim solution is to establish regional success criteria for major wetland classes through consensus agreement among knowledgeable individuals (e.g., academics, regulatory scientists, industrial researchers, professional consultants). These criteria should be compatible with regional mitigation policies that are established by even broader representation from the community (i.e., planners, administrators, politicians, citizen's groups, business and industry leaders). Dames and Moore (1983) used a questionnaire sent to phosphate mining companies to gather opinions regarding success criteria for wetland restoration projects. Combined with information from regulatory authorities, this type of survey could form the basis for establishing success criteria for any physiographic region.

More attention must be placed on how to decide among multiple objectives for a given mitigation project. When are the utilitarian functions of wetlands (e.g., water supply, water treatment) to be substituted for in-kind replications of natural systems? Numerous authors suggested that planning and decision-making by consensus among scientific, industrial, regulatory, and citizen's groups is the appropriate strategy for establishing mitigation policy.

It needs to be mentioned that as wetland restoration technology improves, the mining industries will demand access to additional reserves. Therefore, the rationale for a particular mitigation strategy must have a sound, scientific basis if we are to successfully balance the needs of industry with the necessity of wetland protection.

# RECOMMENDATIONS

## PLANNING

1. Develop site-specific objectives that are related to regional wetland trends. Check for potential conflicts among the proposed objectives.

2. Wetland mitigation should be integrated with mining operations and reclamation plans at the beginning of any project, especially with regard to hydrologic plans for the site.

3. Project planning and evaluation should include input from trained professionals and local constituencies.

4. Mitigation plans for single wetlands should be related directly to the adjacent waterbodies and uplands. Be cognizant of regional trends and needs.

## IMPLEMENTATION

1. Designs for wetlands should mimic natural systems and provide flexibility for unforeseen events.

2. The key elements to successful wetland restoration and creation are basin morphometry and hydrologic control. Assess these parameters first before specifying requirements for soil preparation or establishment of floral and faunal communities.

3. Varying the areas of the wetlands and waterbodies constructed between 0.5-10 ha will meet the needs of many species, as well as human users.

4. Bank slopes and basin bottoms should be varied with emphasis on gentle slopes and irregular bottoms unless dictated otherwise by project objectives.

5. A heterogeneous shoreline is recommended to increase habitat diversity. Extensive littoral zones should be encouraged.

6. A capability to regulate the hydroperiod using water-level control structures is highly recommended.

7. The addition of upland or hydric topsoil provides a good substrate for plant growth, serves as a source for seeds and propagules, and reduces moisture loss of exposed substrates.

8. An integrated approach to establishing vegetation that incorporates direct seeding, transplanting, "topsoiling or mulching", and natural colonization can increase plant diversity and survivorship at a reasonable cost.

9. Revegetate exposed substrates rapidly, preferably with native species. Vegetative buffers around wetlands and waterbodies are essential.

10. Diverse vertebrate and invertebrate communities will colonize newly restored wetlands if basin morphometry and vegetative communities are suitable.

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# MITIGATION AND THE SECTION 404 PROGRAM: A PERSPECTIVE

**William L. Kruczynski**[1]
*U.S. Environmental Protection Agency*
*Region IV*

***ABSTRACT.*** Although the basic language of Section 404 of the Federal Water Pollution Control Act Amendments of 1972 has not changed substantially since the Program's inception, the Program has evolved through revisions in U.S. Army Corps of Engineers (Corps) Regulations and Environmental Protection Agency (EPA) Guidelines, and the judicial history of wetland case law. Compensatory replacement mitigation appeared early in the program as an attempt to replace loss of wetlands, at least on paper. It appeared in projects for which federal commenting agencies chose not to dispute issuance of a Corps permit.

The EPA and the Corps are currently negotiating a joint mitigation policy, but there remains a difference of opinion between the agencies concerning how mitigation should be considered in the permitting process. It is EPA's position that the presumption that there are alternatives to the destruction of wetlands cannot be overcome by the applicant's promise to create new wetlands. However, compensatory replacement mitigation may be appropriate for projects for which there are no practicable alternatives and all appropriate and practicable minimization has been required. There are three categories of proposed projects, those for which impacts are: (1) significant regardless of proposed mitigation, (2) significant unless sufficiently offset by mitigation, and (3) not significant. Consideration of the role of compensatory mitigation for projects which are not immediately rejected from further consideration because of the magnitude of the environmental losses must be made on a case-by-case basis.

## INTRODUCTION

Compensatory replacement mitigation is the attempted replacement of the functions and values of wetlands proposed for filling through creation of new wetlands or enhancement of existing wetlands.

In order to better understand the ongoing controversy concerning the role of mitigation in evaluating Section 404 permit applications, it is necessary to discuss briefly the history of wetlands mitigation and the role of the Section 404 (b)(1) Guidelines in the permit application review process. This discussion will demonstrate how the inappropriate application of mitigation to projects can transform a straightforward review procedure into a complex and confusing analysis based more upon perceptions than scientific principles.

## HISTORY

A review of the legislative and judicial history of the Section 404 program is given by Liebesman (1984, 1986), Want (1984), and Nagle (1985). Section 404 was enacted as part of Public Law 92-500, The Federal Water Pollution Control Act Amendments of 1972 (FWPCA), to control pollution from discharges of dredged or fill material into waters of the United States. Although the Environmental Protection Agency (EPA) is responsible for administration of the Clean Water Act, Congress authorized the Secretary of the Army, acting through the Corps of Engineers, to issue permits under Section 404, since that agency had been regulating dredging and placement of structures in navigable waters under the Rivers and Harbors Act of 1899. However, Congress, in Section 404(b), directed the EPA, in conjunction with the Corps, to develop

[1]The views expressed in this chapter are the author's own and do not necessarily reflect the views or the policies of the Environmental Protection Agency.

the environmental standards, known as the Section 404(b)(1) Guidelines, for the program. Nothing in Section 404 of the FWPCA delineated the role of the Guidelines in the permit review process, but Congress clearly intended that the Guidelines should provide environmental criteria by which to judge the suitability of disposal sites. In addition to the Guidelines, Congress, under Section 404(c), gave EPA the authority to prohibit, withdraw or restrict the specification of a 404 discharge site. This authority, which is known as a 404(c) "veto", can be used by EPA to prevent the unacceptable adverse impact of a 404 project.

On September 5, 1975, EPA, after consultation with the Corps, published in interim final form, the Section 404(b)(1) Guidelines, which established regulatory considerations and objectives to govern decisions concerning issuance of Section 404 permits. These considerations included avoiding discharges that disrupt aquatic food chains and destroy significant wetlands, avoiding degradation of water quality, and protecting fish and shellfish resources. These regulations also set forth a presumption that a permit will not be granted for work in a wetland unless the applicant clearly demonstrates that, for non water dependent projects, there are no less environmentally damaging, practicable alternatives available.

In 1977, Congress amended the FWPCA through passage of the Clean Water Act (CWA). Although sections were added to Section 404 to exempt certain discharges, such as normal agricultural and silvicultural activities, and to establish procedures for transfer of the program to the states, Congress did not change the basic outline of the program which had evolved through Corps Regulations, EPA Guidelines and judicial review.

From 1977 through 1980, there was little conflict between the Corps and EPA in implementing the Program. Although the Corps initially wanted to restrict the extent of its geographical jurisdiction, the Corps complied with a court ruling (NRDC vs. Callaway) and issued revised Regulations on July 19, 1977, which expanded the definition of "waters of the United States" to include wetlands. The Regulations declared that "wetlands are vital areas that constitute a valuable public resource, the unnecessary alteration or destruction of which should be discouraged as contrary to the public interest". The Corps Regulations also reiterated the presumption against filling wetlands for non water dependent projects as stated in the 1975 EPA Guidelines. The Corps proposed that each District Engineer consult with the U.S. Fish and Wildlife Service (FWS), National Marine Fisheries Service (NMFS), Soil Conservation Service, EPA, and state agencies in reaching a decision on whether "the benefits of a proposed alteration outweigh the damage to the wetland resource" and whether "the proposed alteration is necessary to realize those benefits". This has been called the Corps' public interest review. The District Engineer also had to "consider whether the proposed activity is primarily dependent on being located in, or in close proximity to, the aquatic environment and whether feasible alternative sites are available". The Corps Regulations place the burden of proof on the applicant to provide information on the water dependency of a project and evaluation of alternative sites.

The EPA promulgated revised Guidelines on December 24, 1980. These Guidelines reiterated the water dependency tests and presumption against alteration of wetlands found in the 1975 interim Guidelines and the 1977 Corps Regulations. The Guidelines also expanded these presumptions to include special aquatic sites which include sanctuaries and refuges, wetlands, mudflats, vegetated shallows, coral reefs, and riffle and pool complexes. These Guidelines establish a fundamental premise that "the degradation or destruction of special aquatic sites ... may represent an irreversible loss of valuable aquatic resources" and that "dredged or fill material should not be discharged into the aquatic ecosystem, unless it can be demonstrated that such a discharge will not have an unacceptable adverse impact".

The binding, regulatory nature of the Guidelines was emphasized in the 1980 Guidelines because some Corps Districts were issuing Section 404 permits for non water dependent activities when there were less environmentally damaging alternatives. Prior to 1982, when EPA, FWS, or NMFS objected to issuance of a Corps permit, the objecting agency could elevate the permit decision to higher authority. In Region IV during the mid and late 1970's, the threat of elevation of a District Engineer's decisions was usually enough to result in modification, withdrawal, or denial of permit applications for environmentally unacceptable projects. Few permits were elevated each year to Corps Divisions and fewer yet were elevated to the Office of Chief of Engineers, Washington, D.C.

In 1981, the President's Task Force on Regulatory Relief targeted the Section 404 Program for reform. This reform effort seemed to question, among other things, the extent to which the EPA Guidelines should be treated as binding and regulatory. The Corps issued new Regulations as a regulatory relief measure in July 1982 in interim final form. The intent of these Regulations was to expedite the permit issuing process and expand the nationwide permit program.

In July 1982 the Corps revised the memoranda of agreement MOA with EPA, FWS, and NMFS regarding elevation of permit decisions. The new MOA's stated that only specific, higher level, officials of those agencies could request elevation and that the Assistant Secretary of the Army (Civil Works) had the sole discretion to grant such requests. As a result, federal agencies charged with protection of natural resources were less able to influence Corps permitting decisions. Because of shortened processing time, increased workloads, logistics, and interagency politics, compensatory replacement mitigation was frequently used in some parts of the country to resolve differences of opinions between federal agencies concerning the "public interest review". Other Corps Districts issued permits over agency objections without any mitigation. Consideration of compensatory mitigation appearance in permitting decisions was seemingly justified by some promising results in wetland creation projects which had appeared in the scientific literature.

Since the inception of the Program, various factors made compensatory replacement mitigation a popular option in the federal permitting process. The FWS and NMFS did not have any authority similar to the EPA veto authority under Section 404(c). Thus, as early as 1975 agencies would compromise their positions on a permit application as long as there was, at least on paper, no net loss of wetlands. Federal agencies recommended compensatory replacement mitigation, in part, due to EPA's hesitancy to use its 404(c) authority. Also, elevation of Corps decisions was difficult at best, even before regulatory relief measures were adopted. Some agencies may have rationalized that since the Corps, in some cases, would issue permits for projects which were non water dependent and which had practicable alternatives, replacement mitigation was a method of getting some environmental benefit in exchange for filling activities. Agencies within Region IV began writing letters in response to the Corps' public notices which stated that they would not object to permit issuance provided that a similar area of wetlands was created in exchange for the wetlands to be filled. Work in the mid and late 1970's seemed to show that certain wetland systems could be created by man; this was used as a further rationalization to support replacement mitigation. Response of agencies to Corps public notices which included a request for compensatory replacement mitigation became more common after regulatory relief measures were in place and were a clear signal to the Corps that agencies would not elevate permit decisions. A decrease in elevations assured the Corps that it could meet its goal of shortening processing time for permit applications. Commenting federal agencies, particularly after regulatory relief measures were in place, felt that they had "no practicable alternatives" other than to recommend that wetland losses be mitigated through attempted wetland replacement. "Mitigation" came to mean minimize adverse impacts regardless of alternatives, and when that cannot be accomplished, attempt to replace wetlands lost.

On the surface, requiring replacement mitigation seemed to be an equitable solution to a problem. However, the Section 404(b)(1) Guidelines were regularly being ignored in some regions when compensatory mitigation was offered. This was rationalized by concluding that any losses of fish and wildlife habitat and other wetland functions were replaced through attempted wetland creation. Also ignored was the hidden environmental cost of changing or altering existing habitats with values in their present states in hopes of improving these wetland values.

Consultants for applicants quickly adopted mitigation as a means of obtaining permits and undermanned and overworked agency review staffs were soon faced with many difficult decisions. In many cases, because there were little or no data upon which to base decisions, inconsistent recommendations were made concerning acceptable replacement mitigation, including buying and donating lands, mitigation banking, out-of-kind replacement, and off-site replacement. Typically, a permit for filling a wetland, for whatever reason, could be obtained if the applicant was willing to create a similar wetland by scraping down uplands to wetlands elevations and planting the area with appropriate species. There was little or no data available regarding the scientific capability of replicating many kinds of wetlands, particularly during the early years of the program. Also, little or no monitoring of wetland creation projects was required.

