Restoring Wetlands in Washington

A Guidebook for Wetland Restoration Planning and Implementation

March 1993

PUBLICATION #93-17

Acknowledgements

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The authors would like to acknowledge the efforts of the many people who contributed information and time to this publication, particularly Bob Ziegler, Chuck Perry, and Brent Renfrow from the Washington Department of Wildlife; Dave Kaumheimer and Lori Wolff from the U.S. Fish and Wildlife Service; and Scott Lambert and Ivan Lines from the U.S. Department of Agriculture Soil Conservation Service.

The following individuals contributed technical information, reviewed draft manuscripts, or assisted in other ways: Sydney T. Bacchus, Michael Burton, Steve Caicco, Bill Cantrell, Janie Civille, Rex Crawford, Sarah Cooke, Kern Ewing, Richard Gersib, Debbie Greenwalt, Sono Hashisaki, Rich Horner, Tom Hruby, Word Processing, Jim Knode, Jaime Kooser, Bud Kovalchik, Kathy Kunz, Linda Kunze, Dan and Ann McCain, Janine Mckown, Carlos Mendoza, Dennis Peters, Emily Roth, Vicky Saab, Nancy Shaw, Doug Swanson, Ron Thom, Fred Weinmann, Al Wald ,and Mark Young.

Special thanks to all nursery personnel who responded to the authors' requests for information on propagation of wetland plants.

The development of this document has truly been a group effort. A tremendous amount of both energy and personal care have been dedicated to getting this document to the publication stage. It is our hope that the information contained herein will begin to meet the growing needs of restoration practioners in the field.

Preparation of this document was funded by a grant from the Washington Department of Ecology, with additional funds obtained from the National Oceanic and Atmospheric Administration.

"The first rule of intelligent tinkering is to save all the parts."

Aldo Leopold

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Introduction

Washington's population is growing rapidly, and it is estimated that up to half the state's wetlands have been lost to various types of development since the turn of the century. Many of the state's remaining wetlands have been degraded through impacts to hydrology, soils, and vegetation. This has had an adverse impact on wetland species diversity, the quality of fish and wildlife habitats, and wetland functions and values.

In response to similar losses throughout the United States, the National Wetlands Policy Forum (Conservation Foundation, 1988) established a goal of no overall net loss of the nation's remaining wetlands base, with a long-term goal of increasing the quantity and quality of the nation's wetlands resource base. Governor Booth Gardner, in Executive Order 89-10, issued a goal "to achieve no overall net loss in acreage and function of Washington's remaining wetlands base. It is further the long-term goal to increase the quantity and quality of Washington's wetlands resource base." Strategies for achieving no-net-loss in the short term and a net gain in the long term include wetlands enhancement, restoration, and creation. On public and private lands, restoration of degraded wetlands provides many long-term opportunities to reverse the national trend of wetland loss.

As used in this text, the term restoration applies to both regulatory and non-regulatory activities to enhance the wetland resources of Washington. Acknowledging that the regulatory or non-regulatory context of a restoration project may affect the process, this document describes the concepts and procedures of wetland restoration. This information can be applied to both the creation and enhancement of wetlands. Although the primary focus of this document is on the restoration of freshwater wetlands some coverage is provided for estuarine systems. A more in depth treatment of estuarine wetlands is offered in Appendix B.

Restoration is defined as actions performed to re-establish historic wetland functions and processes in areas where wetlands have been converted to non-wetlands (usually as a result of some past human endeavor). Some common methods used to effect wetland restoration include: fill removal, dike breaching, and re-diversion of water. Restoration differs from creation (establishing a wetland at a site where one did not formerly exist) and enhancement (improving or creating select functions, processes, and values of a degraded wetland). Improving some functions and values, however, is often accompanied by a decline in other wetland functions and values.

Experience has shown that the chances of success are greatly increased by restoring degraded wetlands instead of creating new wetlands or enhancing the functions of existing wetlands (Kusler and Kentula, 1989). The Natural Resource Council's recent report on restoration describes an " urgent need to restore large areas of wetland throughout the nation" to reverse historic losses and provide public benefits (Natural Resource Council, 1992).

Washington's Wetlands

Washington has a wide variety of wetland types, including the estuarine salt marshes of Puget Sound and the Pacific coast, the potholes and vernal pools of eastern Washington, and rugged high-elevation meadows and fens. The Cascade Mountains divide Washington into two distinct physiographic regions, with a wide range of climatic conditions and a considerable diversity of geology, soils, vegetation, and water regimes. Franklin and Dyrness (1973) have subdivided the state into seven ecoregions: Olympic Peninsula and Coast Range, Puget Trough, Northern Cascades, Southern Cascades, Columbia Basin, Northern Rockies (Okanogan Highlands), and the Blue Mountains.

The state's physiographic diversity provides for a tremendous variety of wetland types, with wide-ranging characteristics (e.g. elevation, aspect, degree of perturbation, soil chemistry, hydro-dynamics, hydro-period, flora, and fauna). An understanding of wetland characteristics and recognition of their respective regional differences are necessary for successful restoration planning.

Washington has over 2,400 miles of shoreline, primarily west of the Cascades and including the Pacific coast, estuaries and bays, Puget Sound and associated waters, and many large river systems that drain into both Puget Sound and the Pacific Ocean. Although many of the freshwater wetlands of western Washington are associated with ponds, lakes, rivers, and other shorelines, many more are isolated from surface waterbodies and owe their existence to groundwater discharge through springs and seeps and precipitation.

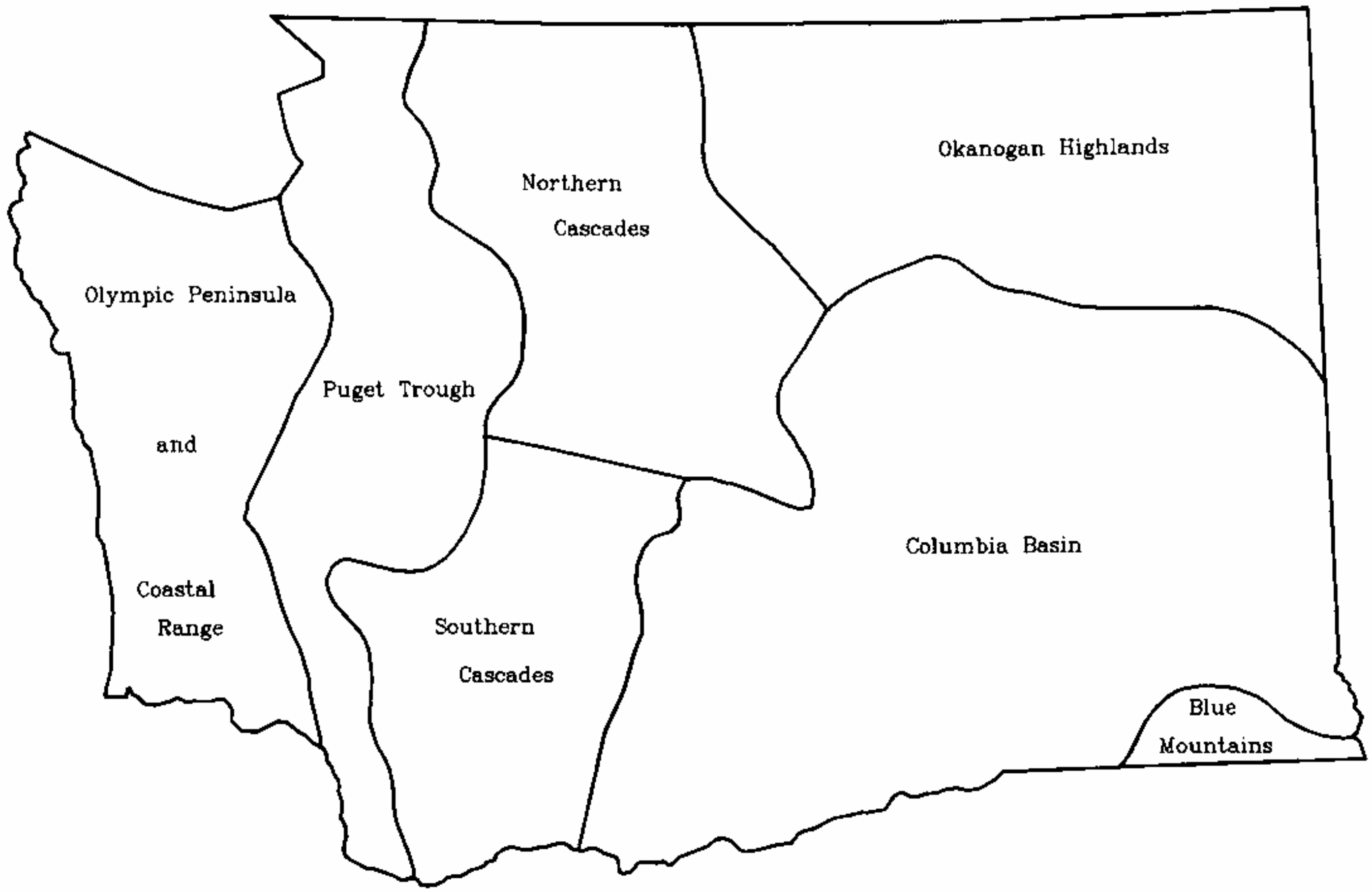
Marine, estuarine and tidally influenced freshwater rivers and streams are associated with the Pacific Ocean, Grays Harbor, Willapa Bay, and Puget Sound. It is these highly productive, richly bountiful tidally influenced wetlands that have been most impacted by human activity: over 80 percent of the state's estuaries have been lost; of those remaining, all have been degraded to some degree.

The climatic regimes of eastern Washington give rise to a variety of permanent and intermittent streams and wetlands. These wetlands are more localized in their distribution but are even more varied in terms of seasonality, chemistry, and plant species composition than their western counterparts. Very little is known about undisturbed, pre-settlement plant communities associated with wetland environments in eastern Washington.

Many existing wetlands in eastern Washington, particularly in the Columbia Basin, have been rearranged by human activities. Large hydro-electric projects in the Columbia River have produced vast expanses of open water habitat, inundating hundreds of miles of riparian habitat adjacent to rivers. Irrigation projects have created wetlands through water redistribution and elevated groundwater tables. At the same time, many valuable riparian wetlands have been eliminated by water reallocation through irrigation projects, agricultural conversion, and livestock grazing. Understanding the source of water available to restoration projects and the current land management practices are critical components to restoration planning, especially east of the Cascade Mountains.

FIGURE 1

Physiographic and Geological Provinces of Washington



(Adapted from Franklin, J.F. and C.T. Dyrness, 1973. Natural Vegetation of Oregon and Washington)

Ecological Restoration

Ecological restoration efforts in the Midwest began more than 50 years ago with the realization that almost all of the nation's tall grass prairies were gone. Under the influence of Aldo Leopold, G.W. Longenecker, N.C. Fassett, and other biologists, the 1200-acre University of Wisconsin Arboretum was founded in 1932 (Curtis, 1959). It was determined that the Arboretum was to be more than a mere collection of trees, and major emphasis was placed on amassing a collection of biotic communities. Native plants and seeds were collected and planted in the same patterns and relative abundances in which they occurred in natural plant communities. Careful observation of the restoration process led to the development of management tools such as fire, weed and pest controls, and flooding.

In the 1930s, the ravages of the "Dust Bowl" led to a flurry of restoration activity, focused primarily on stabilizing eroded soils or restoring particular economically valuable components of the land. Aldo Leopold's work was unique because it was an effort to restore entire communities that had been lost. His efforts marked the beginning of ecological restoration-- the process of intentionally altering a site to emulate the structure, function, diversity, and dynamics of a defined, indigenous ecosystem. Ecological restoration rests on the concept that in order to replicate a community, it is essential to understand the structure of the community that is being replaced and the processes that perpetuate the system.

In addition to the oldest restored prairie in the world, the work inspired by Leopold included marl fen, sedge meadow, shrub-carr, lowland hardwood, black oak barrens, and dry and dry-mesic southern hardwood forests. This restoration work continues today, providing a wealth of information about the process of ecological restoration.

In the Pacific Northwest, the oldest wetland community restoration project is the Salmon River salt marsh restoration project near Newport, Oregon (Frenkel and Morlan, 1990). The project was initiated in 1978, and restoration has been assessed over an 10-year period. The original objective of this project was to return diked pastureland to functioning high salt marsh wetlands. However, because the elevation of the diked area had subsided, reintroduction of tidal water resulted in conditions that encouraged establishment of a low salt marsh system. The low salt marsh community patterns became established within the first six years, and by the tenth year these plant communities were substantially strengthened. Today, after more than ten years of monitoring, results indicate that the site has been successfully restored to a highly productive, functioning low salt marsh. Barring any topographic or hydrologic changes, the researchers expect the restored system to be stable with respect to time (Morlan and Frenkle, 1992).

In Idaho another community approach to restoration was taken, this time on a riparian ecosystem (Stevens and Johnson, 1991). Adjacent riparian areas were used as models for plant community composition, and an attempt was made to re-create these adjacent and undisturbed riparian plant communities. During the first six years of the study some success was achieved and specific challenges were documented. Success was limited by adequacy of available water, radical fluctuations of water level in the Snake River, limited availability of native plant materials, differential plant survival, and long-term management constraints. Offsite influences such as water quality in the springs, trespasses by livestock, and invasion of exotic plant species have and continue to be the greatest challenges to long-term restoration success.