Although numbers fluctuated at first, it became standard practice in the southeastern United States to require replacement mitigation at a ratio of 1.5:1 on an acre for acre basis. Agencies rationalized that greater than 1:1 was justified because of the uncertainty of wetland creation and to compensate for the length of time that it would take to replace fully functional systems. Corps Districts in Region IV generally accepted this argument and included 1.5:1 mitigation as a condition to Corps permits.

Wetland creation practices developed concurrently with the regulatory history. Examples of some pioneers in the field on the Atlantic and Gulf Coasts include Savage (1972), Woodhouse, Seneca, and Broome (1972), Eleuterius (1974), Garbisch et al. (1975), and Lewis and Lewis (1978). At this same time, in response to growing environmental awareness and the increasing problem of acceptable disposal of dredged material, Congress authorized the Corps' Dredged Material Research Program in 1973. One of the primary efforts of that program was to assess the feasibility of developing habitats on dredged material substrate. Although research in wetlands creation originally began as attempts to stabilize dredged material and eroding shorelines, it soon developed in the 1970's into the business of planting wetlands in exchange for wetland acres permitted to be filled. A symposium which started modestly in 1974 as a "Conference on the Restoration of Coastal Vegetation in Florida" soon became a major scientific vehicle to demonstrate what kinds of mitigation for dredge and fill projects were available. The conference is now entitled "Conference on the Restoration and Creation of Wetlands" and is international in scope and interest. Initial successes of marsh creation projects in 1975 through 1978 were used as further justification of replacement mitigation for Section 404 permits.

Revised Corps Regulations, published in July 1982, provided little recognition of the regulatory role of the Section 404(b)(1) Guidelines in the review of permit applications for certain types of wetlands and contained Nationwide Permits for all dredge or fill activities in two categories of waters, isolated waters and waters above headwaters. The National Wildlife Federation challenged these Corps Regulations on several counts including the role of the Guidelines in the review process and the cumulative environmental impacts of the nationwide permits for activities in the two categories of waters. This suit was settled in February 1984 and the Corps agreed to promulgate new regulations which acknowledged, among other things, the regulatory nature of the EPA Guidelines. The Corps also agreed to establish acreage limitations for Nationwide Permits for isolated and headwater waterbodies. The Corps published revised regulations in October 1984 and again in November 1986. The primacy of the Guidelines in the Section 404 review process was settled and the Corps agreed that no permit can be issued unless it complies with the requirements of the Section 404(b)(1) Guidelines. A permit that complies with the Guidelines will be issued unless the District Engineer determines that it would be contrary to the public interest. This sequencing clearly and explicitly highlights the priority of the Section 404(b)(1) Guidelines in permitting decisions.

In 1985, the agencies negotiated new memoranda of agreement which reestablished a first stage elevation of permitting decisions to the Corps Division Engineers. In EPA's case a difference in interpretation of the Guidelines is one criterion by which a permit decision may be elevated.

In 1981, the FWS formalized its mitigation policy and included Guideline precepts (FR 456, 15:7644-7663). The policy also established "resource categories" which defines "significant impact" by delineating wetland types which receive different levels of review. Mitigation can be considered by FWS for proposals that:

1. Are ecologically sound.
2. Select the least environmentally damaging alternative.
3. Avoid or minimize loss of fish and wildlife resources.
4. Adopt all measures to compensate for unavoidable loss.
5. Demonstrate a public need and are clearly water dependent.

EPA and the Corps are currently working on a joint mitigation policy. However, as previously mentioned, there remains a difference of opinion between the agencies concerning if and when mitigation should be considered in the permitting process. The recent Attleboro Mall 404(c) case highlighted the differences of opinion between the Corps and EPA on the place of mitigation in the stepwise application of the Guidelines. Although it is beyond the scope of this document to discuss that case fully, it is important to recognize that the Corps position in this case was that if mitigation will theoretically offset the adverse impacts to wetlands with a net result of "zero impact", a permit applicant need not seek a less environmentally damaging alternative. Several other Corps Districts also appear to be taking this position on the application of mitigation in the review process. Conversely, a recent paper by Thompson and Williams-Dawe (1988) presents legal, scientific, and policy grounds to reject this interpretation of the Guidelines in the decision process. They state that the Guidelines support a sequential approach to mitigation and that mitigation cannot substitute for the alternatives test. The presumption that there are alternatives to destruction of a wetland cannot be overcome by the promise to reduce wetland destruction or create new wetlands elsewhere.

Thompson and Williams-Dawe (1988) state further that failure to follow the stepwise approach of review given in the Guidelines creates practical difficulties. For example, it has become commonplace to contemplate, "What acreage of created permanent waterbodies is adequate mitigation for filling of seasonally flooded wetlands for residential development?" Elaborate procedures such as the U.S. Fish and Wildlife Service Habitat Evaluation Procedures and the U.S. Department of Transportation Wetland Functional Assessment Technique, and other methods are available to answer such difficult questions. But proper application of the Guidelines may obviate the need to ask such questions in most cases.

# GUIDANCE ON THE APPLICATION OF THE GUIDELINES

The Section 404 Guidelines establish specific restrictions which require that no discharge should be permitted unless:

1. There are no less environmentally damaging practicable alternatives to the proposed plan. These alternatives are presumed for non water dependent activities in special aquatic sites.
2. The discharge will not result in a violation of the water quality standards, toxic effluent standards, jeopardize and endangered species, or violate requirements imposed to protect a marine sanctuary.
3. The discharge will not cause or contribute to significant degradation, either individually or cumulatively, of:
   a. Human health or welfare, water quality supply, fish, plankton, shellfish, wildlife, or special aquatic sites;
   b. Life stages of aquatic life or water dependent wildlife;
   c. Aquatic ecosystem diversity, productivity or stability; or
   d. Recreation, aesthetics or economic values.
4. All practicable steps are taken to minimize adverse impacts.

During the evolution of the Section 404 program, and in accordance with the 404(b)(1) Guidelines, the fourth restriction includes compensatory replacement mitigation as a form of impact minimization. Historically, the role of replacement mitigation in the decision making process has been inconsistent and has resulted in confusion in the application of the Guidelines.

## ANALYSIS OF THE APPLICATION OF THE GUIDELINES

Since EPA and the Corps are seeking to develop a joint policy on mitigation, it is therefore premature to give a definitive statement on the role of mitigation in the application of the Guidelines. Thus, the following discussion is an analysis of the author's interpretation of the application of the Guidelines in the review of a permit application.

For many years, EPA has publicly taken the position that mitigation should occur in the sequence of avoidance first, then minimization and, lastly, compensation of unavoidable impacts. EPA considers these specific elements to represent the required sequence of steps in the mitigation planning process as it relates to the requirements set forth in the 404(b)(1) Guidelines. A review of a proposed permit's acceptability under the Guidelines should follow a sequence of events: (1) avoidance [Section 230.10(a)], (2) impact minimization [Section 230.10(d)], and finally, (3) compensation by techniques such as restoration and creation [Subpart H]. The highest level of mitigation appropriate and practicable (as practicable is defined in the Guidelines at Section 230.3) should be achieved at a given step prior to applying techniques in the next step.

In light of the above, compensatory mitigation of wetlands should not be considered in the initial analysis. That analysis should be confined to a consideration of alternative sites or designs, construction methods, or other logistical considerations. If all impacts cannot be avoided, other forms of minimization can be factored into a determination of whether there are less environmentally damaging alternatives. If an applicant fails to demonstrate that there are no practicable, less environmentally damaging alternatives to the proposed action, the applicant fails to meet the test of the first restriction even if the applicant proposes to replace the wetlands intended for filling.

Both minimization of impacts and replacement of wetlands could be factors in determining whether a project passes the second restriction. For example, a project which would result in a violation of a water quality standard, such as turbidity, could be redesigned to reduce the size of the project or treat runoff, and these modifications could result in meeting the standard. It is possible that wetlands created to compensate for wetlands unavoidably lost through filling could also be part of the treatment system.

There is general agreement concerning the relationship between the third and fourth restriction concerning minimization of impacts. It is conceivable that impacts could be minimized to a level which is no longer considered significant. Thus, as proposed impacts of a project are reduced, the significance of the impacts can be reevaluated and, if found acceptable, a project could be determined to comply with the Guidelines. Appropriate and practicable compensatory mitigation will be required for unavoidable adverse impacts which remain after all other appropriate and practicable minimization has been required.

However, there have been different interpretations on the role of compensatory mitigation in the test of significant impacts. The underlying reason for conflicting opinions on this matter is the lack of a standard definition of what constitutes a "significant" impact. There are good reasons for the lack of a standard definition of "significant" since the determination must be made at a local or regional level because of differences in the sensitivity of habitats nationally. Because of the uncertainty regarding the success of compeatory mitigation, a cautious approach should be taken in reaching a finding of no significant degradation based on this type of mitigation. Further, there are some wetland habitats in which any filling would result in significant degradation regardless of the apparent example, it is inconceivable that filling for residential development could be allowed in a vast area of fully functional Everglades wetlands or a pristine intertidal red mangrove swamp. Wetland habitats can be, and indeed have been, ranked locally or regionally and some of these listings provide notice of habitats in which any filling activity would be considered to be significant.

## CONCLUSION

In summary, consideration must be made on a case-by-case basis of the role of compensatory mitigation for projects which are not immediately rejected from further consideration, because of the magnitude of the environmental losses they pose. Discharges into wetlands can be significant regardless of mitigation, significant unless offset through mitigation, or not significant. The second category is most complex. For projects in this category, consideration of whether a proposed mitigation plan will actually prevent the significant impacts from occurring must be carefully evaluated. Factors to be considered in making this determination are considered in the next chapter.

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# OPTIONS TO BE CONSIDERED IN PREPARATION AND EVALUATION OF MITIGATION PLANS

William L. Kruczynski[1]
*U.S. Environmental Protection Agency*
*Region IV*

*ABSTRACT.* Consideration of compensatory mitigation should be confined to projects which comply with the Environmental Protection Agency's Section 404(b)(1) Guidelines. The complexity of designing a successful mitigation plan is due to specific characteristics of many types of wetlands and the many options available at mitigation sites. The types of compensatory mitigation, in order of preference, are: restoration, creation, enhancement, exchange. Preservation should only be considered when the ecological benefits of preservation greatly outweigh the environmental losses of an unavoidable filling activity.

A methodology based upon rating of the options is presented to aid in the selection of an acceptable mitigation plan. In general, on-site, in-kind, up-front mitigation is the preferred option. However, other options may be acceptable based upon availability of sites, plant material, and other variables. The proposed methodology should be used as a guide and not as the only criterion in decision making. Monitoring of mitigation sites is essential to demonstrate creation of functional wetland systems.

## INTRODUCTION

This chapter will discuss the advantages and disadvantages of compensatory mitigation options which are available for projects which receive Section 404 permits. This guidance is based upon my experience. It is intended for both preparers and reviewers of mitigation plans. This analysis is proposed for use as part of the analytical framework for evaluating proposals to mitigate the environmental losses of dredge and fill projects. It is not meant to be a step-by-step approach to selecting the most desirable mitigation option. Development of such an approach would be difficult since the site specific characteristics of the wetland community which will be lost and the available mitigation sites and options cannot be anticipated. Discussion is confined to compensatory mitigation and assumes that a project meets the Section 404(b)(1) Guidelines. Examples given in the text to illustrate specific points reflect the author's knowledge of ecosystems in the southeastern United States, but the conclusions and recommendations are intended to be generally applicable to wetland ecosystems. The recommendations in this chapter have not, at this time, been embraced in the form of formal Environmental Protection Agency (EPA) policy or guidance.

The complexity of designing a successful mitigation plan is due to specific characteristics of the many types of wetlands and the many options available for the manipulation of biotic and abiotic factors at mitigation sites. A brief discussion of the common mitigation options is given below. Factors have been arranged from very general to specific. This order reflects the recommended order in the decision process for preparing a mitigation plan.

## GOAL OF COMPENSATORY MITIGATION

The goal of compensatory mitigation should be consistent with the goal of the Clean Water Act which is "to restore and maintain the chemical, physical, and biological integrity of our Nation's

[1]The views expressed in this chapter are the author's own and do not necessarily reflect the views or policies of the Environmental Protection Agency.

waters". Replacement wetlands should be designed to replace all the ecological functions provided by the destroyed wetlands such as wildlife habitat, water quality, flood storage, and water quantity functions. Sometimes it is suggested that wetland functions can be provided with the successful regrowth of wetland plant species, but often special project designs, such as slope or channel characteristics or watershed area, are necessary to assure replacement of wetland functions such as flood storage. Monitoring of mitigation sites is also essential to demonstrate creation of fully functional compensatory wetland systems.

## PREPARATION AND EVALUATION OF MITIGATION PLANS

Preparation of mitigation plans is an exceedingly complex matter. Federal project managers are often forced to make difficult decisions based upon little or no specific information concerning expected or actual success rates or times necessary to achieve the full functions of created communities. Lack of information is due to either the historical lack of environmental monitoring associated with mitigation efforts or poorly designed monitoring programs for new projects. There are several ongoing efforts to revisit sites where wetlands creation mitigation projects have been attempted as a condition of issued Corps permits. For example, mitigation sites in Florida and in New England are being studied by the Corps of Engineers Waterways Experiment Station. However, there are few published follow-up studies of mitigation sites, and the lack of detailed studies of many community types necessitates a cautious approach concerning decisions on anticipated values of created wetlands.

EPA or U.S. Army Corps of Engineers (Corps) project managers may also not have the broad scientific background or field experience to design mitigation plans for any or all of the many types of wetland systems which exist in each region. In addition, as a matter of policy, the federal agencies are not environmental consultants; design of a project should carry with it assurance of success, and the burden to assure success should be completely on the applicant and his technical consultants. However, while federal project managers should guide applicants through this process, federal agencies should require that applicants prepare and submit detailed mitigation plans for review, rather than actually aiding them in the preparation of plans. Initial input by federal agencies should be limited to generic considerations pertaining to community type, suitable sites, area, source of water, slopes, and watershed size and position.

The complexity of preparing mitigation plans is due to the plethora of options concerning factors such as availability of plant materials, genetic compatibility of stock material with local populations and environmental conditions, handling of plant material, planting schemes, slopes, water depth and periodicity, soils, and fertilization rates. Seasonal timing of planting, flooding and fertilization may be critical to the success of mitigation projects. It would be very unusual for a land owner or developer to have the technical background to personally plan or undertake even a small scale mitigation project. Good intentions alone do not assure mitigation success. Thus, it is recommended that all replacement mitigation be performed by a qualified environmental consultant.

Currently, there are no restrictions on who may call themselves environmental consultants or mitigation specialists. Thus, it is very important that applicants examine the credentials of companies or individuals who may bid on compensatory mitigation projects. Reputable firms which have a long, established record of success in mitigation should be qualified to discuss options which have worked in the past and will be able to give accurate cost estimates. Environmental consultants should be encouraged to publish brochures which list and illustrate their successful and unsuccessful projects. It has been recommended that a national or regional certification process be adopted for environmental consultants specializing in compensatory mitigation. Such a process, modeled after the certification process for professional engineers, has been initiated in Florida. Choice of capable, certified environmental scientists with regional knowledge would reduce the frequency of mitigation projects doomed to failure due to improper planning and design.

# TYPES OF COMPENSATORY MITIGATION

There are three basic types of compensatory mitigation which are available as options to replace wetlands lost to dredging and filling activities: restoration, creation, and enhancement (Table 1). The following discussion will demonstrate that restoration and enhancement are part of a continuum which can be extended to include a fourth and least desirable mitigation option, namely wetland exchange.

Wetland restoration refers to the reestablishment of a wetland in an area where it historically existed but which now performs no or few wetland functions. Disturbance of historic wetland functions could be due to human activities, such as filling, channelization, or eutrophication, or due to natural events such as lake level rise, shoreline erosion, sediment deposition, beavers, or decreased flooding. Typically, wetland soils remain at disturbed sites, but they might be drained, oxidized, or buried.

Wetland creation refers to the construction of a wetland in an area which was not a wetland in the recent past. Typically, wetlands are created by removal of upland soils to elevations which will support growth of wetland species. Removal of soils to achieve proper elevation can, by itself, establish proper hydrology for wetland plants, such as along gently sloping shorelines, or may prepare the site to receive necessary inundation from streams or runoff from upland watersheds. Development of the correct elevation and establishment of a proper hydroperiod is the critical factor in the success of created wetlands. In an area where soils have been thoroughly disturbed, such as through surface mining, any replacement of previously existing wetlands must be considered creation. This is particularly true if the soil stratification and the surficial aquifer have been modified.

Enhancement refers to increasing one or more of the functions of an existing wetland, such as increasing the productivity or habitat value by modifying environmental parameters, such as elevation, subsidence rate, or wind fetch. Enhancement sites differ from restoration sites because they already provide some wetland functions. Enhancement implies a net benefit, but a positive change in one wetland function may negatively affect other wetland functions. The net overall result of enhancement depends upon established management goals. For example, the habitat value of a swamp forest can be increased for wood ducks by increasing the amount of open water. Increased flooding will provide more food for ducks and may kill less water tolerant trees and provide more nesting cavities. However, this type of enhancement may lower the value of the wetland for other species, such as the spotted salamander, deer, or marsh rabbit.

Enhancement taken to the extreme merely exchanges wetland types. For example, habitat value of open water may be enhanced for some species by establishing an emergent marsh or swamp forest on fill material placed in open water. This type of enhancement is more properly called exchange since it results in the replacement of one habitat type (submerged) with another (emergent). The net ecological value of this mitigation option depends upon acceptable management objectives. For example, a diverse forested wetland can be clearcut and planted with one tree species. If the planted species is a mast producer, it could be argued that the habitat value for deer or ducks has been enhanced. However, increased food for a few species has been accomplished through elimination of the complex food web of the swamp forest.

The choice of restoration, creation, or enhancement mitigation for any project depends upon the site specific characteristics of available locations. The choice should be based upon an analysis of factors that limit the ecological functioning of the watershed, ecosystem, or region. The first question to ask in reaching this decision is, "Are there degraded wetland communities on-site or nearby which could be restored to full function?" If there are, the first choice of mitigation options should be to restore historic wetland functions of the degraded system.

Restoration of degraded systems should be the first option to be considered since it would reestablish the natural order and ratio of community composition in the regional ecosystem. Moreover, likelihood of success of this type of mitigation is greater than for other options. If a portion of a particular community has been removed from an ecosystem through degradation, it would be ecologically beneficial to restore that same community back into the system. In some cases a sizable wetland area can be restored with little effort. For example, a wetland area which has been diked and drained through ditching to create a pasture may be returned to a functional wetland through removal of all or part of the dike which separates it from flood waters. Because a wetland previously existed on the site, and provided that the soils are still intact, albeit drained, the chances of success of restoring this area to a fully functional wetland are good once the hydrology is reestablished. If the organic component of the soils has substantially oxidized,

Table 1. Compensatory Mitigation Options.

| Compensatory Mitigation Options | | | |
|---|---|---|---|
| MITIGATION TYPES | | | RECOMMENDED ACREAGE |
| Restoration | – | former wetland, no or few functions | 1.5:1; 1:1 upfront |
| Creation | – | made from different community | 2:1; 1:1 upfront |
| Enhancement | – | increase certain functions | 3:1; 1:1 upfront |
| Exchange | – | enhancement to the extreme | case by case |
| Preservation | – | purchase and donation | case by case |
| TIMING OF MITIGATION | | | |
| Before | – | most prudent; require if unknowns | |
| Concurrent | – | encouraged for typical projects | |
| After | – | discouraged | |
| LOCATION OF MITIGATION | | | |
| On-site | – | same locale in watershed or ecosystem | |
| Off-site | – | different locale or different ecosystem | |
| COMMUNITY TYPE | | | |
| In-kind | – | same species | |
| Out-of-kind | – | different species | |

resulting in subsidence, reflooding of the area may create an open water lake, rather than an emergent wetland.

Restoration grades into enhancement depending upon how many functions have been removed from the ecosystem. A previously wet area which was historically filled may be restored to full wetland function by grading, planting, and restoring the historic hydrological regime. If the wetland had been partially degraded and had lost one or several of its functions, the area could be enhanced to provide full wetland functions. For example, a wetland which has been impounded, retains wetland vegetation, and is managed for ducks, could be enhanced by removing the impoundment dike. This would reestablish a seasonally flooded wetland which provides pulsed export of organic matter to food chains of receiving waters.

It could be argued that the duck impoundment itself was an enhanced wetland since it produced a significantly greater duck population than unimpounded wetlands. But it can only be considered enhanced for that one function, namely duck habitat. It has lost its function to provide detritus on a timely basis for fishery food chains because of its altered hydroperiod. Thus "enhancement" often reflects little more than preference for certain habitat types or values over others.

Another example of wetland habitat exchange is establishment of an emergent marsh on fill material placed in open water. This has been called marsh creation in the past. It also enhances the primary productivity of an area; but, it is an exchange of one functional habitat type for another. Because it results in a loss of functions of existing aquatic habitats, exchange should often be the last option in the choice of mitigation type. Exchange should only be used when there is ample scientific evidence demonstrating that the functions of an ecosystem or region are limited by the lack of a particular community type. For example, exchange may be the option of choice if data demonstrate that the fisheries productivity and ecological stability of an embayment would be significantly increased by establishing a fringe marsh along an unvegetated shoreline and shallow water habitat.

If restoration of a degraded wetland is the first option, and wetlands exchange is the last option and should only be used when scientifically justified, then enhancement and creation are intermediate options. There are good ecological arguments for consideration of wetland creation before wetland enhancement since the former will add to the total wetland area of a site, while the latter may only provide one or more additional functions to an existing wetland. Thus, a logical and defensible order of consideration of the types of compensatory mitigation is: restoration, creation, enhancement, and exchange. This order of preference may be different for a specific mitigation project in light of regional or site specific circumstances, such as quality of wetlands and availability of mitigation sites.

Preservation of existing wetlands through acquisition should not normally be considered as compensatory mitigation for unavoidable wetland losses since there is a net loss of wetland functions and acreage, and wetlands proposed for preservation are usually already regulated through the Section 404 program and provide ecological functions to the public. However, there could be circumstances of such an unusual character that would justify wetland preservation as a mitigation option. For example, if the environmental effects of the proposed filling are very minimal and the benefits of placement of a large area of wetlands (and/or uplands) into public ownership are great, then preservation may be consistent with the goals of wetland protection although some loss may result. This is particularly true if an area proposed for preservation is unique habitat, subject to general or nationwide permitting, or otherwise vulnerable to development. Any agreement for preservation of existing wetlands should explicitly indicate that the preservation shall be required in perpetuity and shall provide assurance for this requirement through an appropriate method such as fee title conveyance to a well established, responsible conservation organization.

Preservation of a large, mixed community might also be an attractive option if, without such preservation, the full functioning of a system could be destroyed through unregulated development of upland portions of an upland-wetland mosaic, such as a bottomland forest mixed with upland bluffs and stands. Loss of upland habitat corridors, edge, and ecological niches could result in the degradation of the functioning of the entire ecosystem, particularly for larger animals, such as black bear. If the ecological benefits of preservation greatly outweigh the environmental losses which will occur in permitting an unavoidable wetland fill, then preservation through acquisition may be considered.

Some have argued that preservation should be considered as a prime mitigation option since it places wetland areas which might be lost through future permit actions or by the dissolution of the federal permitting program, into public ownership or control. Most indications are that the Section 404 program will be strengthened as permitted losses of wetlands cumulatively result in decreased fisheries production and other losses to the national economy.

# CREDIT FOR COMPENSATORY MITIGATION

There is need for guidance to establish and maintain consistency between project managers and between EPA Regions and Corps Districts concerning acceptable ratios between wetland losses and compensation acreages for the different mitigation options. One approach is to require that the ecological functions of the replacement wetland be at least equivalent to those of the wetland proposed for destruction. Attainment of functional equivalency should be the goal of all mitigation activities. However, this approach may result in loss of wetland acreage and requires detailed knowledge of the ecological contribution that the destroyed and replacement wetland systems make to the regional ecosystem. Also, the ecological functions which are considered in the test of equivalency must be carefully chosen. Proposed replacement of a degraded wetland habitat by an improved wetland is another complication which requires thorough analysis. For example, if primary productivity is a major function of a wetland, establishment of less acreage of a very productive wetland may adequately compensate for the loss of more acreage of a low productivity wetland. However, the replacement wetland may provide much less habitat for a particular species than was provided by the destroyed habitat, despite overall improved productivity. Usually there is not enough information available to agencies to formulate scientifically valid, functionally equivalent replacement acreage within the processing period of a permit application. This information must be supplied by the applicant as part of the permit application if he expects the agencies to consider "functional equivalent wetland replacement" as a basis on which to issue a permit.

General ratios between mitigation options can be suggested as flexible guidelines to be considered in each permit decision requiring compensatory mitigation. The following ratios are suggested for on-site, type-for-type (in-kind) replacement mitigation. The analysis becomes more complex when variables such as off-site and out-of-kind mitigation options are considered. The analysis is further complicated by the many types of wetland communities, the varying success rates of community replacement, and the difficulty of justifying ranking and exchange of different wetland values.

## RATIOS FOR RESTORATION

In general, the chances of success in restoration of most destroyed herbaceous wetlands (e.g., marshes) is good because this type of wetland generally grows rapidly and because a wetland previously existed at the site. Restoration is a matter of removing the perturbations and reestablishing the soils, plants, and hydrology at the same site where a wetland was created by nature. Restoration (or creation) of forested streams or bottomland hardwood floodplains has been attempted, but is much more difficult. To date, no restoration projects are known which are of a sufficient age to have achieved a fully functional, self-reproducing system; most are under twenty years of age. Restoration (or creation) of submerged seagrass communities seems to be a "hit or miss" proposition with little documentation concerning specific environmental conditions needed for success.