While the development of wetland restoration techniques is still in the formative stage, restoration projects are far more likely to be successful than creation projects. Restoration is merely attempting to rebuild what once existed, where creation attempts to build a completely new wetland system. However, there are no guarantees for either wetland restoration or creation. Our experiences with the Salmon River and Arboretum prairie projects have revealed that ecological maturation requires time (often more than ten years) and the associated processes are highly variable, frequently resulting in unique systems. Humans set the stage, and the natural processes form the wetland. According to Dr. Fred Weinmann (Personal communication), speaking in terms of successes or failures may not be appropriate for restoration. Instead, restoration should be assessed in relative terms, comparing the functions performed by restored wetlands with those of other restored wetlands or with pre-restoration conditions.

Restoring Wetland Functions and Values

Wetland functions are the physical, chemical, and biological processes or attributes that are vital to the integrity of wetland/upland landscape interrelationships (landscape systems). Wetland values are those attributes that, although not necessarily essential to the integrity of landscape systems, are perceived as valuable to society (Adamus, et al, 1991). According to Adamus and Stockwell (1983), scientists and managers recognize three classes of functions for wetlands: hydrologic functions (such as flood peak reduction, shoreline stabilization, or groundwater exchange); water quality improvement (such as sediment accretion or nutrient uptake); and food-chain support (structural and species diversity components of habitat for plants and animals, including threatened, endangered, and sensitive species).

Loss of wetland functions and values are often advanced as the reasons why society should prevent wetland damage or destruction. Loss of wetland function has many dimensions; most of these are very difficult to assess or quantify. Functional loss may include partial loss, degradation, or complete loss, and losses may be temporary or permanent. Losses associated with cumulative impacts have been especially difficult to assess in a watershed or region and appear to be the most significant (Sheldon, 1989).

Nearly every wetland is unique and to date the refinement of evaluation tools for assessing wetland functions and values have been extremely limited. Most wetland functions are impossible to measure within the time and budgets allotted to most projects, and therefore cannot be successfully replicated at this time. Therefore, using a reference area as a model appears to be the best way to replicate the complex functions of wetlands. In efforts to measure and replace functions, specific habitat characteristics or vegetation types are often selected as measures of overall function; attempts are then made to replace these communities, with the assumption that function will follow. However, replacing habitat characteristics and vegetation does not ensure the replacement of many other wetland functions.

Wetland restoration work that has been conducted in a regulatory context (with wetlands created, restored, and enhanced to replace wetlands lost to development) has yielded information about restoring functions and values to degraded wetlands. The basic concept (known as compensatory mitigation) is that replacement wetlands will provide the same functions and values as the original, natural wetlands. Although mitigation efforts are subject to time constraints, some of the important ingredients for success of restoration projects can be illustrated by monitoring progress.

Based primarily on evaluation of compensatory mitigation projects, the scientific community is generally pessimistic regarding the ability to successfully create functionally equivalent wetlands (Kusler and Kentula, 1990; Zedler, 1990). There have been numerous evaluations of compensatory wetland mitigation projects in the Pacific Northwest (Zedler, 1990; Gwinn and Kentula 1990; Kusler and Kentula, 1990; Pritchet 1989; Kunz, Rylko and Sommers 1988). Compensatory mitigation results have generally been poor, due to inadequate planning, faulty design and implementation, lack of compliance with site plans and specifications, lack of technical information, inadequate or non-existent monitoring, poor development and implementation of contingency plans (including linkage to monitoring results), and insufficient resource management after project implementation (Kentula, 1990). Natural systems are inherently complex, with intricate interactions and relationships that prove difficult for humans to replicate. Success is dependent upon understanding these intricate interrelationships and reinstating the physical and hydrologic features which support them.

Wetlands Within the Landscape

Wetlands exist as integral components of larger landscape ecosystems. Both hydrologic and ecological processes are strongly influenced by activities occurring throughout the watershed. For example, wetlands are integral in the hydrologic dynamics within a watershed. Logging operations, urbanization, or other disturbances in the watershed can increase flooding and drought impacts and invariably make the watershed more vulnerable to climatic change. Disturbance also adversely influences functions such as floodwater detention, groundwater exchange, low-flow augmentation of surface waters, and biological diversity. Wildlife species depend on corridors within and between wetlands and uplands for critical habitat. If the habitat becomes fragmented, the survival of certain species may be jeopardized. Impairment of water quality or quantity will particularly affect plant species diversity and amphibian and bird populations. Effective restoration requires an assessment of compatible land use activities, establishment of buffers (adjacent uplands in which upland plants provide cover and reproduction requirements for wetland-associated wildlife species) and corridors, and control of watershed disturbances. A careful evaluation of the relationship between the wetland and its surrounding watershed is essential to the success of any wetland restoration project.

An understanding of the watershed system can also provide important information that will help to establish restoration priorities. It may not always be practical or feasible to simply restore historic wetland types if land use in the watershed has been altered in such a way that these wetland types would no longer persist. Current conditions (which are usually very different from pre-settlement conditions) may influence the location and type of restoration project. Achieving the no-net-loss objective involves maintaining the integrity and diversity of wetlands in their larger landscape setting.

The science of wetland restoration is relatively young, and, as restoration practitioners, we humans are still on the steep part of the learning curve. Performance expectations of a restoration project should focus on the replacement of much needed functions and values to the wetland/upland landscape system. Exact replication of the function and value integrity of an impacted site is not a likely outcome. However, by taking a thorough approach to the design and implementation of each restoration project, and, on completion of these steps, by standing back and letting natural processes take over, a higher degree of success may be realized and a unique wetland reestablished.by taking a thorough approach to the design and implementation of each restoration project, and, on completion of these steps, by standing back and letting natural processes take over, a higher degree of success may be realized and a unique wetland reestablished.taking a thorough approach to the design and implementation of each restoration project, and, on completion of these steps, by standing back and letting natural processes take over, a higher degree of success may be realized and a unique wetland reestablished.

Program Planning

Although most restoration actions are performed at the project level, these actions are more likely to achieve their goals and objectives if guided with a geographic or landscape perspective (i.e., watershed (size may vary), habitat corridors, local flyway requirements, ecoregion subset, or geomorphic boundary). In this section, the steps for establishing a wetland restoration program to guide the implementation of specific wetland restoration projects are described. The following section describes planning that is necessary at the project level.

Development of a restoration program begins with the adoption of goals and objectives. This is an important step toward setting the program in motion, allocating funding, and measuring success at achieving the desired end results. Goals and objectives should guide restoration activities to effectively maintain whole, functional systems on the landscape. Because restoration programs should outlast any individuals associated with them, stated goals and objectives will help ensure program consistency.

Program Goals. Program goals are usually set by state or federal agencies. For example, a goal of no net loss of wetlands functions and acreage has been endorsed at both the federal and state levels and by some local jurisdictions in Washington, such as the City of Bellevue and Pierce and King Counties. Other goals may focus on retaining estuarine systems or other special interests and needs of the local community or region. While goals will provide direction for the program, some degree of flexibility is appropriate to accommodate additional high quality sites.

Program Objectives. Objectives that address both the recovery of degraded or lost wetlands and the reduction of any future adverse impacts are essential to meet the goal of increasing the quantity and quality of Washington's wetlands. Where such regional programmatic goals and objectives are in place, the discrete project actions should be planned to meet them. For example, objectives for a restoration project in a watershed where estuarine wetlands have been lost through diking and drainage ditch construction might focus on the removal of these dikes and ditches. Wetland preservation programs could focus on acquisition of high-quality estuarine areas, and other programs could focus on the enhancement of other degraded estuarine sites.

The objectives of regional plans developed to meet the goals can include any or all of the following:

To avoid any degradation of existing wetland or upland habitats;

- To recover historic or scarce wetland types;
- To replicate existing wetland types;
- To restore particular wetland functions (e.g., the habitat of an endangered species).

Restoration Program Planning

After program goals and objectives are firmly in place, a plan for their achievement is necessary to facilitate planning for restoration projects. Such a plan should identify:

Responsibility for program administration (usually given to a qualified resource planner). One person should be identified to oversee activities, address problems as they arise, and ensure that program goals are met. Establishing links between departments, agencies, or other players involved in restoration is also essential.

Types of information and levels of detail needed for wetlands restoration. In general, by gathering as much detailed information as possible, the best, most informed decisions can be made. However, the time and cost of acquiring increasingly detailed information must be weighed against the anticipated benefits to the wetlands protection program.

Criteria for the objective selection of restoration projects. Such criteria can help direct program efforts to those projects of greatest benefit to the watershed and the overall program.

Standards and procedures to guide restoration actions. Certain wetland systems may be ill-suited for restoration. Therefore, it is important that clear definitions of appropriate and inappropriate sites be included in the adopted standards of a restoration program.

How the program will be managed and monitored. Establishing general management directives will help guide project actions. During project implementation, the general management directives of the program will be supplemented with more specific directives that address individual project management needs.

Inventory and Gather Data. To obtain an understanding of the role discrete wetlands play within a watershed, it is important to document wetland locations and to characterize the functional attributes of each wetland that has been located. From this information, the interrelationships among wetlands can be assessed within the context of the watershed.

A comprehensive wetlands inventory is a research effort designed to collect data on the presence, extent, condition, characteristics, and functions of wetlands within a defined region. Such an inventory will help to document the status of the wetlands resource within a jurisdiction. Techniques for conducting wetlands inventories are contained in *A Guide to Conducting Wetland Inventories*, publication #89-60 of the Washington Department of Ecology (Ecology). Ecology maintains information on Washington jurisdictions with final, partially completed, or ongoing wetland inventories (described in the *Resources* section of this publication).

By integrating information from the National Wetlands Inventory (NWI) maps prepared by U.S. Fish and Wildlife Service (USFWS) and the "hydric" soil map units from the U.S. Department of Agriculture (USDA) Soil Conservation Service's soil survey maps, a baseline map of potential wetlands within the watershed can be prepared. Experience with compiling these baseline maps in Washington has shown that some wetland types, particularly wet forests, are not reliably identified by this method; other areas may be erroneously identified as wetlands. A more accurate picture of the presence and extent of wetlands can be derived through aerial photography and ground-truthing. During ground-truthing, wetlands can also be characterized and functional attributes assessed. Depending on the level of detail desired, in-depth function and value assessments can be performed by applying best professional judgement or evaluation procedures such as the Habitat Evaluation Procedure (USFWS, 1980) or Wetland Evaluation Technique (Adamus and Stockwell, 1983). Applied in the field, Ecology's wetland rating system provides a means for obtaining some additional information on wetland quality and restoration potential (Ecology, 1991).

Determining the locations, types, and conditions of historic and degraded wetlands is particularly important in planning a restoration effort. By correlating this information with other data on existing wetlands, a wealth of potential restoration sites can be identified. For example, surveyors' records, general land office surveys, old photographs, diaries, and herbarium collections may provide information to assist in the determination of historic distributions of wetland types, previous water regimes, past species abundances, and former rare plant locations. Soil surveys and aerial photos can be used to identify areas with drained hydric soils, or soil surveys alone can be used to reveal undrained hydric soils or describe soil characteristics and drainage patterns of disturbed wetlands.

Identifying land ownership and management patterns are also important parts of the preliminary program planning effort. Some management information can be gathered from conversations with local planning staff and the examination of aerial photos, zoning maps, and parcel maps. More detailed information on other management issues-- the extent of livestock grazing, possible agricultural use, run-off from golf courses and lawns, erosion from poor management practices, slope failure, population density and use patterns, and ecosystem integrity and quality-- can be derived from an aerial survey, or, depending on road access, from a "windshield" survey and analysis. Such information may indicate where restoration projects might be most needed, more compatible with surrounding activities, and more efficient and cost-effective.

As part of the inventory process, information can be gathered and presented as a series of overlay maps. These overlay maps are then used with selection criteria to identify potential restoration sites.

Known high-quality wetlands may be used as models, or templates, for restoring degraded wetlands. For this reason, it is important to identify remaining high-quality wetland sites within a watershed and to assure that these sites are obtaining adequate protection through acquisition, voluntary protection, and/or regulatory programs. Impacts to these areas should be avoided.

The Washington Natural Heritage Program of the Washington Department of Natural Resources

(DNR) has inventoried native plant communities and identified some remaining pristine wetland communities in various parts of the state. The Washington Natural Heritage Program and the Washington Department of Wildlife (WDW) maintain databases with information on known locations of rare plant and priority animal species (presented as Appendix B of this document). WDW also maintains information on migratory bird concentrations.

Establishing Selection Criteria. Information obtained in the inventory and data-gathering processes should provide an understanding of current and historic locations, conditions, functions, and ownership and management of wetlands. Selection criteria can be used to establish priorities for restoration. By correlating data from these sets, it should be possible to identify those highest-quality wetlands that are best suited to preservation/acquisition efforts, those adequately protected by regulatory efforts, and, ultimately, those sites where restoration work should be considered.