Because of the varying rates of success of restoration of different vegetative communities, it is difficult to justify general criteria for acreage credit for restoration of all types of wetlands. Indeed, if it has not been demonstrated conclusively that restoration of a particular wetland community is possible, then the prudent approach is to reject any proposed replacement mitigation. If the ecological loss through filling of such a wetland is determined to result in significant environmental degradation, then filling of such a wetland is unacceptable. However, if it has been convincingly demonstrated that a particular wetland type can be restored, then 1.5 to 1 mitigation should be required on an acre-for-acre basis; that is, 1.5 acres restored for each acre unavoidably lost. The justification for requiring greater than parity is due to the uncertainty that a particular project will be successful and to compensate partially for the length of time that the restored, planted wetland system takes before becoming fully functional. Planting of the restored system is required unless it can be conclusively demonstrated that a natural colonization will result in the vegetative community of choice.

The ratio of wetlands restored to wetlands lost can be reduced to 1 to 1 if wetland restoration is performed "up front", that is before a filling activity is initiated. Reduction of the ratio to parity assumes that a replacement wetland has been constructed and monitored according to an approved plan and that it has been found to be fully functional. Reduction of the ratio to 1 to 1 might also be justified if data demonstrate that the restored site will provide increased ecological and hydrological value to the area.

## RATIOS FOR WETLAND CREATION

Wetland creation involves increased risk since it is an attempt to establish a new wetland at a site where one has never existed, or where the previously existing conditions which supported a wetland community have been greatly modified. Wetlands established on land which has been thoroughly disturbed, such as through surface mining, are created wetlands even if they occur on the same geographical sites as previously existing wetlands. Creation of wetlands from existing uplands is the common form of compensatory creation mitigation associated with dredge and fill permits. If it has been convincingly demonstrated that a particular wetland type can be created, then 1.5 to 1 or 2 to 1 mitigation ratios should be required on an acre-for-acre basis. Increasing the ratio to 2 to 1 can be justified on the basis of the greater risk associated with any particular site. The ratio may also be adjusted depending upon whether planting or natural revegetation is part of the proposal. If successful creation (i.e., similar value between created and natural wetland) is performed upfront of proposed filling, then the ratio can be reduced to 1 to 1.

## RATIOS FOR WETLAND ENHANCEMENT

Wetlands proposed for enhancement are performing wetland functions, and it will often be difficult to document net improvements to wetland functions. There is a risk that although some functions will be improved, other currently existing functions could be degraded. Due to this uncertainty, a 3 to 1 mitigation should be required on an acre-for-acre basis. This ratio can be lowered to 2 to 1 if it is performed upfront. It can never be lowered to parity since there was an existing wetland which provided some wetland functions at the site.

Wetland types should not be exchanged except under unusual circumstances. Since exchange is the replacement of one wetland type with another, it is, by definition, on a 1 for 1 basis. Gains in one wetland type cannot be equated with losses of another type since each performs different functions and are unique assemblages of physical, chemical and biological variables. To say that they are equal and that the exchange of one wetland type for another is acceptable is the same as trying to equate apples and oranges; they are judged by different sets of criteria. However, there may be unusual circumstances where one wetland type is particularly rare and one wetland type is particularly abundant; such circumstances could justify exchange of wetland types as compensatory mitigation.

## RATIOS FOR WETLAND PRESERVATION

Wetland preservation through acquisition should not be considered as compensatory mitigation except in unusual circumstances because a net overall loss in function and acreage will occur. It can also be argued that preservation through donation, conservation easements, restrictive covenants and the like is tantamount to purchasing a dredge and fill permit, and is limited to developers with sufficient capital to make the offer large enough to be attractive to regulatory agencies. Small landowners seeking an individual permit usually lack the land resources or capital to make such an offer. Thus, formalizing a policy or an exchange ratio justifying such an action is ethically and legally questionable.

# ECOLOGICAL COSTS OF COMPENSATORY MITIGATION

There must be a careful analysis concerning the ecological trade-offs associated with conversion of one habitat type to another. This analysis should consider the ecological value of non-wetland as well as wetland sites proposed for compensatory actions. An area proposed to be restored to wetlands or an area proposed for wetland creation may have ecological value in itself. For example, an upland pasture which was historically a wetland that was diked and drained may have become important habitat for terrestrial species, such as doves, quail, raptors, bears, or bobcats.

Unless there are unusual site-specific or regional circumstances, it is not justifiable to scrape down a functional hydric or mesic forest adjacent to an existing marsh to create equal or greater area of marsh in exchange for filling of another area. In a similar vein, an impounded marsh may provide habitat for wading birds or ducks in an area where there is little natural suitable habitat for these species. Restoration of such an impoundment to a seasonally flooded system would disrupt the community which has adapted to the existing conditions. The difficult question which must be answered in analyzing the ecological value of proposals of this sort is, "Do the ecological changes associated with habitat restoration, creation, or enhancement outweigh the overall ecological functions of the 'donor' community?" This question is hard to answer objectively because of the bias which exists for dwindling wetland resources. It also requires gathering and interpreting data for upland or disturbed wetland systems and dredge and fill project managers may have little or no experience in performing these analyses. Comparing existing ecological values with anticipated values of replacement systems is no easy task. This analysis should be performed by a team of experts representing a wide range of disciplines and expertise. The multi-disciplinary team of scientists and engineers at the Corps Waterways Experiment Station is an excellent model for interagency evaluation. They have published many studies evaluating created wetlands and comparing them to natural reference sites; their methods provide an excellent source for standardizing these comparisons.

The use of a "quantitative" methodology, particularly by inexperienced personnel, to solve this problem may only add to the confusion. For example, the Habitat Evaluation Procedures (HEP) of the U.S. Fish and Wildlife Service has often been used to calculate "habitat suitability indices" for sites. These indices are often biased. A HEP index is a numerical expression of the potential use of a site for a particular species of fish or wildlife chosen for evaluation. This measure of potential (quality) of a site for these species, when multiplied by area, yields the number of "habitat units", a numerical expression of the useful habitat within the study area. Habitat units can be used to compare different sites for chosen species and to calculate acreage of replacement habitat as mitigation for habitat lost through regulated filling.

HEP uses models which relate biological needs and tolerances of evaluation species to environmental conditions which occur in their habitats. These conditions are expressed as variables, such as water depth, flooding periodicity, vegetation density, and soil type. Through the use of formal, documented models, HEP provides "standardized" numerical expression of habitat suitability, and thus reduces variability due to subjective differences of opinion.

Because HEP appraises environmental value according to habitat suitability for particular species, the selection of species to be used in the evaluation is one of the most controversial parts of any study. The methodology can be easily misused with improper selection of evaluation species. HEP procedures advise forming an interagency team to select the species list, so that all constituencies can be represented. Those interested in maintaining or enhancing historic conditions commonly select the most sensitive (habitat limited) species in the community; others, wishing to modify or develop the site, select species most consistent with the proposed development or management plan. Moreover, since it is impossible to exactly duplicate a natural system, and since developers generally prefer to replace a wetland with a retention pond or lake, they usually prepare compensatory mitigation plans with different environmental conditions which will support a different species assemblage than exists at the "donor" site.

During a recent application of HEP in a seasonally flooded East Everglades wetland, a consultant chose such a list of species which may have historically existed at the site, but currently occur infrequently due to hydrological modifications to the wetlands. The HEP calculations yielded low habitat units for the chosen species under the existing conditions. The procedure was repeated for the habitat which would result when the site was developed as a residential area; development included several borrow lakes as enhancement (exchange) mitigation. Because of the different, "improved" hydrologic conditions, the HEP analysis concluded that development of the site would be ecologically beneficial (for the selected species).

The underlying premise of this conclusion was that management should optimize habitat for Everglade species which historically were more widespread than they are today, such as large-mouth bass and wading birds. The distribution of these species is limited by suitable hydrological conditions. However, the disruption of historic hydrological conditions in the East Everglades has also resulted in "disturbed" Everglades habitats which are wetlands, and are habitat for species other than wading birds and bass. Thus, the trade of many acres of disturbed Everglades, with the resultant loss of habitat for bobcats, raccoons, red tailed hawks, etc. for a residential community with a few acres of enhanced wetlands (borrow lakes), which would provide habitat for bass and wading birds, is not ecologically equitable. Yet the choice of HEP evaluation species supported that conclusion.

Regulatory agencies should be concerned with habitat restoration, such as restoring historic hydrologic conditions to the disturbed wetlands, instead of enhancement or exchange of a small portion of the wetlands through inappropriate mitigation associated with filling of a majority of the wetland area. Also, regulators should consider all aspects of habitat exchange and realize that advantages to the species of choice may not be balanced by impacts to other displaced species.

Another ecological cost which must be considered in preparing mitigation plans is the availability of appropriate plant material. Plant material may be collected from a donor wetland only if that action does not significantly degrade the ecological functions provided by the donor system. Vegetation plugs may be removed from a herbaceous wetland donor site and planted at a prepared mitigation site. But plugs should be harvested at sufficiently spaced intervals to maintain the functional integrity of the donor site.

If plant material is obtained from a commercial source, care should be taken to assure that the propagated plants are from a stock which is reproductively compatible and has similar ecological requirements as stands which naturally occur in the locale. A method which has recently been shown to be cost-effective in restoring or creating large wetland areas in some locales is mulching of a contoured mitigation site with the upper soil horizon from a donor wetland. This mulch contains viable seeds and rhizomes which usually allows rapid establishment of a diverse plant community. Proper application of this technique has been effective in creating or restoring both herbaceous and wooded wetlands. Appropriate tree species are planted in the mulched area, which provides effective soil, moisture, and shading for young trees. Choice of donor wetlands should be carefully controlled so that existing mature wetland systems are not avoidably lost in order to create other wetlands. It is preferable that this material be obtained from the wetland which is proposed to be impacted, and can be stockpiled for a short period if wetland replacement is not concurrent with alteration of the donor site.

## TIMING OF COMPENSATORY MITIGATION

Three options exist in timing of a mitigation project relative to receipt of a Section 404 permit. Mitigation can be performed before the permit is issued, concurrent with project initiation and completion, or after a filling activity is completed. Often an initial Section 404 permit is needed for the work performed as part of the mitigation project itself since dredging or filling in waters of the United States is usually required to restore, create, or connect the mitigation site to a source of water. Upfront mitigation is possible as a separate permit action or as part of a phased permit, with the receipt of the second phase, project construction, contingent upon successful completion of the first phase, demonstration of successful mitigation.

Upfront mitigation is the most prudent of mitigation timing options and should be required for all projects which have considerable ecological risks by virtue of their size, complexity, or uncertainty of community establishment at the mitigation site. For example, a permit was issued by the Corps to a mining company for the connection of two tidal creeks, which were constructed in uplands, with existing waters. These created systems were monitored and only when success criteria were satisfactorily met did the Corps process a permit application to mine across an equal acreage of natural, existing tidal creeks.

If mitigation cannot be completed in advance, it should proceed concurrent with project construction since mitigation becomes an integral part of the proposed project; this discourages viewing mitigation as an "add on" cost of receiving a Corps permit. However, a problem inherent in concurrent mitigation is the association of timing of the receipt of a permit and initiation of a project with the timing of maximum anticipated success rate due to seasonality of biological and/or hydrological factors. In general, early spring is the best time to plant most coastal herbaceous species, whereas optimum transplanting times for scrub-shrub or palustrine forested wetlands is during winter when plant material is senescent. Obviously, the Corps cannot refuse to process a permit application if it is received at a time of year when transplanting is not optimal. However, an issued permit can be conditioned to include a date for initiation of construction and mitigation which is consistent with maximum survival rates of transplanted material. Another option is to allow earth moving associated with project construction and mitigation to proceed simultaneously and delay planting of the site to conform with time of expected maximum survival rates.

Regardless of the time of the year when mitigation is initiated or completed, it is always advantageous to require a guaranteed survival rate of transplanted plant material with every mitigation plan. This is particularly important if the Corps issues a permit for project construction and the applicant performs the required mitigation during a time period when expected transplant survival is less than optimum. Typically in Region IV, a guaranteed survival of 70% of transplants after two years is requested. Replanting should be required until a 70% survival rate is obtained for one year. This requirement necessitates monitoring of the mitigation site.

Mitigation performed after a project is completed should be discouraged since it fragments the project into a construction phase and a mitigation phase. Once the construction phase of a project is completed, there is little incentive to complete the mitigation phase in a timely, satisfactory manner. If post project mitigation is the only practical option, the mitigation plan included in the Corps permit should always contain an initiation date and a completion date. If one or both of these dates are not honored, the Corps should be encouraged and supported to take enforcement action for violation of a permit condition. Post-project mitigation should be restricted to small projects which have a very high probability of success or for situations where project construction must be initiated before the time period when maximum survival of transplants is assured. Even then, the earth moving and other physical amenities necessary for preparation of the mitigation site for planting should be performed concurrent with the remainder of the project. A performance bond should be required from the developer for any mitigation project which has an uncertain chance of success.

## LOCATION OF COMPENSATORY MITIGATION

The goal of mitigation is to replace the functions which were provided by the wetland area and which were unavoidably lost through a permitted activity. Since the wetland area provides ecological functions such as food chain support or wildlife habitat to the ecosystem of which it is a part, it is important that ecological values of the replacement wetland be provided to the same ecosystem which was impacted by the filling activity. Thus, both on-site (same locale) and off-site (different locale) mitigation should usually be performed in the same ecosystem and functional watershed as the filled wetland area.

The problem with this rule is the difficulty of defining the limits of a particular ecosystem. Ecosystems may be conceived and studied in various scales. For example, an ocean, an embayment, a lake, a pond, or a small aquarium may be called an ecosystem. For our purposes, it is best to define ecosystem as any area of nature which is part of the same watershed which includes interacting living organisms and nonliving substances, and where there is an exchange of materials and energy.

Restoration, creation or enhancement of wetlands should, in most circumstances, occur on-site, that is within the same ecosystem and in the immediate vicinity of the proposed filling activity. For example, if a permit is issued for fill in wetlands to construct a boat ramp and mitigation is required, a disturbed area along the same reach of stream should be restored to wetland elevation to replace the functions which were lost. (Of course this assumes that it was not practicable to locate the boat ramp in an area of disturbed wetland.) There is adequate ecological justification for this approach since the ecosystem will remain unchanged and the chance of success of the mitigation is maximized since it is close to an area which already supports the vegetative community which is being replaced.

If there are no potential mitigation sites in the immediate area, off-site locations within the same embayment, stream reach, or watershed (ecosystem) should be selected. If a thorough analysis reveals that there are no adequate mitigation sites within these areas, this may be adequate reason to recommend that no permit be issued for the proposed activity.

Only in unusual circumstances should off-site mitigation in a different ecosystem or functional watershed be considered as acceptable mitigation. This is due to the difficulty in equating the impacts of the loss to one ecosystem with the advantages to another system. The burden of proof rests with the applicant to demonstrate that the anticipated advantages to the off-site area greatly outweigh any losses that would result through filling of a wetland site. For example, a proposal to mitigate filling of an intertidal marsh through creation of a forested wetland must contain data which supports the conclusion that the loss of intertidal marsh will not individually or cumulatively result in significant degradation to that portion of the coastline and that the created wetland will greatly improve the ecological functioning of the adjacent, riverine ecosystem.

Wetlands mitigation banking is an off-site compensatory mitigation concept which may be used to aggregate smaller wetland impacts towards restoration, creation, or enhancement of larger wetland mitigation bank sites. However, it also entails considerable legal, scientific, and administrative complexity and has the potential for being seriously misused. Therefore, due to the experimental status of this concept, it is recommended that development and use of a mitigation bank for an individual project be assessed by a thorough case-by-case review.

As with all forms of mitigation, a wetland mitigation bank cannot justify a project not otherwise in compliance with the Section 404(b)(1) Guidelines. Any restoration, creation, or enhancement project should be carefully designed by the applicant and agreed to by all concerned parties through a legally enforceable wetland mitigation banking agreement. The bank should be located in the same geographical area and consist of wetland types similar to the wetland where impacts will eventually occur.

The bank should be operational prior to allowing any project to use the bank's value as compensation for unavoidable impacts. Long-term operational, maintenance, and monitoring plans, and legal guarantees should be included in the mitigation plan which assure that tasks are feasible and will be undertaken by the appropriate parties under the force of law.

## COMMUNITY TYPE

Most recommendations provided thus far in this discussion are based upon the assumption that wetlands which are unavoidably lost will be replaced by the same wetland community type. The chances of replacement with the same wetland community can be maximized by planting the site. Natural recolonization of a mitigation site is recommended only when there is an adjacent seed source and the applicant agrees in advance that if the desired density or species composition are not present at the mitigation site after one or two growing seasons, that the site will be planted to achieve the recommended plant community.

In-kind mitigation is desirable since it replaces the same community type which was lost and restores the equilibrium of community types which had developed as a result of natural causes. Out-of-kind mitigation should only be approved under unusual circumstances in which the data demonstrate that replacement of a different vegetative type for the one destroyed would clearly benefit the ecosystem or geographical area being evaluated. For example, if a mining company receives a permit to mine ore which exists under a wetland vegetated predominantly by cattails, a mitigation plan may be approved which includes creating a more diverse herbaceous community at this site. If the created system provides increased diversity of habitat or other ecological functions compared to the monotypic stand of cattails, the replacement ratio may be reduced to 1 to 1.

The decisions and value analyses of out-of-kind mitigation proposals must be made carefully and must include an evaluation of the entire community which exists on the site. For example, it is inappropriate to argue that the loss of a wetland which has a hydroperiod which has been reduced compared to historic levels can be mitigated through creation of a smaller sized lake with a permanent hydroperiod. That conclusion overlooks the ecological values provided to organisms which are currently using the drier wetland site. Such a proposal could be approved only if it could be demonstrated that the acreage of drier wetland habitat was not a limiting factor in the area and the presence of a lake would significantly improve the ecological functioning of the ecosystem. In no case should the replacement ratio of this type of mitigation be reduced to lower than 1 to 1.

Out-of-kind mitigation might also be approved if there is a requirement to rapidly stabilize an area, and there is ample assurance that in-kind species will eventually invade the planted area. For example, on suitable sites, Spartina alterniflora may completely cover a site in one growing season after planting at an appropriate density. Rapid cover may be desirable to stabilize the shoreline at the mitigation site. If there is an adjacent marsh vegetated by the slower growing Juncus roemerianus, it may invade the planted Spartina area and eventually achieve an equilibrium. Thus, planting of an area with Spartina to mitigate the destruction of a Juncus marsh may be justified in this case.

## SELECTION OF MITIGATION OPTIONS

Choice of a mitigation option should consider site specific and cumulative impact assessments conducted for the proposed site and should be based on sound ecological principles based upon large-scale, landscape considerations. The best choice of a mitigation plan can only be made when the status of the functions and values that will be affected are known. For example, enhancement of waterfowl habitat by creation of a "green tree" reservoir may be inappropriate for a watershed that already has several such reservoirs, and particularly in a watershed which has water quality problems, which such reservoirs are known to exacerbate. Preservation may be a defensible option if the proposed project is on a site with low functional values and the area proposed for preservation is of high functional value or threatened, and is located in the same watershed. Only when the tradeoffs associated with mitigation options are considered on a scale that is ecologically appropriate (e.g., watershed) can decisions be made which effectively protect or replace wetland functions and values.

The goal of the selection of any mitigation plan is to replace, as near as possible, the ecological functions of the wetlands which will be destroyed. Potential options are summarized in Table 1. One selection method is to rank all potential options by assigned values. Values can be regional or site specific. Options can be evaluated through the development of a matrix with assigned values based on assumptions concerning preference of the options. An example of such a matrix is given in Figure 1 which includes all mitigation options and an example of assigned values.

As discussed above, generally restoration is the preferred option, followed by creation and enhancement. Thus, these options have been assigned values of 3, 2, and 1 respectively. These values are almost exactly the opposite of the recommended acre-for-acre replacement ratios discussed above; that is, the recommended replacement acreage is 1.5:1 for a restoration project, 2:1 for a creation project, and 3:1 for an enhancement project.

Values of 3, 2 and 1 have been assigned to upfront, concurrent, and post project mitigation. This is descriptive of the timing of the initiation and completion of the replacement wetlands. The rationale for this weighting is simply that the faster the mitigation project is completed, the faster the wetland functions are replaced in the ecosystem. Having replacement wetlands in place and functioning before the wetlands permitted for filling are destroyed is most desirable.

Values of 3 and 1 are assigned to in-kind and out-of-kind community composition, respectively. Generally, ecosystems reach an equilibrium of community types which maximizes trophic and nutrient cycling efficiencies. Thus, replacement of the same community as that which is lost to filling may restore the integrity of the ecosystem.

Values of 3 and 1 have been assigned to on-site and off-site replacement, respectively. On-site mitigation fulfills the goal of compensatory mitigation, that is to replace the functions that a filled wetland community provides to the portion of the ecosystem of which it was a part. Thus, on-site mitigation is weighted more than off-site mitigation.

The weighting of upfront, in-kind, and on-site mitigation options are presumed equal since each option represents a similar input toward the success and overall effectiveness of replacement mitigation.

The overall values of the 36 mitigation options given in Figure 1 were calculated by adding the value assigned to each component. Values range from 12 to 4. By this method, on-site, in-kind, upfront restoration is the most desirable option, which is reflected in the high value it received (12). Off-site, out-of-kind, post project enhancement of an existing wetland is the least desirable option (4).

It is recommended that project managers and preparers of mitigation plans strive to achieve the highest value of mitigation type possible for each mitigation project. A limit of acceptable mitigation options can be set. For example, acceptable projects could be confined to mitigation options with values of 9 or higher and only in unusual circumstances would a mitigation plan with a mitigation option lower than 9 be approved. Project managers have more flexibility in the acceptability of mitigation options for community types for which success of replacement has been conclusively demonstrated. For example, the success of creation of a Spartina alterniflora marsh at proper elevations is well documented. Thus, an acceptable mitigation plan might include creation of an S. alterniflora marsh in exchange for filling a similar marsh if it is performed concurrently and on site (10). Mitigation for this marsh might also be possible by concurrently restoring a Spartina marsh in the immediate vicinity (11). However, it would take an unusual set of circumstances to approve a mitigation plan for the loss of this marsh which includes creation of a cypress swamp at some other location (7).

Figure 1 will help simplify the selection of ecologically acceptable mitigation options, and can be used to quickly compare the "values" of different options. However, because of the myriad of site specific possibilities and restrictions, Figure 1 and recommendations made herein should be used as a guide and not as the only criterion used in decision making.

Some reviewers of this method have suggested determining the acreage of mitigation which is required by the value of the mitigation given in such a matrix. For example, if a value of 10 is the acceptable level of mitigation options, but the applicant can only perform mitigation options with a value of 7, the option with the lower value may be acceptable if the acreage was increased by 10/7. It is possible that a refinement of a general technique such as this may be acceptable in some regions.

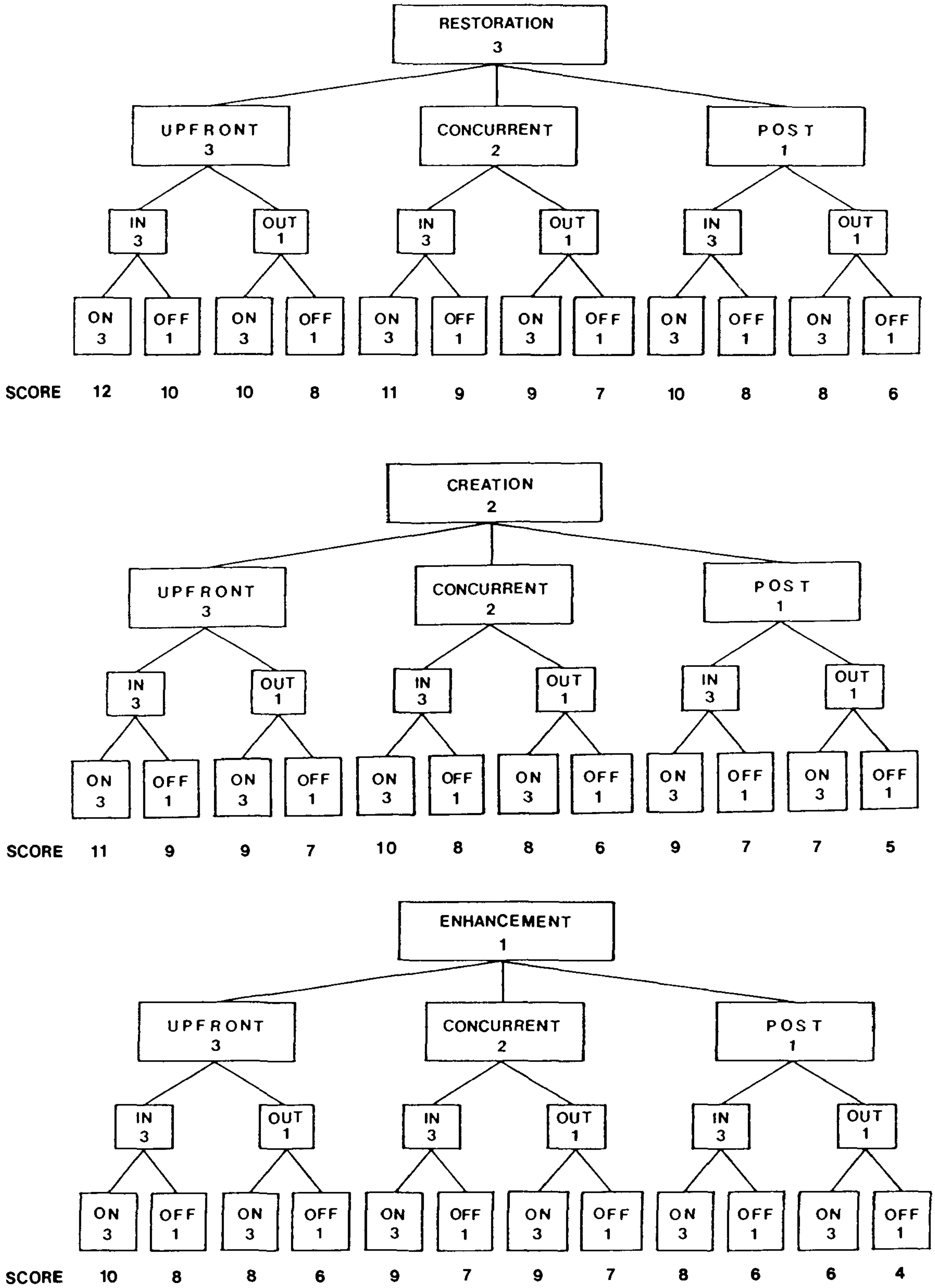


Figure 1. Options to be considered in the preparation and evaluation of mitigation plans. Interpretation of the scores is explained in the text.