Selection criteria that have been developed for wetlands preservation programs include hydrological, biological, and cultural functions of wetlands and their ecological integrity, community needs and opportunities, site liabilities, availability of public access, and management costs. Detailed discussions of these criteria are contained in Ecology publication #92-18, *Designing Wetlands Preservation Programs for Local Government: A Guide to Non-Regulatory Protection*. These considerations should be augmented with specific restoration criteria which include:

- The commitment of landowners to restore and permanently protect the wetland or the landowner's willingness to sell the site;
- An evaluation of sites that provide opportunities for improving functions and values, including an evaluation of existing functions and values on sites that would be lost or impacted by restoration;
- An assessment of the feasibility of successfully restoring the site, including an evaluation of current and projected use of the land in and around the potential restoration site and an assessment of the landscape and potential problems that could affect the outcome of the restoration project;
- Consideration of the estimated cost of the restoration project and availability of funds to plan, implement, and provide stewardship for the site (Zeigler, personal communication).

Selection criteria can be applied in a phased or sequential approach. Which criteria are applied at what stage in the process is largely a matter of individual choice. Sites that are inappropriate for further consideration can be eliminated initially, preventing any unnecessary assessments of site attributes. This process can be used to identify an initial list of sites with restoration potential under the program. From this list, areas can be prioritized and targeted for immediate action (within a time frame of 2 or 3 years).

Establishing Procedures and Standards for Implementing Restoration Projects. Clear definitions of appropriate and inappropriate sites are needed for restoration work. Principles to consider in framing such definitions include:

That the restoration site be a former wetland that has been historically impacted and degraded to a degree that it no longer performs its original functions;

That in its current state, the site should provide only limited habitat values (For example, a former wetland that currently provides excellent upland habitat values might not be readily considered for a wetland restoration; however, a wetland vegetated by planted pasture grasses on mineral or organic soils with an available source of hydrology would provide excellent restoration opportunities). Restoration projects initiated on low-diversity wetlands with mineral soils and available sources of water have experienced the highest degree of success. Peat soils with any remnant native plants would make good candidates for protection efforts (for example, buffer enhancement), but not for restoration efforts which could cause disturbances to the soils or hydrology. However peat systems that have been cropped or are extremely disturbed would be appropriate restoration sites.

In general, high-quality wetlands that contain native plant communities or provide habitat for plants or animals with special protection status should not be considered as possible restoration sites without thorough environmental assessment. Restoration of high-quality wetlands would be appropriate in some instances-- for example, if the site is being invaded by exotic or highly competitive native plant species or if the project goal is to enhance habitat for threatened, endangered, sensitive, or priority species. High quality wetlands include sites identified by the Washington Natural Heritage Program as an "element occurrence"; sites with Category 1 designations under the wetlands rating system developed by Ecology; mature forested wetlands; bogs and fens; high-quality estuarine areas; and large, diverse scrub-shrub or emergent wetlands.

High-quality regionally rare wetlands (such as peatlands and forested, estuarine, kelp, or eelgrass-bed wetlands) are sensitive to disturbance and take a very long time to recreate. In most cases, restoration of high-quality wetlands should be avoided, and preservation is the preferred option.

A program plan should also specify the means of determining whether program goals and objectives have been successfully met. These should provide a direct, quantitative approach for measuring progress-- e.g., the functional replacement of historic saltwater marshes within a particular estuary.

Milestones for implementation of the program plan (including tasks and time frames for completion) should also be established. For example, a program milestone might be to restore three estuarine wetlands within a 2-year period.

Maintaining documentation of restoration activities is seldom considered under restoration projects. Consequently, useable information on restoration successes and failures is limited. This lack of information hinders the evolution of successful restoration efforts and contributes to continued resource loss without adequate replacement. A restoration program should establish documentation requirements that are mandatory for all projects.

The potential for success in a wetland restoration program will be maximized when the practitioner follows the advises outlined in the preceding pages. With commitment, patience, and attention to detail we can more effectively restore that which once was.

The following chapters provide more detailed information that will guide the restorationist on the project level. The chapters are presented in sequence according to the steps involved in the development and implementation of a restoration project:

Chapter 2, *Project Planning*, is a brief presentation of important planning steps necessary on the individual project level that are best taken at an early stage.

Chapter 3, *Site Assessment*, describes the steps in assessing existing site conditions, including a wetland delineation of the existing site, function and value assessment of the habitats present, the presence or absence of adequate soils and hydrology, and potential offsite impacts such as stormwater input.

Chapter 4, *Preliminary Restoration Design* explains how to develop a preliminary site design from which the feasibility and practicality of the proposed restoration can be assessed.

Chapter 5, *Final Restoration Design and Implementation*, offers an overview of the detailed elements that must be provided in construction plans-- grading elevations, planting plans and details, scheduling, and detailed hydrologic analyses.

Chapter 6, *Monitoring*, contains information needed to develop an ongoing monitoring plan.

Chapter 7, *Management of Restoration Sites*, provides information on both short-term and long-term stewardship of restored wetlands.

A guide to restoring estuarine wetlands, an overview of regulations pertaining to work in or near wetlands, a directory of sources of technical and financial assistance, and other helpful information for restoration projects are presented as appendices to this book.

CHAPTER 2: Project Planning

Project planning begins with the formulation of goals and objectives, ensuring that those actions that are most likely to achieve restoration success will be implemented. This step is particularly important for mitigation projects, in which specific expectations of wetlands replacement must be met. However, because most projects must achieve certain broad, regional objectives (for example, to retain functional ecosystems on the landscape), the process of drafting goals and objectives is also important for non-mitigation projects. If a restoration program plan has already been created for a watershed or region, these general goals and objectives will prove helpful in defining the more narrowly focused goals and objectives of each project.

Although the goal of a restoration project may be "to restore a specific function," most functions and values are not readily quantified. To evaluate the success of a restoration project, it is essential that adopted objectives are expressed in measurable terms. Convenient "measures of success" include various water quality parameters, plant and animal species compositions, and the survival rates of various wetland plants.

Getting Started:

Permits and Project Approval. Gaining approval for a restoration project in general and some individual permits in specific is an ongoing and sometimes iterative process. As a result this step is conducted concurrently with other project steps and is introduced here to provide a context for project development.

The appropriate permits and project approvals should be obtained as early in the project design process as possible. The permit process should be initiated at the local level and begin with consultations with permitting agencies prior to plan development, thus encouraging flexibility in site design and leading to reduced costs. Most restoration projects must be reviewed under the State Environmental Policy Act process. If a permit is required for placement of fill according to Section 404 of the Clean Water Act, the permit process is particularly likely to cause some project delays and require modification of project design. Information on those restoration activities that may require permits from state and local government is presented in Appendix D.

Sources of technical assistance for restorationists are contained in Appendix C.

Reference Sites

In restoration, the ultimate reference site is the historic wetland itself in its pristine or nearly pristine condition. If this information is available (i.e., historic plant lists, old photographs, site descriptions, etc.) it should be used as the project reference conditions. If this kind of data is not available other reference sites can be selected in order to provide a model for restoration planning and to establish a control with which to gauge the degree of restoration success. Each reference site provides baseline data that can be used for developing design, construction, and monitoring guidelines. The reference site may be an existing wetland that exhibits the structure and functions to be replicated at the restoration site. Under certain circumstances, it may be advantageous to choose several different reference sites, each reflecting some of the desired characteristics or communities of the actual restoration site.

From detailed information on the composition of the reference communities, the complex functions of specific wetlands can be approximated. However, characterization of reference communities may be quite difficult. No two wetlands are identical in species lists, physical parameters, distribution, or ecological processes, and information on the microtopography of most wetlands (especially in peatlands and interdunal areas) is usually difficult to obtain. The significance of mycorrhizal relationships and other long-term contributing factors such as soil morphology and hydrology are poorly understood. Seasonal variability can also complicate attempts at characterization, as can extreme naturally occurring events (e.g., flooding, fire, wind, volcanoes) and human impacts throughout the watershed (Zedler, 1990; Franklin, 1990). Long-term changes such as sea level rise, biological succession, or human error (oil spills, toxic waste spills, leaking underground storage tanks) are impossible to predict or account for.

Choosing A Restoration Site Carefully

Engaging in any restoration action is a waste of time and money unless long-term stewardship of the restored wetland is assured. Therefore, restoration activities should only be undertaken on public or private lands that have been designated for long-term preservation.

The Washington Natural Heritage Program is in the process of creating preliminary classification systems for wetland systems in three regions of Washington State: Puget Trough, Southwestern Washington, and the Olympic Peninsula. These classification systems are based on extensive field work in pristine wetland systems and will provide excellent characterizations of native wetland communities. Information on this work can be obtained from the Natural Heritage Program. A description of estuarine and marine wetlands can be found in Appendix A. This information may guide the identification of appropriate reference communities for wetland restoration.

Data on the structure and functions of Puget Sound's urban and suburban freshwater wetlands are provided by the Puget Sound Wetlands and Stormwater Research Program. To evaluate localized stormwater impacts, this program has compiled and analyzed long-term floral, faunal, and hydrologic data from 16 wetlands within Puget Sound (Azous, 1991; Cooke, 1990, 1989; Richter, 1991, 1990, 1989; Horner, 1986, 1982). These wetlands may serve as valuable reference sites for Puget Sound wetlands in urban and suburban environments. The Puget Sound Estuary Program of the U.S. Environmental Protection Agency has assessed the functions and structure of estuarine systems and published its findings in *Estuarine Habitat Assessment Protocol*.

Reference Site Criteria

Criteria for identifying appropriate reference sites should be derived from the goals and objectives of the restoration program. The overall objective of such identification is to find the highest quality sites with similar characteristics to the project site and within the same watershed as the project site. Selection criteria can be influenced by the goals of restoring specific functions or values, replicating the most pristine wetlands within individual basins or watersheds, or restoring wetland community types that may have once existed but are no longer represented or scarce. Additional considerations for selecting reference sites include:

- How the wetland's overall size, shape, and position in the watershed as well as the composition, distribution, and relative condition of plant communities are comparable to those of the restoration site;
- How similar the site's sources of water are to those of the restoration site;
- If soil types and substrates closely match or approximate those of the restoration site;
- If fish and wildlife habitat features can be created within the restoration site;
- If the historic, chronic, and potential disturbances (including land use activities) that influence the quality of water entering the wetland are similar to those of the restoration site;
- Whether permission to conduct sampling can be obtained from the owners of reference site properties.

Reference sites from the same geographic area as the restoration site may be more likely to display characteristics similar to the restoration site. Ideally, a reference site should be located within the same wetland complex or basin as the restoration site, thereby providing a degree of certainty that the restored wetland will ultimately be adapted to specific conditions within the watershed.

CHAPTER 3: Site Assessment

During the early stages of a restoration project, information is collected and evaluated to understand conditions at proposed restoration or impact sites and reference sites. From this assessment, the feasibility, scope, and cost of restoration projects can be estimated. Many of the tasks required to complete projects can also be identified during this assessment.

For a site assessment, information on a number of wetland attributes must be collected. These attributes include:

- Wetland system
- Hydrology
- Topography
- Soils
- Wetland boundary delineation
- Water quality
- Ecological communities
- Wetland values and functions

Each of these attributes is discussed in this chapter. Detailed descriptions of methods for collecting data on each of these attributes are provided in Chapter 5 of this document. Data collected for site assessments can also be used as baseline data for comparison with post-restoration wetland data. Therefore, it is essential that data collection methods for site assessment be identical to those for post-restoration monitoring.

Before any field assessments are begun, all existing information on the topography, hydrology, soils, and ecological communities of the restoration site should be compiled. The compiled information may be presented as paired base maps, one at a scale of 1" = 2,000' and the other at a scale of 1" = 400'. Large-scale maps are useful for recording detailed site information, and small-scale maps, which show wetlands within a watershed, can be used to record information on offsite attributes. Any additional information collected from existing sources or field studies should be added to copies of these base maps. Some common sources of this information are listed in Table 1.

TABLE 1: Information Sources for Restoration Site Assessment and Design

General map, using the U.S. Geological Survey Quadrangle (1:24,000 or 1:25,000)
Site map (scale 1":400'or larger)
Topographic map of the project area, preferably with 2-foot contour intervals
Aerial photographs, with overlays displaying property lines and restoration site boundaries
Site designated on a USFWS National Wetlands Inventory map, local government wetland inventory map, or USDA Soil Conservation Service (SCS) Wetland Inventory Map
Site designated on a Soil Survey Report soils map, with soil profile information included

NOTE: *Unpublished knowledge of the site by conservation personnel, researchers, amateur naturalists, neighbors, public works departments, local government officials and others should not be overlooked as important sources of information.*

Following this preliminary data collection, a detailed site assessment should be conducted. This second assessment ideally includes extensive field observation, performed over a period of at least one year prior to initiating any restoration work. From such observation, an adequate understanding of natural variation in the ecosystem can be obtained. Because many wetland functions are influenced by seasons, knowledge of the seasonal variations within reference and restoration sites is essential in developing a restoration plan.

Site assessment data collected at the restoration site, the reference site, and/or the impact site should be used to establish specific objectives and performance standards for the proposed restoration project. Often the reference site serves as a guide for replicating the same conditions at the restoration site.