# MONITORING COMPENSATORY MITIGATION PROJECTS

A serious problem in evaluating proposed mitigation plans is the dearth of quantitative data on existing mitigation projects, particularly documentation of changes through time. As stated above, several studies currently underway will revisit sites to determine if the mitigation which was recommended was performed. Data will be collected to evaluate conditions which contributed to success or failure of completed projects. However, because there is so little quantitative information on replacement of many wetland communities, particularly forested communities, it is recommended that all mitigation plans contain an approved monitoring plan. Further, it is recommended that if success criteria established for a project are not met, the applicant must be required to take corrective actions until the criteria are met. This is best accomplished by making the criteria which define success, the monitoring plan, and the corrective actions explicit special conditions of the Corps permit. Performance bonding may also be required in circumstances where compensatory mitigation is required for large projects, for projects where the anticipated success is not high, and projects proposed by applicants who have a poor record of compliance with permit conditions or have a history of enforcement actions.

A proposed monitoring plan should be reviewed by an interagency team consisting of representatives from the Corps, EPA, FWS, NMFS (when appropriate), and State regulatory and resource agencies. The basic question is to ascertain whether the data collected through monitoring will be sufficient to demonstrate that the replacement habitat will adequately compensate for the destroyed habitat. This may be systematically analyzed by listing all known wetland functions which are provided by the wetland permitted for filling, and comparing these with anticipated functions of the replacement habitat. It is probable, especially in forested wetland creation projects, that the development of full ecological functioning of the replacement community may take a number of years. In these cases, some reasonable judgement must be made concerning the level of function to be used as a measure of success. For example, the goal of swamp creation might be to produce a functional, self reproducing, stable community. This may take 30 years or more to accomplish. It would be reasonable to predict the potential success of such a project by monitoring tree growth and survival and the ability of the faster maturing species to produce viable seeds for a much shorter period of time. Recent evidence indicates that planted intertidal marshes on dredged material may take many years to develop soil characteristics, such as depth to redox zone and organic matter, comparable to naturally occurring marshes. However, it may be adequate to monitor a created or restored site for plant growth and survival, and establish success based upon these easily measured criteria. This approach assumes that once the plants are established, the other functions must necessarily follow. For systems with many unknowns, the prudent approach is to withhold judgement on success until a self-sustaining community is achieved.

Success of mitigation projects can be determined through use of a "mitigation scorecard". This document summarizes the success criteria which must be achieved before a project is declared fully successful. The scorecard should contain criteria for both biotic and abiotic factors which are integral parts of the community which is being mitigated. Quantitative limits should be set using reasonable, best available estimates, taking into consideration factors such as time since establishment, distance from a water source or from donor communities, planting densities, and natural processes. Applicants do not usually have to supply continuous data which demonstrate progress toward meeting the success criteria, unless there are scientifically justifiable reasons to require such monitoring. When an applicant is ready to demonstrate that success criteria have been met, the interagency team which reviewed the monitoring plan should examine the site, sampling locations, techniques used, and the data.

Agreement upon the parameters and quantitative limits on the scorecard constitutes a contract between the regulators (Corps) and the applicant. Anticipated remedial actions such as replanting with the same or different species should be agreed upon before a project is initiated and must be made part of the contract. The contract should only be changed through agreement of all parties including the Corps, the applicant, and the interagency review team.

# SUMMARY OF GENERAL RECOMMENDATIONS FOR PREPARATION AND EVALUATION OF MITIGATION PLANS

The following is a list of specific issues which should be explicitly addressed during the permit review process to improve the prospects of successful compensatory mitigation of wetland losses for projects which otherwise comply with the Section 404 Guidelines. A similar listing is found in Reimold and Cobler (1986) and other publications.

## SLOPES AND GRADIENTS

A common problem to many unsuccessful sites is steepness of slopes within the mitigation area or in surrounding areas. A gentle slope of 1:5 to 1:15 (vertical:horizontal) is recommended for successful wetland establishment since it provides maximum flooding and minimizes erosion.

## SOILS

Plant growth can be facilitated by proper soils. If it is not possible to supply proper wetland soils, the area may be mulched to provide an organic surface horizon, and/or fertilized to stimulate plant growth. Some mitigation sites are slow to become established because of the lack of proper soil microflora. It is possible that such soils must be inoculated with soil microflora during site preparation to assure rapid and healthy plant growth.

## PLANT MATERIAL

Transplanting sprigs or other plant stock at mitigation sites is usually preferred over allowing natural colonization, since transplanting promotes favorable community composition and hastens the establishment of a functional wetland. Sites should be planted at appropriate times of the year with stock or seeds that are genetically compatible with vegetation native to the locale. Planting density and survival rates should be specified. Donor sites should be protected from over-harvesting.

## HYDROLOGY

Proper water depth and periodicity is the most important element in planning a successful mitigation plan. Long term stage records or tidal data should be used to determine depth and extent of flooding limits, and mitigation sites should be planned at elevations within the flooding tolerance limits of the community type. The methodology of establishing frequency of inundation in tidal areas which are distant from a bench mark is given in Marmer (1951) and Swanson (1974).

## MONITORING

Success criteria should be agreed upon before issuance of a permit. Post-project monitoring should be continued by the applicant until success criteria are met. Changes in the mitigation plan or success criteria should be possible only with approval of all members of the interagency review team. However, the Corps has the final authority on permits, including special conditions to permits which might contain mitigation plans and success criteria.

## TIMING

Upfront mitigation should be encouraged, particularly when it is determined that risk of failure is high. Concurrent mitigation is acceptable for projects where success is probable.

## LOCATION

On site mitigation should be encouraged so that there is no net loss of wetland type or functions to the local ecosystem.

## COMMUNITY TYPE

Replacement of the same kind of habitat which was destroyed should be encouraged in order to restore the natural balance of community types in the ecosystem.

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# CONTRIBUTORS

## ROBERT P. BROOKS

**Affiliation:**

School of Forest Resources
Forest Resources Laboratory
Pennsylvania State University
University Park, PA 16802

**Related Experience:**

Robert Brooks' primary research effort for the past 5 years has involved the characterization, restoration, and creation of freshwater wetlands on disturbed landscapes in the northeastern U.S. Studies related to habitat selection by wetland wildlife, monitoring methods for mitigation, coal-mined lands and mine drainage, peatlands, and wetland-riparian systems impacted by agriculture have resulted in 13 publications.

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## STEPHEN W. BROOME

**Affiliation:**

Department of Soil Science
North Carolina State University
Box 7619
Raleigh, NC 27695

**Related Experience:**

Stephen Broome's involvement in creation and restoration of coastal salt and brackish tidal marshes began in 1969. His research includes studies of the establishment of marsh vegetation for dredged material stabilization, shoreline erosion control, conversion of upland to intertidal vegetation for mitigation, and revegetation of a marsh on the coast of France impacted by an oil spill. He has authored or co-authored a total of 30 publications related to these projects.

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## STEVEN W. CAROTHERS

**Affiliation:**

President, SWCA, Inc.
Environmental Consultants
1602 E. Ft. Lowell
Tucson, AZ 85719

**Related Experience:**

Steven Carothers has studied the preservation and management of Southwestern riparian ecosystems for more than 20 years. In recent years, he has become involved in a number of habitat restoration efforts, some of which have included the salvage and transplanting of desert riparian trees and shrubs for major land development projects. Prior to the establishment of SWCA, Inc. in 1981, Carothers was curator of biology at the Museum of Northern Arizona for ten years. He has published numerous papers relating to riparian habitats in the Southwest.

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## ROBERT H. CHABRECK

**Affiliation:**

School of Forestry, Wildlife and Fisheries
Agricultural Center Louisiana State University
Baton Rouge, LA 70803

**Related Experience:**

Robert Chabreck has worked for 31 years on coastal marsh research and management projects. He has planned, supervised, or evaluated over 40 projects that involve wetland creation, restoration, or enhancement, and has 33 publications on the subject.

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## JOHN R. CLARK

**Affiliation:**

Rosenstiel School of Marine and Atmospheric Sciences
University of Miami
4600 Rickenbacker Causeway
Miami, Florida 33149

**Related Experience:**

John Clark has 16 years of experience in wetlands policy analysis and formulation, and in implementation of wetlands regulations with the Conservation Foundation, Wetlands Technical Council, and in private practice. He has been responsible for site specific project advice on planning and development projects since 1974 (Marco Island). Most of his experience is with coastal wetlands in Florida, New Jersey, New York, South Carolina, and California. He has twenty publications in this field.

## ANDRE F. CLEWELL

**Affiliation:**

President
A.F. Clewell, Inc.
1447 Tallevase Road
Sarasota, FL 34243

**Related Experience:**

Andre Clewell earned his Ph.D. in botany from Indiana University in 1963 and served 16 years on the faculty at Florida State University. He is currently President of A.F. Clewell, Inc., which specializes in vegetation restoration, particularly for the Florida phosphate mining industry. He has 10 years experience in vegetation restoration, including research and development, project design, and project monitoring. He is currently in charge of 17 forest creation and restoration projects that collectively occupy 152 acres and include the creation of 7 headwater streams. He is the recipient of a 5-year research grant on tree establishment from the Florida Institute of Phosphate Research. He is well known as a botanist and as the author of Guide to the Vascular Plants of the Florida Panhandle (University Presses of Florida, 1985).

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## CHARLENE D'AVANZO

**Affiliation:**

School of Natural Science
Hampshire College
Amherst, MA 01002

**Related Experience:**

Charlene D'Avanzo has been involved in wetlands research for 15 years, primarily in salt marshes systems in the northeast. She has published numerous articles on nutrient cycling, food chain dynamics, and primary production in salt marshes. Her experience with wetland mitigation includes project reviews as a Conservation Commissioner in Massachusetts and several papers and talks concerning mitigation and vegetation in northeast wetlands.

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## KEVIN L. ERWIN

**Affiliation:**

President/Principal Ecologist
Kevin L. Erwin Consulting Ecologist, Inc.
2077 Bayside Parkway
Fort Myers, FL 33901

**Related Experience:**

Kevin Erwin has worked with wetland ecosystems for the National Marine Fisheries Service, Florida Department of Natural Resources, and Florida Department of Environmental Regulation since 1971 and prior to establishing his firm in 1980. His involvement in wetland creation and restoration covers over 50 projects encompassing thousands of acres of mangrove, salt marsh, freshwater marshes and swamps. Current research on sites in Florida ranging in size from 5 to 150 hectares has provided information on design, construction techniques, tree survival and growth, macrobenthic community structure, water quality, wildlife utilization, and evaluation and monitoring methods.

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## VICKI M. FINN

***Affiliation:***

Graduate Assistant
School of Public and Environmental Affairs
Indiana University
Bloomington, Indiana 47405

## MARK S. FONSECA

**Affiliation:**

Research Ecologist
National Marine Fisheries Service
NOAA, Beaufort Laboratory
Beaufort, NC 28516-9722

**Related Experience:**

Since 1975, Mark Fonseca's research has centered on various aspects of the ecology of seagrass meadows including: hydrodynamics, productivity and nutrient cycling, population growth and meadow development, transplanting technology, application of basic seagrass ecology to management strategies, and succession of restored seagrass beds. He has provided guidance on approximately 30 seagrass restoration projects, domestic and foreign. He has authored 10 papers on seagrass restoration and management, and has authored or co-authored 36 papers on seagrasses.