Wetland System Disturbances

Wetlands are part of the chemical, hydrologic, and biologic system that includes both the uplands and wetlands within a given watershed. The degree of disturbance and development adjacent to the wetland and within its landscape greatly influence the functions and fate of the restored wetland. For example, typically in large urban areas, the water regime has been altered, water quality impaired, wildlife corridors have been degraded or destroyed, and native plant communities displaced by invasive species. Within this landscape, restoration of a wetland site to a predisturbance state will not be possible, and restoration goals should reflect these constraints. Conversely, for a wetland site within an area that has not been disturbed, restoration efforts will benefit from the site's connection to other natural systems.

Conditions in a watershed may have changed dramatically since a wetland was first observed, and the existing conditions may continue to change. To design a project that can persist in the face of such change, it is necessary to understand any existing and potential offsite influences to wetlands. Such influences on the persistence and viability of a restoration site include other wetlands in the area, associated water sources, adjacent uplands, and migration corridors. The presence of exotic or invasive plant or animal species, drainage structures, filled areas, or any other signs of past or chronic disturbance should be studied. Filled areas may contain contaminated soils or toxic waste, especially in wetlands located near industrial centers. Testing may be needed to determine whether fill soils are contaminated and need special handling. The potential for weed invasion, water quality problems, animal depredation, erosion or slope failure, and flooding or channel relocation should also be determined.

The viability of restoration projects has frequently been threatened by impacts from the surrounding landscape. These impacts have been well documented (Kentula 1990) and commonly include:

- Invasion by exotic plants and animals, including reed canary grass, purple loosestrife, domestic pets, bullfrogs, and rats;
- grazing by geese, muskrats, and other animals;
- destruction of vegetation or the substrate by floods, erosion, fires, and other catastrophic events;
- stormwater (particularly with heavy metals), septic leachate, sediment, nutrient

- and pesticide (weed and feed) fluxes, toxins, garbage, off-road vehicles, and
- groundwater pumping.

Boundaries And Delineation

Wetland boundaries can be located on National Wetlands Inventory maps, local wetland inventory maps, or both types of maps. Regardless of which type is used, additional field delineation work will be necessary to establish accurate wetland boundaries.

If the site is being assessed for compensatory mitigation, a detailed delineation report, using the currently accepted federal wetland delineation manual, must be prepared to establish the exact location and extent of all onsite wetlands.

Hydrology

Establishing and maintaining the appropriate hydrology is the most critical factor in wetland restoration. Thus, a thorough analysis of hydroperiods (the seasonal occurrence of flooding and/or soil saturation) within watersheds must be conducted, evaluating wetlands within a watershed to assure that available volumes of water on the restoration site are adequate for replicating the conditions of reference communities. Such an analysis includes identifying and characterizing all springs, groundwater, flood-water, tidal water, rainfall or snowmelt, irrigation overflows, and other surface and subsurface sources that enter and exit the site. Seasonality of these sources (e.g., whether irrigation waters are available only in mid- to late-summer months) should also be considered. Water quality and quantity must also be determined, including the maximum and minimum volumes and rates of surface or piped flows that can be expected during seasonal, annual, 10-year, and 100-year periods. The overall condition of the contributing watershed and anticipated future impacts to the water regime of the restoration site should also be examined. For example, changes in water quantity, quality, and rate of flow may be observed in urbanizing watersheds.

The hydrology of a wetland defines most of the ecological characteristics (for example, the composition of plant and animal communities) that will eventually become established. Problems associated with topography, configuration, jurisdictional connections, plantings, and control of nuisance and exotic species can only be solved if the site has an appropriate hydrologic regime (Bacchus, 1991).

Alterations to surface or groundwater, particularly through transfer of water rights, groundwater withdrawal, or drought can effectively impair restoration and mitigation efforts.

The likelihood of meeting the identified objectives is low if the elevation of the water table is not controlled, if wetland creation efforts are far from surface or groundwater sources, or when fluctuating water tables exceed expectations. Results can be unpredictable, even if water control structures are in place.

Restoration Success Depends On The Quality Of A Site's Hydrologic Conditions

The Puget Sound Wetlands and Stormwater Management Research Program has conducted several studies in Puget Sound wetlands. The results of these studies can be particularly useful for restoration planning in urban and suburban areas where watersheds have been disturbed. Analysis of data compiled by the program has indicated that alteration of stormwater runoff can result in increased peak flows, as well as prolonged and intensified seasonal drought conditions (Azous, 1991). Wetlands with high water level fluctuations are characterized by poorer plant diversity. Invasive weedy species are given a competitive edge through alteration. In particular, the numbers of sedges and rushes may decrease in areas with altered water regimes. Wetlands with high plant diversities can be correlated to relatively high water quality and limited alteration of area hydrology by humans. The existence of many natural wetlands (e.g., vernal pools) is contingent upon dramatic seasonal water level fluctuations that are easily disturbed.

Program research has also revealed that amphibians and mammals depend on high water quality and relative freedom from predators such as cats, dogs, rats, and bullfrogs. The availability of a preferred plant and the overall water quality are the most significant associations with mammal richness. Bird species richness tends to be correlated to high plant structural diversity and wetland size.

To gather adequate baseline information, hydrologic data on proposed restoration or reference sites should be collected, if possible, in all seasons for several years. However, the quantity of water that is stored by or flows through the site during winter months may be a significant factor for flood retention and water quality considerations.

After watershed hydrology has been analyzed, the relationship of water movement to topography for both the existing site and reference communities must be established. Because the distribution of wetland plant communities is largely determined by the hydrologic gradient of a site, the gradients of reference sites must be carefully analyzed before they can be replicated at restoration sites. Seasonality and depth of surface and subsurface waters are the most important factors in the survival of wetland plantings. These factors also greatly influence the ability of wetland plants to compete with upland plants. Using data on water depth, a profile of the site should be drawn.

Some restoration projects may allow enough flexibility in the construction schedule to design for a lag time between the grading and flooding phase and the planting phase. The benefits of this approach include a greater certainty of the topographic and hydrologic balance to be expected at the site, and more definite reference points for use when designing site planting plans. Furthermore, natural revegetation will begin within the first growing season and plants will become established in the most appropriate soil moisture zones. While natural revegetation can be a benefit, it is also a time when non-native aggressive species can gain a decided advantage over slower growing native plants. By delaying planting the restorationist can return during the following growing season, locate non-native plant problem areas, eliminate these species and proceed with an appropriate revegetation program. Delaying planting for one season or timing earth work for early fall and planting for the following spring can add confidence and improve the success of a restoration project.

The frequency, duration, and depth of inundation appear equally important for determining the water regime that is necessary for maintaining healthy wetland systems (Bacchus, 1991).

Correlations should be made between hydrologic patterns and plant community composition.

Water Quality

Water quality may vary tremendously both within and among wetlands over time. Within a wetland, water quality is influenced by many factors including water sources (e.g, precipitation, groundwater, stormwater, and surface water) and annual, seasonal, and diurnal variations in water quantity, velocity, and chemistry. Size, topography, geographic location, and adjacent land use also influence the water chemistry of individual wetlands.

Measures of water quality provide important insights into restoration potential. Unfortunately, state water quality standards specific to wetlands have not yet been established, and appropriate parameters must often be determined on a case-by-case basis. Nonetheless under most circumstances, water quality parameters such as conductivity levels, temperature, Total Organic Carbon, fecal coliform, enterococci, oil and grease, total nitrogen, phosphorous, Ph, heavy metals and other elements should be measured to provide baseline conditions. The nature of each restoration project will dictate the selection of parameters that will provide information necessary to plan the restoration project. Water quality monitoring in wetlands involves measuring both the soluble and insoluble elements present in the water column. Additional information on water quality parameters is presented in *Guide for Wetland Mitigation Project Monitoring* (Horner and Raedeke, 1990), a publication of the Washington State Transportation Center. Information is also presented in Chapter 5 of this guidebook.

Topography And Soils

Proper water depths are an important factor in the establishment and maintenance of wetlands (Garbisch, 1986). A topographic or bathymetric survey of the restoration site, correlated with tidal or other water level data, is an essential tool for the restoration planner. Contour intervals of the survey should be 6 to 12 inches in deeper portions of the wetland. They should, however, be a maximum of 6 inches or less (preferably 1 to 2 inches) in areas of the wetland that are expected to produce cattails and other emergent hydrophytes.

It is important to determine soil types and characteristics in relation to the targeted vegetation communities. Certain species will only thrive on saturated peat soils and others on impervious clay or well-drained sandy soils. Soil characteristics such as texture, pH, nutrient content, and degree of compaction are important factors that influence plant growth. The soil's potential to pond and release water is also a primary consideration for reviewing potential restoration sites. Most emergent species will only emerge from 1 to 2 inches of water. Soil information acquired during site assessment may influence the planting plan for a site and help determine the need for soil amendments. A soil seed bank study can be performed to determine the presence of desirable and undesirable plant species. This information may influence the planting plan and help assess whether salvaging topsoil or planting is necessary (Glass, 1989).

Soils are generally classified as either organic or mineral (Stevens and Bursik, 1990). Mineral soils may be distinguished by texture and drainage class. Fine textured soils (such as silty clay loams) and poorly or partially drained clays make good restoration candidates. These are usually listed by the SCS as "hydric soils" or "drained hydric soils." Organic soils are identified by the amount of plant material that can be distinguished. In organic peats, less than one-third of this material is decomposed, and more than one-third is decomposed in organic mucks. The components of organic soils are easily disturbed. These soils should be handled and stored carefully.

Soil texture and drainage class information is contained in Soil Survey reports and state hydric soils lists, available from the SCS. Soil survey information can also be obtained through each county's Cooperative Extension Service, local planning departments, and libraries. Within a Soil Survey report, each soil map unit is described in detail with respect to its morphology and classification. These detailed descriptions can be very helpful in determining the properties of soil units. In the Pacific Northwest, it is common to have small "inclusions" of differing soils within the larger mapped units of upland soils. Descriptions of mapped soil units often include brief discussions of these "inclusions," which can be very helpful for determining the potential presence of hydric soil pockets within mapped upland soil units.

The following steps are recommended for assessing soil characteristics, prior to developing a restoration plan:

> A copy of the SCS County hydric soil list should be obtained.
>
> Soil mapping units, drainage classes, topographic positions, and soil characteristics of the wetland should be compiled from the Soil Survey report. The survey's text and tables should be studied for relevant descriptions or soil properties. For example, a drainage classification may note that soils are "very poorly" drained or have winter ponding. Text and tables will often describe the relative locations of perched water tables near the surface. Any specified limitations of construction and building may actually be attributes for wetland restoration.
>
> The existing soils on the restoration site must be analyzed and mapped to determine their types, extent, depths, and locations. Soils analysis should be conducted prior to extensive design work, providing data that will direct the design and location of specific restoration elements. Soils can be exposed for analysis with hand-dug soil pits and auger holes; however, for the most efficient analysis, a large soil drill may be needed.
>
> Because soil texture, Ph, nutrient content, degree of compaction, and other characteristics may influence plant growth, soil information developed during the site assessment phase may influence the planting plan developed for the site and help determine the need for soil amendments.
>
> Each county's soil survey report includes a discussion of soil capabilities for holding water or allowing infiltration of perched water tables within the restoration site. If feasible, a map of soil characteristics of the proposed restoration site should be prepared.

Ecological Communities

As discussed in Chapter 2, effective restoration efforts hinge on detailed information on plant communities at restoration sites and, if applicable, at reference and impact sites. If the existing site is to be used as the reference community, then plant species densities, distributions, and relative abundances should be recorded in detail so that the restored community can mimic natural patterns. Less intensive plant sampling may be appropriate at highly degraded sites. A wetland ecologist familiar with the wetland communities in the area should determine which specific sampling regime to use.

A plant inventory should be conducted at intervals during the growing season to ensure that most species are sampled. The USFWS Wetland Indicator Status of each species should be provided (USFWS, 1988). If sampling is only performed once, it should be conducted during the portion of the growing season when the majority of species can be identified.

Classification of wetland plant communities should follow the classification scheme of USFWS, as described by Cowardin (1979). For each sample collected, data on species present, density, distribution, and relative abundance (measured by the percentage of cover) of each dominant species in each community should be collected. This data can be analyzed to determine the potential for plant salvage or propagation and to identify potential weed problems. Plant community structure, species mosaics, age distribution, connection and proximity to known water bodies, known or suspected wildlife use, habitat features, evidence of recent or historic disturbances, and relationships with adjacent habitats should also be evaluated. Plant species and communities should also be mapped relative to soil and hydrology data.

Understanding the ecological processes at a site can also be very helpful in developing a restoration plan. Factors such as disturbances to the hydrologic regime; the presence of colonizing species (e.g., annuals and propagules from wind-dispersed seeds); alteration of soils from compaction, placement of fill dirt, or the removal of native wetland topsoils; and the presence of invasive plant materials, herbivores, or predators are all reasons for closer inspection. These factors may lead to increased management costs and responsibilities.

The distribution and abundance of exotic species such as reed canary grass (Phalaris arundinacea), purple loosestrife (Lythrum salicaria), Eurasian milfoil (Myrophyllum spicatum), common reed (Phragmites australis), creeping Canada thistle (Cirsium arvense), and other aggressive plants should also be considered during development of the restoration plan. If these species are already present at or near the site, plans for controlling them and other problem species should be developed. Adequate control of these species may be difficult or impossible. If seeds are present in the soil, and the soil is disturbed, it is extremely difficult and costly to contain their spread. Sites with heavy infestations of these species may not be suitable for restoration.

Potential donor sites (sources of wetland plant seeds, rhizomes, or fragments for establishing new populations) may be identified during the assessment. "Passive donor sites" are sites that are upgradient from and linked hydrologically to the restored wetland. Active donor sites are existing wetlands with plant populations that are needed at restoration sites. Seeds and plants should be harvested with great care to avoid damaging donor sites.

Wildlife and domestic animals may impact restoration efforts. Livestock, deer, beaver, muskrat, nutria and waterfowl (especially Canada geese) are the most commonly reported species limiting successful establishment of wetland vegetation. Bullfrogs, starlings, carp, rats, domestic pets and other feral animals have limited the establishment of native fish and wildlife populations. If these species are known to occur at or near a restoration site, plans to manage herbivory and predation will be necessary prior to installation of plant materials.

Wetland Values And Functions

Because the goal of most restoration projects involves the re-establishment of specific wetland functions or increase in specific values, it is critical to understand the existing conditions of restoration and reference sites. By comparing functions of restoration sites with those of reference sites, the extent of the needed restoration effort can be determined. Wetland functions that must be reintroduced can also be identified in this way. General wetland functions and values that are often evaluated include: water quality improvement, ecological habitats, floodflow alterations, groundwater exchange, and recreation/aesthetics.

The best professional judgement of the region's wetland scientists and professionals is considered the most reliable mechanism for assessing these attributes, making any assessment a qualitative task. Semi-quantitative methods such as the Wetland Evaluation Technique (WET) and Habitat Evaluation Procedure (HEP) should not be the sole assessment techniques for basing a restoration plan because the applicability of these varies with the specific functions, values, and wetland types to be assessed.

In the following sections, some general information pertaining to wetland functions is presented.

Water Quality Improvement. By slowing the movement of water and causing sediments and their associated pollutants to settle and be deposited within the wetland substrate, wetlands can improve water quality. The surfaces of leaves, stems, and litter from dense herbaceous and woody wetland vegetation can physically catch and filter suspended sediments. Wetland vegetation provides extensive attachment surfaces for bacteria, which are the primary mechanism for nutrient (nitrogen and phosphorous) reduction. Certain toxins can be broken-down by plant metabolic processes, and other toxins remain within the plants' biomass until the plants decompose. Plants that decompose slowly throughout months with high water flows are often excellent sources of biofiltration. Small sediment particles may also settle in standing open-water ponds, providing some additional improvement to water quality.

Ecological Habitats. The function of ecological habitat is among the easiest to restore in wetlands and their buffers. HEP models for individual wildlife species or groups of species can be used to identify critical habitat features that can be restored. The variables specified in these models can also be used as monitoring criteria.

Several features have been identified by wetland ecologists as components of high-quality habitat. These features include:

- High structural diversity, especially emergent, shrub, and forested canopy layers for birds;
- Adequate buffers to protect native plants and to provide key components of habitat;
- Undisturbed corridors between rivers, streams, wetland systems, intact upland habitats, and other natural areas;
- High diversity or abundance of native plants and animals;
- Either seasonal or intermittent open water; and
- Absence of rats, bullfrogs, and other introduced predators.

Floodflow Alteration. Assessing a wetland's ability to provide for flood attenuation (storage) and desynchronization is an extremely complex task. Wetlands located within floodplains of streams and rivers are usually assumed to provide some attenuation of flood flows. To accurately assess this attribute of a wetland function, detailed topographic information about the wetland, its watershed, and its relationship to its floodplain is needed before the storage capacity of the wetland at the time of runoff (relative to the quantity of discharge) can be calculated.

The value of wetlands for flood water storage is most often limited during mid- to late-winter, when soils within the wetland have become fully recharged after months of precipitation. During long, slow precipitation events, some wetlands in the Pacific Northwest may actually be "filled" by flows from their upper basins, severely limiting the wetland's function as an attenuator. Wetland soils may remain dry during fall storm events, and storage and attenuation may be significant.

Groundwater Exchange. Wetlands may provide significant groundwater recharge if the wetland is characterized by underlying substrates that permit the downward or lateral movement of water into deep aquifers. Typically, this function is extremely difficult to assess because information collected during site reconnaissance seldom reveals the stratigraphy of sub-surface soils.

Although the role of wetlands in recharging deep aquifers may be difficult to assess, groundwater discharge into wetlands is relatively easy to determine. At the bases of many steep slopes that are subtended by impervious till or bedrock, shallow, laterally moving groundwater often surfaces to create what are commonly called "seep" wetlands. These wetlands are directly associated with groundwater discharge zones.

The ability of a wetland to provide long-term flow augmentation is directly influenced by topography. Wetlands with pervious soils and that are located up-slope and directly discharge to a stream may serve a high recharge function. Conversely, limited flow augmentation may be provided by wetlands that are contained by depressions of tight clay soils, which restrict the lateral movement of water.

Recreation/Aesthetics. This value includes open space, passive recreation, and education-- all relating to the positive use of a wetland by people. Wetlands should be highly rated if they provide visual relief within a developed landscape, allow access for fishing, or, by virtue of their proximity to schools, can be used as outdoor classrooms. Protected wetland remnants and restored wetlands with buffers provide areas of beauty and diversity within urbanized and suburbanized settings. Recognizing the aesthetic and educational values that wetlands provide, many urban communities have protected and restored these areas. Aesthetics are often related to size of the wetland, presence of open water, diversity within the system, and wildlife use.

CHAPTER 4: Preliminary Restoration Design

Following the formulation of goals and objectives and the completion of site assessments, a preliminary site design can be drafted for the restoration project. Before approaching this step in the planning process, it is important to re-examine the objectives of the project. With more specific objectives, better criteria can be developed to guide the design. For example, specific objectives may target individual species and communities or focus more generally on increasing biological diversity.

A preliminary site design specifies the desired physical structure of the site and its topography and hydrologic conditions. It also designates the spatial location and composition of the natural communities within the site (Nuzzo and Howell, 1990). Both written and graphic materials should be included in such a design.

During the development of a preliminary site design, physical parameters such as the slope, aspect, soil structure, hydrology, habitat, and human use of the site are considered. The level of detail of each of these elements can vary from one project to the next. It should be noted however, that each of these elements is directly related to the others and none can be realistically addressed alone.

Hydrology

Proper site preparation and management of water are more critical to the success of vegetation establishment than either seeding or planting (Ivan Lines, personal communication). Regardless of the species that are seeded or planted, vegetative success will be determined largely by the site's soil and water constraints.

As discussed in the previous chapter, the degree of soil saturation, water depth, and duration and frequency of inundation (especially during the growing season) must be determined while conducting the initial site assessment. During the development of a wetland restoration design, water regimes must be carefully considered. It should be determined if the existing site specific water regimes should be maintained or modified (by either adding or removing water or altering water depths) to produce plant communities that meet other restoration objectives.

The distribution of wetland plant communities is governed by the water gradient of a site. Prior to planning the vegetation patterns for the restoration site, it is essential to understand the "micro-hydrology," so that the proper species can be selected for seeding or planting. A description of the general hydrologic requirements for various wetland plants in the Northwest is presented in Table 2. The table can be used as an initial guide in developing a planting plan. For example, optimum results occur when seedlings of cattails, bulrushes, and many other emergent species are planted in shallow water less than 2 inches deep. An unsuitable site for these seedlings may need to be modified to create proper depths for establishment and survival.

Appendix E contains additional information on the habitats, common associate species, and propagation techniques for various wetland plants.

Many techniques can be employed to physically alter soil saturations, water depths, and frequencies and durations of inundation at wetland sites. Through such alterations, the hydroperiods and vegetation patterns of reference communities can be established at restoration sites. The addition of supplemental water (irrigation) may be needed in many situations to maintain suitable water regimes. Alteration techniques are discussed in *Techniques for Wetland Management* (Linde, 1969) and *Techniques Handbook of Waterfowl Habitat Development and Management* (Atlantic Flyway Council, 1972).

Site topography and grading considerations should be regarded as ways to create desired water regimes. Shorelines of lakes, ponds, or excavated sites should be irregular, with as many bays, inlets, coves, and pond bars as possible. Figures 1 and 2 show examples of different enhancement techniques used in some project designs. (While these features have clear benefits to the project, they represent a choice to enhance the quality of one function rather than restore an original function and should be developed with that knowledge in mind.) Lake bottoms should be irregular, providing a variety of water depths. If wildlife habitat enhancement is a project goal, water depths and planting plans should reflect the needs of plants, which, in turn, provide habitats for target species of wildlife. Diving ducks, dabbling ducks, geese, shorebirds, fur-bearing mammals, and cavity nesters all require different habitat types (Figure 3).

Additional considerations include:

> **Volumes and flow rates.** Each engineering design should include an analysis of anticipated volumes and flow rates in relation to storm events, ensuring that storage and conveyance of flood flows to the restoration site will be adequate but not excessive. For proposed restoration projects at sites associated with streams or rivers, an analysis of flood conditions is an essential element of the design.
>
> **Impoundment.** Numerous types of pipes, valves, gates, weirs, and flashboard structures can be used to regulate water levels in impoundments. Technical assistance from hydrologists and engineers should be sought to ensure that all water level control structures are properly designed to allow passage of peak runoff. Flashboard structures are generally preferable to gates or valves because they automatically regulate water levels without constant adjustment.

Figure 2. Shoreline Irregularity. Figures 2.a. and 2.b. show wetlands with similar total areas but different levels of shoreline development. While the system shown in Figure 2.a may adequately restore acreage, the wetland shown in Figure 2.b. both restores acreage and provides a superior level of habitat and plant community function.

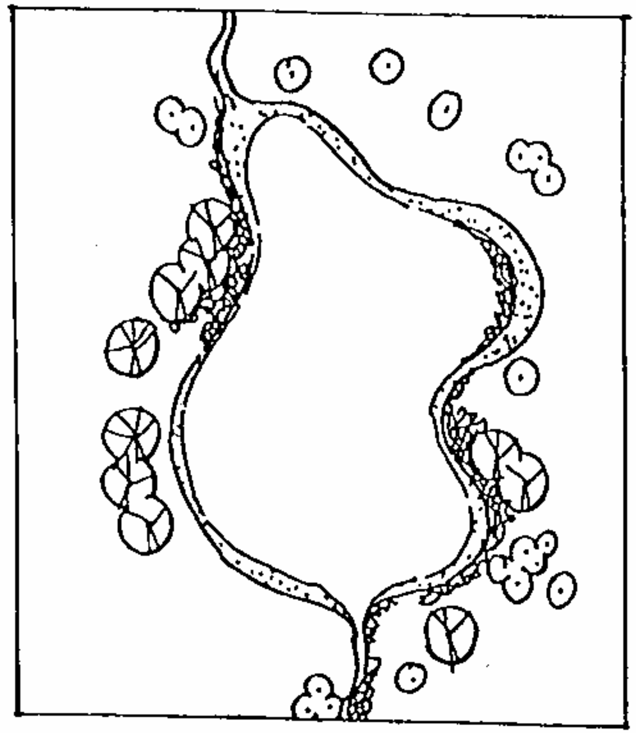


FIGURE 2.A.

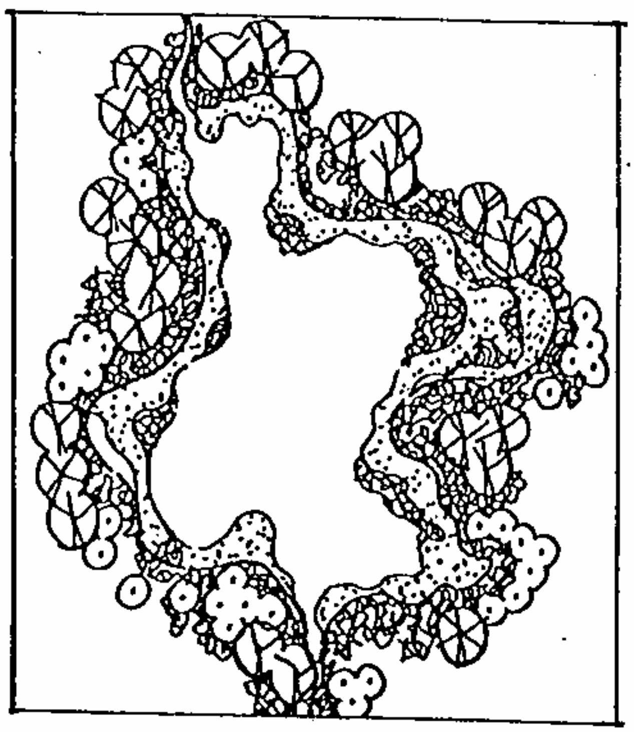


FIGURE 2.B.