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## EDGAR W. GARBISCH

**Affiliation:**

Founder and President
Environmental Concern Inc.
P.O. Box P
St. Michaels, MD 21663

**Related Experience:**

From 1972 through 1988, under the leadership of Ed Garbisch, Environmental Concern, Inc., has designed and constructed over 290 wetland creation/restoration projects throughout the eastern United States. A majority of these projects involve brackish tidal marshes and saltmarshes; however, many represent tidal freshmarsh, non-tidal freshmarsh, and wooded wetlands. Approximately 120 of these projects relate to the application of wetland creation for shore erosion control throughout the Maryland portion of the Chesapeake Bay. The majority of the balance of these projects were constructed as compensation for wetlands lost or damaged by permitted developments. However, some of these projects were constructed for (1) wetland habitat development on dredged materials, (2) stormwater management, (3) wastewater treatment, (4) wildlife habitat, and (5) education and aesthetics. Over 96% of these projects are considered successful, based on their construction according to planned hydrological performance and vegetation establishment. The largest project completed is 100 acres of brackish tidal marsh at Secaucus, New Jersey.

**Related Publications:**

Garbisch, Jr., E.W. and L.B. Coleman. 1978. Tidal Freshwater Marsh Establishment in Upper Chesapeake Bay: Pontederia cordata and Peltandra virginica. In R.E. Good, D.E. Whigham, and R.L. Simpson (Eds.), Freshwater Wetlands Ecological Processes and Management Potential. Academic Press, New York.

Garbisch, E.W. 1986. Highways and Wetlands: Compensating for Wetland Losses. U.S. Dept. of Transportation, FHA Report No. FHWA-IP-86-22.

## THEODORE GRISWOLD

**Affiliation:**

Pacific Estuarine Research Laboratory
San Diego State University
San Diego, CA 92182-0057

**Related Experience:**

Theodore Griswold has 4 years of experience in coastal wetland ecology, including one year as manager of San Diego State University's wetland research facility, a 30-acre site containing 72 artificial wetlands.

**Related Publications:**

Griswold, T. 1988. Physical factors and competitive interactions affecting salt marsh vegetation. M.S. Thesis, San Diego State University.

## AMANDA K. HILLER

**Affiliation:**

Graduate Assistant
School of Public and Environmental Affairs
Indiana University
Bloomington, Indiana 47405

## GARRETT G. HOLLANDS

**Affiliation:**

Principal-in-Charge
Wetlands Group
IEP, Inc.
Northborough, MA 01532

**Related Experience:**

Garrett Hollands has 22 years of experience as a professional geologist and has worked on a wide range of geologic projects throughout the U.S. and Canada. For the past 13 years, he has focused on wetland geology and hydrology while working in New England, the Mid-Atlantic States, Wisconsin, Oregon, Washington, and British Columbia. Clients have included federal, state and local agencies, environmental organizations, and the private sector. He has been involved in the actual design, construction, and monitoring of man-made wetlands for replication and urban runoff mitigation in a wide variety of geohydrologic settings.

**Related Publications:**

Hollands, G.G. and W.S. Mulica. 1978. Application of Morphological Sequence Mapping of Surficial Geological Deposits to Water Resources and Wetland Investigations in Eastern Massachusetts, Geological Society of America Abstracts with Programs, Northeastern Section.

Hollands, G.G., and D.W. Magee. 1985. A Method of Assessing the Functions of Wetlands. In Proceedings of the National Wetland Assessment Symposium, Association of State Wetland Managers, Berne, New York.

Hollands, G.G., G.E. Hollis, and J.S. Larson. 1987. Science Base for Freshwater Wetland Mitigation in the Glaciated Northeastern United States; Hydrology. In J.S. Larson and C. Neill (Eds.), Mitigating Freshwater Wetland Alterations in the Glaciated Northeastern United States: An Assessment of the Science Base. The Environmental Institute, University of Massachusetts at Amherst, Publication No. 87-1.

## SHERMAN E. JENSEN

**Affiliation:**

White Horse Associates
P.O. Box 123
Smithfield, UT 84335

**Related Experience:**

Sherman Jensen has studied riparian habitats since 1980. He has participated in 20 projects in 6 physiographic provinces of the West and contributed to 8 publications pertinent to riparian and stream habitats. He is presently involved in 2 projects to create riparian and wetland habitats in southern Idaho, and several projects to devise management strategies to restore stream and riparian habitats.

**Related Publications:**

Jensen, S., M. Vinson, and J. Griffith. 1987. Creation of riparian and fish habitats, Birch Creek Hydroelectric Facility, Clark County, Idaho, p. 144-149. In K.M. Mutz and L.C. Lee (Eds.), Proceedings of the Society of Wetland Scientists Eighth Annual Meeting, Seattle, Washington.

Platts, W.S., C. Armour, G.D. Booth, M. Bryant, J.L. Bufford, P. Cuplin, S. Jensen, G.W. Lienkaemper, G.W. Minshall, S.B. Monsen, R.L. Nelson, J.R. Sedell, and J.S. Tuhy. 1987. Methods for Evaluating Riparian Habitats with Applications to Management. U.S. Dept. Agric., Forest Service, Intermountain Research Station, Gen. Tech. Rep. INT-221. Boise, Idaho.

## R. ROY JOHNSON

**Affiliation:**

School of Renewable Natural Resources
Cooperative National Park Resources Studies Unit
University of Arizona
Tucson, AZ 85721

**Related Experience:**

Roy Johnson's research efforts have been largely concerned with botanical and zoological investigations in the deserts of the southwestern United States and northern Mexico since 1952. For the past 20 years, he has concentrated largely on the impacts of "water projects" on the riparian environment, and research and management implications of those projects on recreational and wildlife values. Most of his 200 publications have been on riparian issues, the most significant resulting from three national and international riparian conferences for which he was Technical Co-Chairman.

**Related Publications:**

Johnson, R.R. and D.A. Jones (Tech. Coords.). 1977. Importance, preservation and management of riparian habitat: a symposium. U.S. Dept. Agric., For. Serv. Tech. Rep. RM-43. Rocky Mountain For. and Range Exper. Sta., Fort Collins, Colorado. 217 pp.

Johnson, R.R. and J.F. McCormick (Tech. Coords.). 1978. Strategies for the protection and management of floodplain wetlands and other riparian ecosystems. [Proc. symp., Callaway Gardens, Ga., Dec. 11-13, 1978.] U.S. Dept. Agric., For. Serv. Gen. Tech. Rep. WO-12. Washington, D.C. 410 pp.

Johnson, R.R. and S.W. Carothers. 1982. Riparian habitats and recreation: interrelationships and impacts in the Southwest and Rocky Mountain region. Eisenhower Consortium Bull. 12, Rocky Mtn. For. and Range Exp. Sta., U.S.D.A. Forest Serv., Ft. Collins, Colorado.

Johnson, R.R. et al. (Tech. Coord.). 1985. Riparian ecosystems and their management: reconciling uses. Gen. Tech. Rpt. RM-120. U.S.D.A. Forest Serv., Rocky Mtn. Forest and Range Exp. Sta., Ft. Collins, Colorado. 523 pp.

## MICHAEL JOSSELYN

**Affiliation:**

Romberg Tiburon Center & Department of Biological Sciences
San Francisco State University
P.O. Box 855
Tiburon, CA 94920

**Related Experience:**

Michael Josselyn is an estuarine scientist focusing on the ecology and restoration of wetlands. Since 1978, he has received support from federal, state, and regional agencies to study and monitor tidal and riparian wetlands throughout California. His research interests include plant succession patterns, introduced wetland plants, habitat use by wetland wildlife, and impacts of sea-level rise on wetlands. He has also consulted on over 60 restoration and mitigation projects throughout the United States for the federal and state resource agencies and highway departments. Dr. Josselyn is a Fellow of the California Academy of Sciences and Senior Scientist at the Romberg Tiburon Center for Environmental Studies, an estuarine research facility of San Francisco State University.

**Related Publications:**

Josselyn, M.N. (Ed.). 1982. Wetland restoration and enhancement in California. California Sea Grant College Program. Report #T-CSGCP-007.

a. Josselyn, M.N. and J. Buchholz, Summary of past wetland restoration projects in California. p. 1-10.

b. Zedler, J., Josselyn, M., and Onuf, C. Restoration techniques, research, and monitoring: vegetation. p. 63-72.

Josselyn, M.N. 1983. Tidal Marshes of San Francisco Bay: A Community Profile. U.S. Fish and Wildlife Service, Division of Biological Services, Washington, D.C. FWS/OBS-83/23.

Josselyn, M.N. 1988. Effectiveness of coastal wetland restoration: California. In J.A. Kusler, M.L. Quammen, and G.Brooks (Eds.), Mitigation of Impacts and Losses. Assoc. State Wetland Managers, Berne, New York.

## JOHN E. KLARQUIST

**Affiliation:**

Graduate Assistant
School of Public and Environmental Affairs
Indiana University
Bloomington, Indiana 47405

## WILLIAM L. KRUCZYNSKI

**Affiliation:**

U.S. Environmental Protection Agency, Region IV
Environmental Research Laboratory--Sabine Island
Gulf Breeze, FL 32561

**Related Experience:**

While a research associate for the Wetland Ecology Project at Florida A & M University, William Kruczynski conducted research on the zonation of tidal marshes, and the vegetative stabilization and colonization of dredged material. From 1978-1986 he served as Project Officer and Chief of the Wetlands Section for Region IV of the Environmental Protection Agency (EPA). There he was involved in the review of Section 10/404 permit applications, mitigation plans and success criteria for projects including phosphate mine reclamation. Presently William Kruczynski is the Wetland Scientist/Liaison Officer for EPA Region IV, stationed at Environmental Research Laboratory, Gulf Breeze.

**Related Publications:**

Breitenback, G., C.L. Coultas, W.L. Kruczynski, and C.B. Subrahmanyam. 1978. Vegetative stabilization of dredged spoil in North Florida. Jour. Soil and Water Conservation 33:183-185.

Kruczynski, W.L. 1983. Salt marshes of the Northeastern Gulf of Mexico, p. 71-87. In Roy R. Lewis (Ed.), Creation and Restoration of Coastal Plant Communities. CRC Press, Boca Raton, Florida.

Durako, M.J., J.A. Browder, W.L. Kruczynski, C.B. Subrahmanyam, and R.E. Turner. 1985. Salt marsh habitat and fishery resources of Florida, p. 189-280. In W. Seaman (Ed.), Florida Aquatic Habitat and Fishery Resources. American Fisheries Society.

## RUSS LEA

**Affiliation:**

Director, North Carolina State Hardwood Research Cooperative
College of Forest Resources
North Carolina State University
Raleigh, NC 27695-8002

**Related Experience:**

Russ Lea has over ten years of research experience in soil science and forestry. For the past eight years he has been associated with the North Carolina State Hardwood Research Cooperative. He directs the Cooperative which has sixteen industrial and public agency members with land holdings in the thirteen Southern states. The Cooperative conducts research and provides consulting on forested wetland systems (naturally occurring and artificially created), and intensively managed hardwood plantations. The type of activity ranges from basic research to applied operations and regulatory consulting. He served as a mitigation consultant to North Carolina Phosphate Company, Savannah River Plant, Occidental Chemicals and Texas Gulf Phosphate. Lea has served on Forestry Best Management Practice committees for several southern states and is a consultant on a 350 acre waste water land application/hardwood tree plantation project in coastal North Carolina.

**Related Publications:**


Lea, R. 1986. Management of Eastern United States bottomland hardwood forests, p. 185-194. In D. Hook (Ed.), The Ecology and Management of Wetlands, Vol. 2. Crown-Helm, London.

Lea, R. 1987. Response of wetland forests to pumped agriculture wastewater. North Carolina Water Resources Research Institute Report No. 231.

Mader, S.F., W.M. Aust, and R. Lea. 1989. Changes in functional values of a forested wetland following timber harvesting practices, p. 149-154. In D. Hook and R. Lea (Eds.), Forested Wetlands of the Southern U.S., Orlando, Florida.


## DANIEL A. LEVINE

**Affiliation:**


School of Public and Environmental Affairs
Indiana University
Bloomington, Indiana 47405


## Roy R. LEWIS III

**Affiliation:**


Lewis Environmental Services, Inc.
P.O. Box 20005
Tampa, FL 33622-0005


**Related Experience:**

Roy Lewis has 22 years of experience in marine wetland research. He has been involved with approximately 100 wetland restoration or creation projects in Florida and the Caribbean. He has forty publications on the subject.

**Related Publications:**


Lewis R.R. (Ed.). 1982. Creation and Restoration of Coastal Plant Communities. CRC Press, Boca Raton, Florida.

Lewis R.R. Management and restoration of mangrove forests in Puerto Rico, U.S. Virgin Islands, and Florida, U.S.A. In Proceedings of the International Symposium on Ecology and Conservation of the Usumacinta Grijalva Delta, Mexico. Villahermosa, Tabasco, Mexico. (In press).

Lewis, R.R., R.G. Gilmore, Jr., D.W. Crewz, and W.E. Odum. 1985. Mangrove habitat and fishery resources of Florida, p. 281-336. In W. Seaman, Jr. (Ed.), Florida Aquatic Habitat and Fishery Resources. Fla. Chapter, American Fisheries Society, Kissimee, Florida.