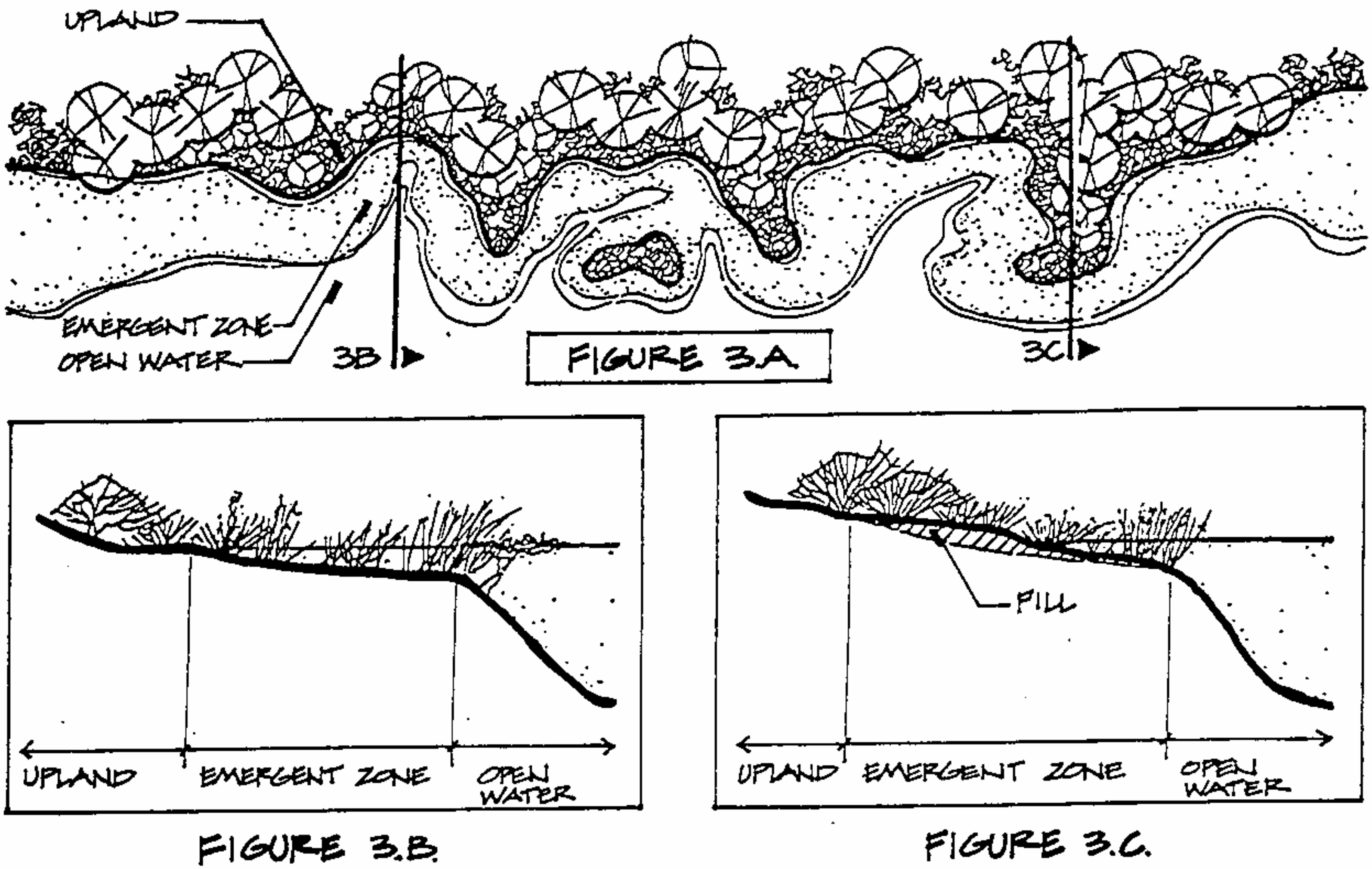


Figure 3. Shoreline Development. Figure 3.a. shows details of a restoration or enhancement approach to shoreline development -- note the integration of bays, coves, peninsulas, bars, and islands. Figures 3.b. and 3.c. show the kind of graphical and surveying information useful in project designs.

Figure 4. Bottom Irregularity. Figure 4.a. shows a very simplistic system with little attention given to the development of benthic habitat. Benthic, or bottom dwelling, organisms are integral to the food webs of aquatic ecosystems and require habitat with structural development for refuge, food supply and other critical life support features. The wetland bottom surface shown in Figure 4.b. is highly developed and provides much more habitat structure.

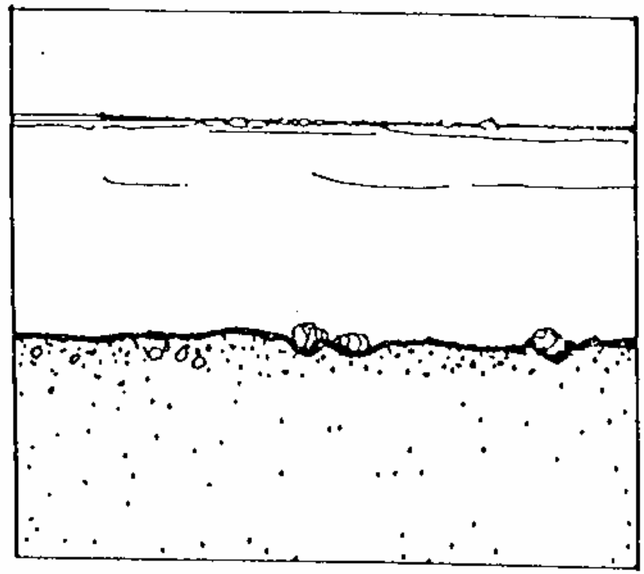


FIGURE 4.A.

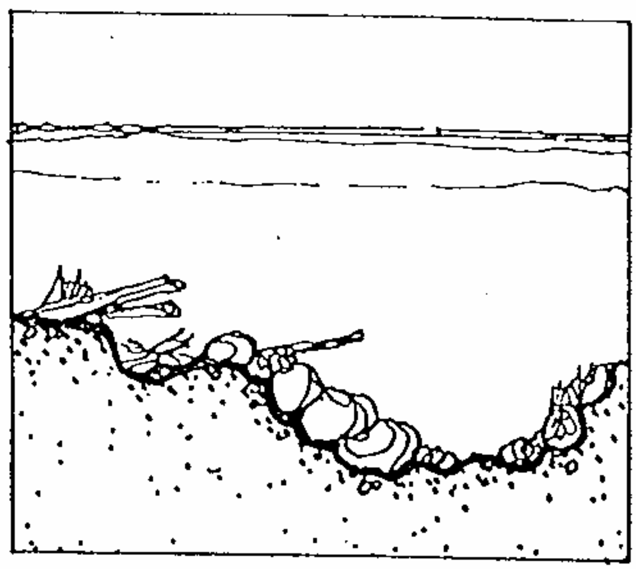


FIGURE 4.B.

Conveyance. If water for a restoration project is obtained from a designed storm drain system, then the restoration design must identify how the flows will be conveyed from the storm drain system to the restored wetland. Issues associated with conveyance include energy dispersion, re-infiltration, erosion control, potential water quality concerns, and duplication of natural conditions.

The natural water regime of land previously drained for agricultural purposes can usually be restored with relative ease. Techniques range from benign neglect of drainage ditches and drain tiles to more active measures (such as breaching flood control dikes, disabling tide gates, and plugging or filling drainage ditches and drain tiles).

By excavating potholes and level ditches with bulldozers, draglines or blasting methods, below-ground impoundments can be created in areas with high water tables or at sites unsuitable for dams or dikes. This type of activity usually requires additional local, state, or federal permits (discussed in Appendix D).

Pond construction may be a wise choice for habitat enhancement, particularly for waterfowl. However, like the creation of impoundments, this activity usually requires state or federal permits. The handbook *Ponds - Planning, Design and Construction* and other detailed information on pond construction may be obtained from the SCS and USFWS. In addition, 4 videotapes on pond construction may be obtained from the Thurston Conservation District.

In Washington, extensive open water habitats have been created through large-scale irrigation projects and reservoir construction. However, the construction of ponds in high-quality wetlands, however, is strongly discouraged for several reasons: the relative overall scarcity of forested riparian areas, estuarine, scrub-shrub, and native sedge or grass wetlands; the difficulty of creating or restoring the values and functions of native floral and faunal communities; and the risk of increasing statewide net loss of wetland function and quality.

Topography

If the existing topography is unsuitable for the establishment of desired plants, plans for topographic modification should be developed. Ideally, for wetland restoration, slopes should be varied to control water depth and hydroperiod, providing a range of microhabitats for plants and animals.

The proposed grading design for site topography should be based on analyses of hydroperiods and vegetation communities at targeted reference sites. Such a design must also consider the permeability of the substrate or water retention capabilities in the area of any proposed excavation. The depth of any proposed excavation should be influenced by the depth of underlying soil material, so that a decision to preserve or remove the substrate can be made.

Aspect

The relative position of an area to the sun (its "aspect") can affect initial plant establishment, growing season lengths, plant species selection, soil moisture content, and both water and soil temperatures. Therefore, aspect should be carefully considered in any site design.

If a site design calls for water to be held throughout the year without constant inputs, thought should be given as to how much sun that area can receive. Direct sunlight on small bodies of water may raise water temperatures, causing excessive evaporation and increased algal growth. Planting woody vegetation for shade may assist in lowering temperatures at the site.

Aspect should also be considered when establishing plants at a site. Some plants are sensitive to the amount of sun they receive, and, unless they are advantageously positioned, may need to be artificially shaded. For example, saplings of western red cedar (Thuja plicata) could be planted in the shade of existing deciduous trees or among fast-growing deciduous companion trees that can provide necessary shade. As the cedars grow, these companion trees, if undesirable, can be removed. Information on individual species' shade tolerances is presented in Table 2.

Table 2. Wetland plant growth requirements and landscaping specifications
Legend

Species* Scientific name according to Hitchcock and Cronquist (1976), with synonyms used in the nursery trade. Collection from natural wetlands is strongly discouraged for species marked with an asterisk(*).

Common Name According to Hitchcock and Cronquist (1976).

USFWS Wetlands From National List of Plan Species that Occur in National Summary (Reed, 1988.)

Indicator: Status

OBL	Obligate wetland plants almost occur in wetlands(estimated probability 99%) under natural conditions.
FACW	Facultative wetland plants usually occur in wetlands (estimated probability 67-99%) but occasionally are found in nonwetlands.
FAC	Facultative upland plants usually occur in nonwetlands but occasionally occur in wetlands. (estimated probability 1-33%)
NI	No indicator status assigned

Ecoregions As described in Chapter 1:

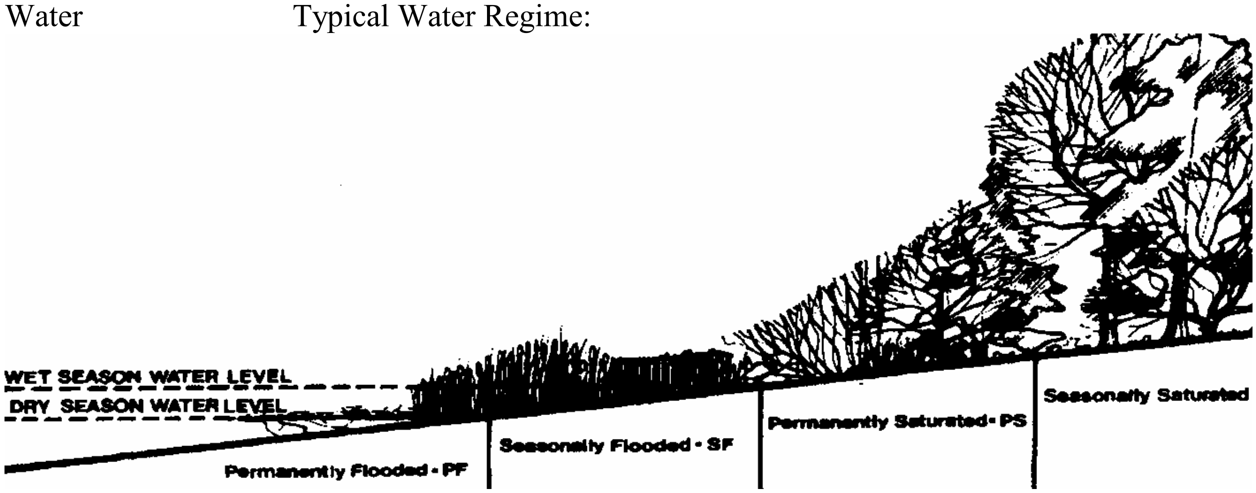
1) Olympic Peninsula & Coast Range
2) Puget Trough
3) Northern Cascades
4) Southern Cascades
5) Columbia Basin
6) Okanogan Highlands
7) Blue Mountains

Community Cowardin. classes where species typically grows.

PFO - Palustrine Forested
PSS - Palustrine Scrub-Shrub
PEM - Palustrine Emergent
PAB - Palustrine Aquatic Bed
LAB - Lacustrine Aquatic Bed

Soil Mineral (M) or Organic (O).

Water Typical Water Regime:



Light Typical light requirements: ○ (FULL SUN) ▲ (SUN/SHADE) ● (SHADE)

Condition As available from nurseries ("-" indicates the species is generally unavailable from nurseries)

Size As typically planted for restoration projects.

Spacing Recommended spacings.

Table 2. Wetland plant growth requirements and landscaping specifications. (continued)

SPECIES	COMMON NAME	USFWS RATING	ECOZONES	WETLAND COMMUNITY	SOIL	WATER	LIGHT	CONDITION	SIZE	SPACING
TREES										
Alnus incana	speckled alder	FACW	4,6,7	PFO, PSS	m	PS, SF	O, ▲	containers	12’	6’+
Alnus rubra	red alder	FAC	1,2,3	PFO	m	SF, PS, SS	O, ▲	bareroot, containers	3 - 8’	6’+
Betula occidentalis	water birch	FACW	4,6,7	PFO, PSS	m	PS, SF	O, ▲	containers	12"	6’+
Crataegus douglasii	black hawthorne	FAC	1 - 7	PSS	m	SS, PS	O, ▲	containers	12"	6’+
Fraxinus latifolia	Oregon ash	FACW	1,2	PFO	m	SF, PS, SS	O, ▲	bareroot, containers	3 - 8’	6’+
Picea sitchensis	Sitka spruce	FAC	1,2,3	PFO	m/o	PF, SF, PS, SS	O, ▲	bareroot, containers	6"	6’+
Populus trichocarpa	black cottonwood	FAC	1 - 7	PFO	m	SF, SS	O	bareroot, containers	3 - 8"	6’+
Populus tremuloides	quaking aspen	FAC	2,4,6,7	PFO	m	SF, PS, SS	O	bareroot, containers	1 - 8’	6’+
Salix lasiandra	Pacific willow	FACW	1,2,3,4,6,7	PFO, PSS	m	SF, PS, SS	O	bareroot, rooted or unrooted cuttings, containers	1 - 6’	6’+; 2’+ for cuttings
Salix sitchensis	Sitka willow	FAC	2,3	PFO, PSS	m	SF, PS, SS	O	bareroot, rooted or unrooted cuttings, containers	1 - 8’	6’+
Thuja plicata	western red cedar	FAC	1,2,3,6	PFO	m/o	SF, PS, SS	O, ▲	bareroot, containers b&b	1 - 8’	6’+

Table 2. Wetland plant growth requirements and landscaping specifications. (continued)

SPECIES	COMMON NAME	USFWS RATING	ECOZONES	WETLAND COMMUNITY	SOIL	WATER	LIGHT	CONDITION	SIZE	SPACING
SHRUBS										
Alnus sinuata	Sitka alder	FACW	3,4,6	PSS	m	SS	O		bare-root, con-tainers	6'+
Cornus stolonifera (C. sericea)	red osier dogwood	FACW	1 - 7	PFO, PSS	m	SF, PS, SS	O, ▲	bareroot, unrooted cuttings, containers	1 - 6'	4'+; 2'+ for cuttings
Kalmia occidentalis*	western swamp laurel	OBL	1,2,3	PSS	o	PS	O	– – –	– – –	4'+
Ledum gladulosum*	mountain labrador-tea	FACW	4,6	PSS	o	PS	O	– – –	– – –	4'+
Ledum groenlandicum*	bog labrador-tea	OBL	1,2,3	PSS	o	PS	O	– – –	– – –	4'+
Lonicera involucrata	black twinberry	FAC	1,2,3,4,6	PSS	m	PS, SS	O	– – –	– – –	4'+
Physocarpus capitatus	ninebark	FAC	1,2,3,4,6,7	PSS	m	PS, SS	O, ▲	bareroot, containers	1 - 3'	3'+
Pyrus fusca (Malus fusca)	western crabapple	FAC	1,2,3	PSS	m	PS, SS	O, ▲	– – –	– – –	4'+
Rhamnus purshiana	cascara	FAC	1,2,3	PFO, PSS	m	PS, SS	O	bareroot	1 - 4'	4'+
Rubus spectabilis	salmonberry	FAC	1,2,3	PFO, PSS	m	PS, SS	O,▲●	bareroot	1 - 3'	4'+
Salix amygdaloides	peachleaf willow	FACW	5	PSS	m	PS, SF	O	– – –	– – –	6'+
Sambucus cerulea	blue elderberry	FAC	1 - 7	PSS	m	SS, PS	O, ▲	bareroot, containers	1 - 4'	21'+
Salix exigua	sandbar willow	OBL	4,5,6,7	PSS	m	PS, SF	O	containers	12"	6'+
Salix hookeriana	Hooker willow	FACW	1,2	PSS	m	SF, PS	O	cuttings, containers	1 - 4'	4'+
Sambucus racemosa	red elderberry	FACU	1,2,3,4,6,7	PFO, PSS	m	SS	O, ▲	bareroot, containers	1 - 4'	4'+
Spiraea douglasii	Douglas' spirae	FACW	1,2,3	PSS	m/o	SF, PS, SS	O, ▲	bareroot, rooted or unrooted cuttings, containers	1 - 4'	3'+; 2'+ for cuttings

Table 2. Wetland plant growth requirements and landscaping specifications. (continued)

SPECIES	COMMON NAME	USFWS RATING	ECOZONES	WETLAND COMMUNITY	SOIL	WATER	LIGHT	CONDITION	SIZE	SPACING
Vaccinium oxycoccus*	bog cranberry	OBL	1,2,3,4,6	PSS, PEM	o	PS	O	– – –	– – –	1'+
HERBS										
Allium geyeri*	Geyer's onion	FACU	4,5	PEM	m	SS	O	– – –	– – –	6"+
Athyrium filix-femina	lady fern	FAC	1,2,3,4,6,7	PFO	m	PS, SS	O, ▲	containers	1 - 2'	4'+
Carex aperta	Columbia sedge	FACW	1,2,3,4,6	PEM	m	PS, SS	O	sprigs	6"	12 - 18"
Carex nebrascensis	Nebraska sedge	OBL	4,5,6,7	PEM	m	PF, SF, PS	O	– – –	– – –	12 - 18"
Carex obnupta	slough sedge	OBL	1,2,3	PFO, PSS, PEM	m	SF, PS	O, ▲●	sprigs	6"	12 - 18"
Carex rostrata	beaked sedge	OBL	1,2,3,4,6,7	PEM	m	SF, PS, SS	O	sprigs	6"	12 - 18"
Carex sitchensis	Sitka sedge	OBL	1,2,3	PEM	m/o	PF	O	sprigs	6"	12 - 18"
Carex stipata	sawbeak sedge	FACW	1,2,3	PEM	m	SF, PS	O	sprigs	6"	12 - 18"
Deschampsia caespitosa	tufted hairgrass	FACW	1 - 7	PEM	m	PS, SS	O	seed container	6"	12 - 18"
Dulichium arundinaceum*	dulichium	OBL	1,2,3,4,6,7	PEM	m/o	PF, SF, PS	O	containers	12"	12 - 18"
Eleocharis palustris	common spikerush	OBL	1 - 7	PEM	m	PF, SF, PS	O	sprigs	6"	12 - 18"
Eqisetum hyemale	common scouring- rush	FACW	1 - 7	PFO, PSS	m	PM	O	containers	2-3'	12 - 18"
Grindelia nana	low gumweed	FACU	5	PEM	m	SS	O, ▲	– – –	– – –	12 - 18"
Heracleum lanatum	cow parsnip	FAC	1 - 7	PEM	m	PS, SS	O, ▲	containers	1"	2'+
Juncus balticus	Baltic rush	OBL	1 - 7	PEM	m/o	PS, SF, SS	O	sprig	6"	12 - 18"
Juncus ensifolius	dagger-leaf rush	FACW	1 - 7	PEM	m	PS, SS	O	sprig	6"	12 - 18"
Lemna minor	duckweed	OBL	1 - 7	PEM, PAB	– – –	PF	O, ▲	transplant	– – –	– – –
Lomatium grayi*	Gray's desert-parsley	NI	5	PEM	m	SS	O	– – –	– – –	12 - 18"
HERBS										

Table 2. Wetland plant growth requirements and landscaping specifications. (continued)

SPECIES	COMMON NAME	USFWS RATING	ECOZONES	WETLAND COMMUNITY	SOIL	WATER	LIGHT	CONDITION	SIZE	SPACING
Lysichitum americanum	skunk cabbage	OBL	1,2,3	PFO, PSS	m	PF, SF, PS	O, ▲	bareroot, containers	6 - 12"	24"+
Montia linearis*	narrow-leaved montia	NI	1 - 7	PEM	m	SS	O, ▲	– – –	– – –	12 - 18"
Nuphar polysepalum	yellow pond-lily	OBL	1,2,3,4,6,7	LAB	m/o	PF	O	rhizome	dorman t	24"+
Oenanthe sarmentosa	water parsley	OBL	1,2,3	PFO, PSS, PEM	m	PF, SF, PS	O	bareroot, containers	2 - 6"	12 - 18"
Polygonum spp.	smartweed	FAC-OBL	1 - 7	PEM, LAB	m	PF	O, ▲	– – –	– – –	12 - 18"
Potamogeton spp.	pondweed	OBL	1 - 7	LAB	m	PF	O	tubers	dorman t	12 - 18"
Sagittaria latifolia	wapato	OBL	1,2,3,6	LAB	m	PF	O	tubers	dorman t	12 - 18"
Scirpus acutus and Scirpus validus	hardstem bulrush	OBL	1 - 7	PEM	m/o	PF	O	rhizomes	dorman t	12 - 18"
Scirpus americanus	three-square bulrush	OBL	1,2,5	PEM	m	PF	O	rhizomes	dorman t	12 - 18"
Scirpus cyperinus*	wool grass	OBL	1,6	PEM	m	PS	O	containers	6 - 18"	24'+
Scirpus microcarpus	small-fruited bulrush	OBL	1,2,3,4,6,7	PEM	m	PS, SF	O, ▲	sprigs	6"	12 - 18"
Sparaganium eurycarpum	broad-fruited burreed	OBL	1 - 7	PEM	m	PF	O	rhizome	dorman t	12 - 18"
Sphagnum spp.	sphagnum moss	OBL	1,2,3,4,6,7	PEM, PSS	o	PS	O	– – –	– – –	– – –
Typha latifolia	common cattail	OBL	1 - 7	PEM	m	PF, SF, PS□	O	rhizome	dorman t	12 - 18"

Soils

The soil types and characteristics of reference communities must be carefully assessed, and the appropriate growing medium must be provided for the survival of specific plants. This will require the identification of soil locations within the proposed restoration site.

At pond sites, the soil should contain a layer of material that is impervious and thick enough to prevent excess seepage. Clays and silt clays are excellent for this purpose; sandy clays are usually also satisfactory. Coarse-textured sands and gravel mixtures are highly pervious and, therefore, usually unsuitable. A liner of bentonite or synthetic material may be needed to hold water at such sites. The use of impermeable membranes is not recommended, as these are easily ruptured and prevent any interaction between water and substrates. Information on the suitability of specific soils for construction purposes can be obtained from a soil specialist or through the analysis of a published soil survey.

Restoration sites with suitable soil types are often limited. A broader range of soil types may be used at restoration sites, however, with amendments, especially if target plant communities have general substrate requirements. Processed peat, straw, or hay can be mixed with more mineral soils to provide preliminary levels of organic matter. This may also increase the soil's ability to retain moisture. Importing hydric soils from other sites brings additional benefits; these soils may contain seed sources, roots and rhizomes of wetland species and may retain micronutrients, mycorrhizae, and other necessary components for plant growth. However, this must be done with care so as not to damage or destroy other wetlands or contaminate the new site with exotic or noxious weed species. Other amendments for plantings are described in Chapter 4.

Ecological Communities

Planting procedures and other detailed revegetation information should be presented in a site plan developed by a landscape architect or other knowledgeable professional. Such procedures should indicate the quantities of seeds or other propagules per unit area, and the intended frequencies, densities, and distribution patterns of plantings (Howell and Nuzzo, 1990). Standard or "cookbook" seeding rates are not available for restoration. Rather, an appropriate approach should be developed for each project, based on such species-specific information as difficulty of establishment, growth habits, aggressiveness, seed weight, and seed viability (Nuzzo, 1989).

The availability of seeds and plantings should be taken into consideration in site design specifications. Plant size, required survivorship, acceptable condition of plant materials at the time of installation, plant community interspersion and composition, necessary mulch, fertilization, and irrigation should also be specified in the site plan (Howell and Nuzzo, 1990). Only where hydrophytic seed banks are present or where known examples of successful revegetation have been identified should natural revegetation of a site be allowed to occur.

In a few instances, restoration goals have involved the re-introduction of a bird or other animal species. However,the majority of projects have relied on natural recolonization of these animals.

Site Revegetation

When acquiring plants and seeds for restoration projects, native species and endemic plant materials should be selected. By using local plant materials, the chances of introducing ecotypes (that are adapted to local climate and soils) and preserving local genotypes can be maximized. Such materials should be grown under contract at least a year in advance of project need.

Species that take advantage of select but different hydrologic conditions should be planted. Priority should be given to commercially available species that have been successfully used in the past.

Significant areas of a site should not be committed to species that have questionable potential for establishment.

Establishment of aggressive native species such as common cattail (Typha latifola) and Douglas' spiraea (Spiraea douglasii) should be phased to follow that of non-aggressive species. Phasing in this manner may help avoid creating a monoculture. However, these species will invade unless water depths are planned to discourage their growth. Similarly, planting woody vegetation after the site water regime has been established will help insure proper placement.

It is not always possible to replicate certain conditions of the target community (e.g., mature forested or shrub communities). It is often the purpose of the restoration project to "set the stage" for the target community to become established on the site over time.