Lewis, R.R. and K.C. Haines. 1981. Large scale mangrove planting on St. Croix, U.S. Virgin Islands: second year, p. 137-148. In D.P. Cole (Ed.), Proceedings of the 7th Annual Conference on Wetland Restoration and Creation. Tampa, Florida.

## ORIE L. LOUCKS

**Affiliation:**

Department of Zoology
Miami University
Oxford, Ohio 45056

**Related Experience:**

Orie Loucks has conducted research on land-water interactions, emphasizing the wetlands interface, for nearly 20 years. His papers have addressed transport of water and nutrients into marsh and littoral zone wetlands, and investigated effects through field studies and predictive models of the long-term functioning of wetland systems.

**Related Publications:**

Loucks, Orie L. and Vicki Watson. 1978. The Use of Models to Study Wetland Regulation of Nutrient Loading to Lake Mendota, p. 242-252. In C.B. DeWitt and E. Soloway (Eds.), Wetlands, Ecology, Values, and Impacts. Proceedings of the Waubesa Conference on Wetlands. Inst. for Env. Studies, Univ. of Wisconsin-Madison.

Livingston, Robert J. and Orie L. Loucks. 1978. Productivity, Trophic Interactions, and Food-Web Relationships in Wetlands and Associated Systems, p. 101-119. In Wetland Functions and Values: The State of Our Understanding. Amer. Water Resources Assn., Minneapolis, Minnesota.

Loucks, Orie L. 1985. Looking for Surprise in Managing Stressed Ecosystems. BioScience 35(7):428-432.

Loucks, Orie L. 1989. Wetland Characteristics--Their Land-water Interactions. In Wetlands and Shallow Continental Water Bodies; Volume 1. Academic Publishing, The Hague, The Netherlands. (In press).

## DENNIS J. LOWRY

**Affiliation:**

Wetland Ecologist
IEP, Inc.
P. O. Box 780
6 Maple St.
Northborough, MA 01532

**Related Experience:**

Since 1984, Dennis Lowry has been involved in the design of more than one dozen inland wetland creation sites. On more than half of these projects, he has been actively involved in the construction process, including supervising equipment operation, conducting the planting efforts, and monitoring the vegetative growth. He was one of 20 scientists invited to participate in the University of Massachusetts' workshop, Mitigating Freshwater Wetland Alterations in the Glaciated N.E. United States, An Assessment of the Science Base.

**Related Publications:**

Lowry, D.J., E.R. Sorenson, and D.M. Titus. 1988. Wetland replacement in Massachusetts: regulatory approach and case studies, p. 35-56. In M.W. LeFor and W.C. Kennard (Eds.). Proceedings of the Fourth Connecticut Institute of Water Resources Wetlands Conference, Storrs, Connecticut.

Golet, F.C. and D.J. Lowry. 1987. Water regimes and tree growth in Rhode Island Atlantic white cedar swamps, p. 91-110. In A.D. Laderman (Ed.), Atlantic White Cedar Wetlands. Westview Press. Boulder, Colorado.

Daukas, P., D.J. Lowry, and W.W. Walker, Jr. 1988. Design of wet detention basins and constructed wetlands for treatment of stormwater runoff from a regional shopping mall in Massachusetts, p. 686-694. In D.A. Hammer (Ed.) Constructed Wetlands for Wastewater Treatment, Proceedings of the International Conference in Constructed Wetlands for Wastewater Treatment. Chattanooga, Tennessee.

## G. SCOTT MILLS


**Affiliation:**

Senior Biologist
SWCA, Inc.
Environmental Consultants
1602 E. Fort Lowell
Tucson, AZ 85719


**Related Experience:**

Scott Mills has studied riparian ecology in the Southwest for more than 15 years. His research emphasis has been the relationships between the structure of riparian plant communities and avian communities. He has recently participated in two major riparian forest creation efforts along the Lower Colorado River. For the Mittry Lake Project, Scott Mills created the planting design and calculated mitigation values for the planting of more than 5500 trees. For a study of the terrestrial ecology of modified bankline habitats, he created an experimental design to identify simple and cost-effective methods to revegetate rip-rapped banklines and to assess effects of vegetation on wildlife use. These experiments included various planting techniques such as rooted cuttings, dormant poles, and seeds, and a range of environmental parameters such as soil amount, planting location, depth to water, and irrigation regime.

**Related Publications:**


Mills, G.S. and J.A. Tress, Jr. 1988. Terrestrial ecology of Lower Colorado River bankline modifications. Report to Bureau of Reclamation, Boulder City, Nevada.


## WILLIAM A. NIERING


**Affiliation:**

Botany Department
Connecticut College
New London, CT 06320


**Related Experience:**

William Niering has been involved in wetland research since he completed his Ph.D. thesis in the early 1950's at High Point State Park, N.J. His major research has been on tidal marshes. In the late 1960's a joint project involved an inventory of inland wetlands of the United States for the Department of the Interior. An extensive survey of over 100 Connecticut marsh systems was undertaken in the early 1970's. Current research is a study of four decades of vegetation change in the Barn Island marshes and the factors responsible. Niering is also a member of the National Wetlands Technical Council.

**Related Publications:**


Niering, W.A. and R. Scott Warren. 1974. Tidal Wetlands of Connecticut: Vegetation and Associated Animal Populations. Vol. I. Connecticut Dept. of Environmental Protection.

Niering, W.A. and R. Scott Warren. 1980. Vegetation patterns and processes in New England salt marshes. BioScience 30(5):301-307.

Niering, W.A. 1985. Wetlands. (The Audubon Society Nature Guides) A.A. Knopf, New York.

## WILLIAM S. PLATTS

**Affiliation:**

Platts Consulting
Don Chapman Consultants
3180 Airport Way
Boise, ID 83705

**Related Experience:**

William Platts has studied streams and riparian habitats since 1955. He has participated in hundreds of projects throughout the United States and has published 166 articles. He is currently involved in studies to develop grazing management for enhancing riparian habitat, and to identify types of stream and riparian habitat that will respond similarly to management.

**Related Publications:**

Platts, W.S., C. Armour, G.D. Booth, M. Bryant, J.L. Bufford, P. Cuplin, S.E. Jensen, G.W. Lienkaemper, G.W. Minshall, S.B. Monsen, R.L. Nelson, J.R. Sedell, and J.S. Tuhy. 1987. Methods for Evaluating Riparian Habitats with Applications to Management. U.S. Dept. Agric., Forest Service, Intermountain Research Station, Gen. Tech. Rep. INT-221. Boise, Idaho.

Platts, W.S. and J.N. Rinne. 1985. Riparian and stream enhancement management and research in the Rocky Mountains. North Amer. Jour. Fish. Manag. 5(2A):115-125.

## JOSEPH K. SHISLER

**Affiliation:**

Vice President
Environmental Connection Inc.
P.O. Box 69
Perrineville, New Jersey 08535

**Related Experience:**

While on the staff at Rutgers University, Joseph Shisler has been involved in the evaluation of the management of wetland systems for the control of mosquito populations for over 15 years. During this period, he has monitored the effects of open marsh water management and tidal restoration of salt hay impoundments on over 30,000 acres of wetlands. He has published over 100 manuscripts on the subject of wetland management and impacts on wetland components. He directed the research on the evaluation of wetland mitigation for the New Jersey Department of Environmental Protection. Governor Kean has appointed him a chairperson of the New Jersey Wetlands Management Council.

**Related Publications:**

Shisler, J.K. and D.J. Charette. 1984. Evaluation of artificial salt marshes in New Jersey. New Jersey Agricultural Experiment Station, Publ. No. P-40502-01-84.

Shisler, J.K., R.A. Jordan, and R.N. Wargo. 1987. Coastal Wetlands Buffer Delineation. New Jersey Agricultural Experiment Station Publ. No. P-40503-01-87.

Shisler, J.K. and T.L. Schulze. 1988. Coastal wetland habitats as a beneficial use of dredged material, p. 55-58. In M.C. Landin (Ed.), Beneficial Uses of Dredge Material, Proceedings of the North Atlantic Regional Conference. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

## JOHN T. STANLEY

**Affiliation:**

The Habitat Restoration Group/John Stanley and Associates, Inc.
6001 Butler Lane
Scotts Valley, California 95066

**Related Experience:**

John Stanley consults on the restoration, management and enhancement of watersheds, river systems and wetlands. He has been a naturalist for the National Audubon Society and the Sierra Club, and has taught conservation, environmental studies and natural history courses at San Jose State University and the University of California, Santa Cruz. He has 16 years experience consulting for several flood control districts on the assessment and mitigation of biotic impacts of flood control project plans on riparian and stream habitats. He has supervised the preparation of revegetation plans for the re-establishment of riparian vegetation along numerous rivers and streams in central California.

**Related Publications:**

Stanley, J.T., L.R. Silva, H.C. Appleton, M.S. Marangio, and B. Goldner. Lower Coyote Creek (Santa Clara County) Pilot Revegetation Project. In D. Abell (Ed.), California Riparian Systems Conference: Protection, Management and Restoration for the 1990's. U.S. Dept. Agric., Forest Service. (In press).

Stanley, J.T. and W.A. Stiles, III. 1983. Revegetation Manual for the Alameda County Flood Control and Water Conservation District. County of Alameda Public Works Agency, Hayward, California.

## MILTON W. WELLER

**Affiliation:**

Caesar Kleberg Professor in Wildlife Ecology
Department of Wildlife and Fisheries Sciences
Texas A & M University
College Station, TX 77843

**Related Experience:**

Milton Weller's long-term interests have been in wetlands as habitats for waterfowl and other wildlife. Most of his research projects have dealt with the natural dynamics of wetlands and their effect on wildlife populations, as well as on management strategies. Studies of emergent wetlands in the Prairie Pothole Region emphasized experimental drawdowns for revegetation; studies of coastal marshes and forested wetlands in Texas have detailed plant-water relationships important in management for wetland establishment and maintenance.

**Related Publications:**

Weller, M. W. and C. E. Spatcher. 1965. The Role of Habitat in the Distribution and Abundance of Marsh Birds. Iowa State Univ. Agric. & Home Econ. Exp. Sta. Spec. Sci. Rept. No. 43.

Weller, M.W. and L.F. Fredrickson. 1974. Avian ecology of a managed glacial marsh. Living Bird 112:269-291.

Weller, M.W. 1978. Management of freshwater marshes for wildlife, p. 267-284. In R.E. Good, D.F. Whigham, and R.L. Simpson (Eds.), Freshwater Wetlands, Ecological Processes and Management Potential. Academic Press, New York.

Weller, M.W. 1987. Freshwater Marshes; Ecology and Wildlife Management. 2nd Ed. Univ. Minn. Press, Minneapolis, Minnesota.

## DANIEL E. WILLARD

**Affiliation:**

Director of Environmental Science & Policy Programs Professor of Biology
School of Public and Environmental Affairs
Indiana University
Bloomington, Indiana 47405

**Related Experience:**

Daniel Willard has worked in wetlands since 1960. He has studied wetland regulation and natural history in California, Oregon, Texas, Wisconsin, Illinois, Michigan, and Indiana. He served on the Office of Technology Assessment's Wetland Committee; the Des Plaines River Project's Advisory Committee; the Environmental Protection Agency's committees on Wetland Research Priorities and Wetlands and Water Quality; the National Academy of Science, National Research Council's Committee on Agricultural Induced Water Quality Problems; and as Advisor to the National Wetlands Forum.

**Related Publications:**

Willard D.E. Persistence: the need for eternal care for urban wetlands and riparian habitats. Proc. Nat. Wetlands Conf. on Urban Wetlands. Association of State Wetland Managers, Berne, New York. (In press).

Willard, D.E. 1988. Restoration and creation of wetlands in severely perturbed ecosystems, p. 115-122. In John Cairns (Ed.). Rehabilitating Damaged Ecosystems; Volume I. CRC Press, Boca Raton, Florida.

Willard, D.E. 1987. Agricultural Wastewaters and Wildlife: An Overview. In annual papers, U.S. Committee on Irrigation and Drainage. Denver, Colorado.

## JOY B. ZEDLER

**Affiliation:**

Pacific Estuarine Research Laboratory & Biology Department
San Diego State University
San Diego, CA 92182-0057

**Related Experience:**

Joy Zedler's current research focuses on determining how well artificial wetlands replace the functional values of natural ecosystems. This follows 15 years of research experience in coastal wetland ecology, including 6 years of restoration work. With several collaborators, she has 10 funded projects on wetland ecosystem functioning, including monitoring and restoration.

**Related Publications:**

Zedler, J.B. 1984. Salt Marsh Restoration: A Guidebook for Southern California. California Sea Grant College Program. Report No. 7-CSGCP-009.

Zedler, J.B. 1988. Salt marsh restoration: lessons from California, p. 123-238. In J. Cairns (Ed.). Rehabilitating Damaged Ecosystems; Volume I. CRC Press, Boca Raton, Florida.

Zedler, J.B. 1988. Restoring diversity in salt marshes: Can we do it?, p. 317-325. In E.O. Wilson (Ed.), Biodiversity. National Academy Press, Washington, D.C.