By manipulating the site water regime, some hydrophytes can be established and managed without seeding or planting. Drawdowns (lowering water levels) and reflooding for revegetative establishment and management has been used throughout the country, particularly for waterfowl habitat enhancement in the prairie pothole region of the northern Great Plains. These practices are thoroughly described by Merendino and Smith (1991), with citations for additional sources of information on this subject. (Adapted from Garbisch, 1986)

Structural Aspects Of Plant Communities

Structure refers to the physical complexity within each plant community. It is not always desirable, feasible, or even possible to replicate the existing structural complexity of target plant associations. A mature, forested wetland cannot be instantly created or restored, but a young sapling community can be planted that will develop into a mature system over time. Each site design must reflect the fact that restored plant associations will evolve and mature over time.

To replicate structural complexity, several elements must be addressed in the restoration design. These include spacing, patch size, interspersion, and persistence.

Spacing. Within each target plant community, the patterns of species and their spatial relationships should be measured. It should be noted if species tend to grow in clumps or clusters of multiple specimens or if each specimen is represented singly. Patterns within communities should be distinguished. For example, a shrub crabapple community that fringes a bog should be assessed separately from the Labrador tea/bog laurel (Ledum glandulosum/Kalmia microphylla) community within it, although both are technically shrub communities. A planting plan can then be designed to emulate these patterns.

Patterns of vertical stratification should also be recorded. Many communities are composed of species with different vertical growth patterns. It is important to note such differences and develop a design to incorporate them. For example, the vertical structure of a forested swamp includes trees in the overstory canopy, trees in the midstory, shrubs in the understory, and herbs forming the ground layer. Other important components of the ground layer are logs and stumps, which provide habitat for insects and amphibians, and are a source of nutrients and organic matter. In contrast, a marsh community has relatively simple layering, with sedges, rushes, or other forbs forming the herbaceous canopy and mosses and diminutive herbs forming the ground layer. To create a community with good structural diversity, these layers should all be addressed in the restoration design, although it may not be feasible to replicate each of those elements at the time of planting.

The structural patterns within the overall targeted wetland community must also be replicated. Each animal species has a different requirement for optimum patch size. "Interspersion" refers to the degree of complexity of patches within a system or the transitions among various plant communities. Plant community types are distributed throughout an ecosystem in spatial arrangements that range from simple to complex (Figure 4). Simple patterns tend to be associated with regular shapes (such as circles or squares) and often present an orderly progression of plant communities in concentric rings or linear bands. More complex patterns of plant communities are the result of natural or human-induced variations in the environment, and may be a reflection of the maturity of the system.

In general the relationships between patch size, structure, edge, and dispersion/interspersion in the landscape are the critical factors affecting wildlife value of a system. Where spatial complexity is high, so is the amount of transitional area between plant communities. Such transitional areas are referred to as "edges". In general, edges are rich in wildlife, both in numbers of individuals and species, and are considered important components of functioning ecosystems. Transitional edges offer wildlife proximity to several habitat areas and structural variety. However, if the amount of edge in a system is extremely high, the integrity within individual plant communities may be lost. Care must be taken to avoid the extremes of overly simple or overly complex forms in ecosystem design.

Persistence. The persistence of vegetation that has died is also extremely important to a marsh system. Persistent species such as cattail and bulrush offer year-round structure and cover and, unlike less persistent species such as American water plantain (Alisma plantago aquatica) or mannagrasses (Glyceria borealis and G. elata), provide a source of organic material.

Figure 5. Plant Community Structure. Simplistic structural development of plant communities occurs in concentric rings when bottom depth contours are created in a radially symmetric pattern (Figure 5.a). Varied bottom depths will create a mosaic or interspersion of plant communities which provides a higher quality of habitat (Figure 5.b). Figure 5.c. shows a channelized riverine system with laterally symmetric plant communities. The addition of an adjacent palustrine wetland would increase the plant community structure of this system.

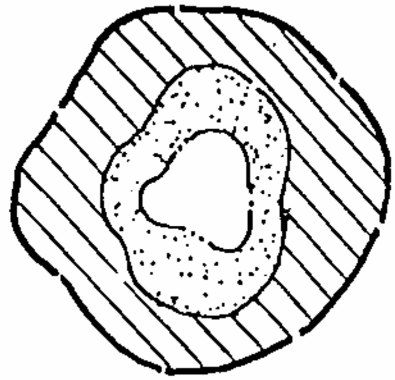


FIGURE 5.A.

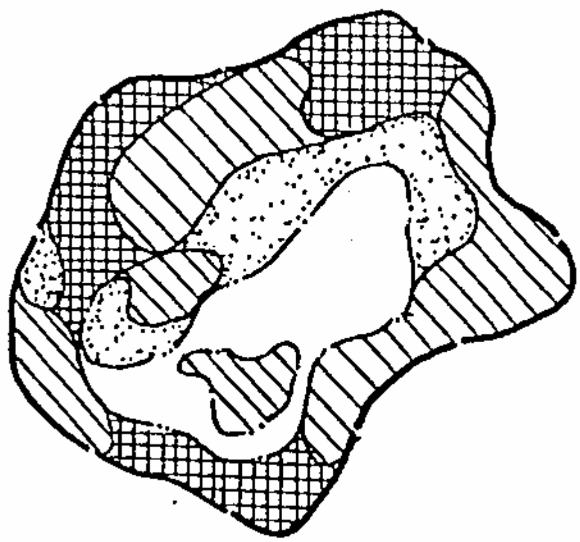


FIGURE 5.B.

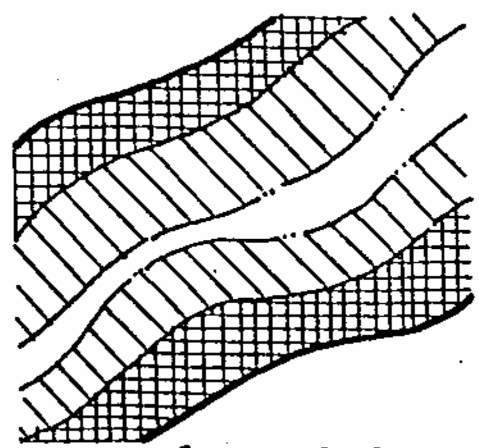


FIGURE 5.C.

Species Selection

As a general rule, non-native wetland species should not be used in restoration plantings or introduced into natural wetlands in an attempt to enhance aesthetic or wildlife values. If non-native grasses or forbs (such as legumes) are to be used to stabilize newly exposed soils over an extended area, non-aggressive annual species should be used. Annual species are recommended because they tend to be less invasive and to compete less with perennial native species.

Common cattail and Douglas' spiraea are aggressive native species that should be used cautiously or, in some cases, avoided completely in restoration projects. Although in undisturbed native wetlands these species typically grow in species-rich communities, disturbance favors their formation in dense, monotypic stands.

Several invasive plant species are occasionally introduced or recommended because they provide rapid cover, control erosion, or are considered aesthetically pleasing. However, their use leads to environmental problems because these species usually out-compete native species and can spread to infest adjacent wetlands. Invasive non-native species available from commercial nurseries include creeping buttercup (Ranunculus repens), narrow-leaved cattail (Typha angustifolia), soft rush (Juncus effusus), and reed canary grass (Phalaris arundinacea var. picta). The following competitive plant species should not be used for wetland restoration:

Scot's broom (Cytisus scoparius), a common invasive of disturbed sites, especially fill and disturbed till, with limited habitat value for food sources or nesting sites.

Purple loosestrife or yellow loosestrife (Lysimachia terrestris), exotic ornamental herbs that invade marshes throughout the northern United States and are still available in the ornamental nursery trade. The Washington State Department of Agriculture has recently added purple loosestrife to its Class B noxious weed list, requiring landowners to control its spread. Transporting, buying, selling, transplanting, or distributing plants or seeds of either species in Washington State is also prohibited.

Yellow iris (Iris pseudacorus), a showy exotic species that has become well-established in marshes throughout the state. Its use in restoration projects will increase its spread into undisturbed or pristine wetlands.

Reed canary grass (Phalaris arundinacea), an invader of open, seasonally wet or saturated areas (including previously farmed or grazed sites), where it forms monotypic stands. Unfortunately, reed canary grass is still used for erosion control and to establish cover in seasonally wet areas despite its invasive properties.

Reedgrass (Phragmites australis), well-established in brackish marsh communities around Puget Sound and riparian areas of eastern Washington, where it forms dense stands that prevent the growth of native vegetation.

Russian olive (Elaeagnus angustifolia), widely planted in eastern Washington to control erosion and provide quick cover. Its dense stands quickly out-compete native riparian vegetation, especially in areas that are cultivated or heavily grazed.

Saltmarsh Cordgrass (Spartina alterniflora, an East Coast species that has invaded intertidal mud flats in Padilla Bay, Willapa Bay, and several other estuarine wetland areas in Washington, displacing native animal and plant species. Other cordgrass species, such as S. townsendii, S. anglica, and S. patens have also colonized Washington's estuaries. Historically, cordgrass was brought to the Northwest as packaging for oysters, and its spread was encouraged to provide natural duck blinds.

Sources For Plant Materials

It is important that the preferred plant communities and species are identified early in the design process. This is particularly important when large numbers of specimens will be required for planting purposes. Many native species are not always readily available from commercial suppliers, and it may be necessary to make arrangements with nurseries to grow specimens. Currently, nurseries grow only a small fraction of the species that could be used to restore the most common wetland communities. They do not grow species needed to restore uncommon wetland types. Plants from these nurseries are generally true-to-name, well-grown, and free of undesirable species. However, it is a good idea to ask the seller to provide information about the source of the materials. Some sources for native plant materials for the Pacific Northwest Region appear in this Appendix F.

Wetland plants for restoration projects can also be obtained by collecting plant materials or seed from existing wetland systems or by salvaging plant materials from wetlands that are to be eliminated. Ideally, to help maximize plant survival and maintain the genetic integrity of restored wetland communities, plants should be obtained that are indigenous to the project area (Mulroy, 1989; Millar and Libby, 1989). In decreasing order of preference, plant materials for restoration projects should come from: the site itself, the same ecoregion as the project site, or, lastly, outside the project ecoregion. Detailed information on collecting, salvaging, and purchasing wetland plants is presented in Appendix F. Some names and addresses of nurseries supplying wetland plants are also presented in this appendix.

Special Habitat Features

Restoration projects can provide valuable wildlife habitat by integrating appropriate habitat enhancement characteristics in the restoration design (see Figure 5). Enhancement features that can be incorporated in a restoration design include:

- Snags
- Nest boxes and platforms
- Logs and large woody debris
- Islands
- Trees
- Buffers

Incorporating these elements increases landscape diversity and, in the case of snags and logs, restores habitat elements that are often scarce or absent at sites that have been cleared. Each of these elements is described briefly in the following sections.

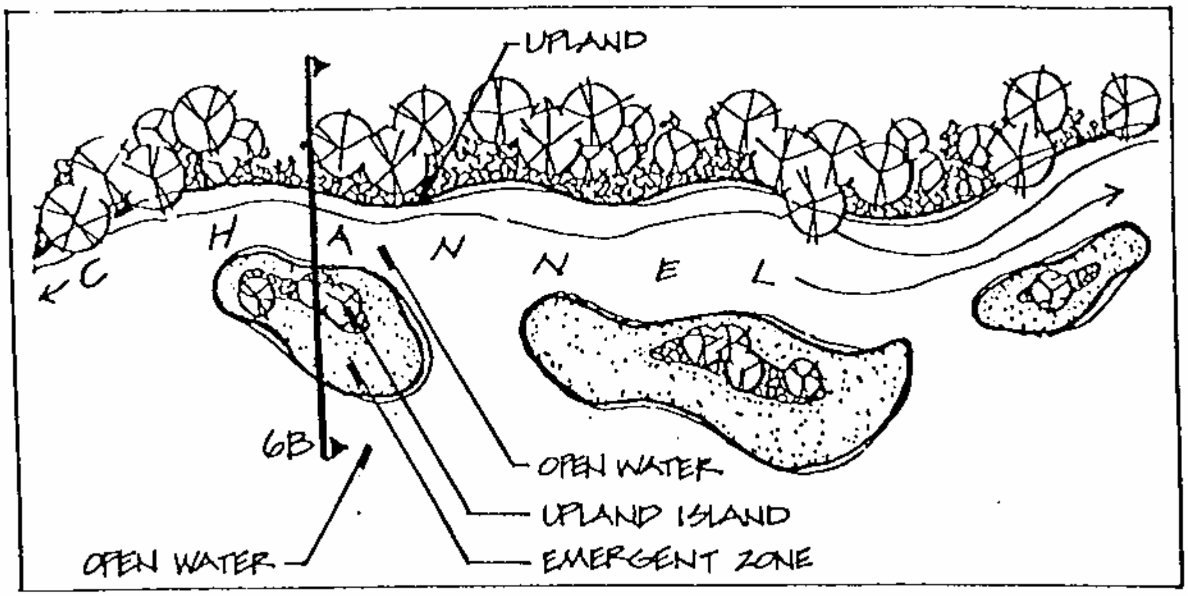


Figure 6.a. Plan View of Habitat Enhancement Features.

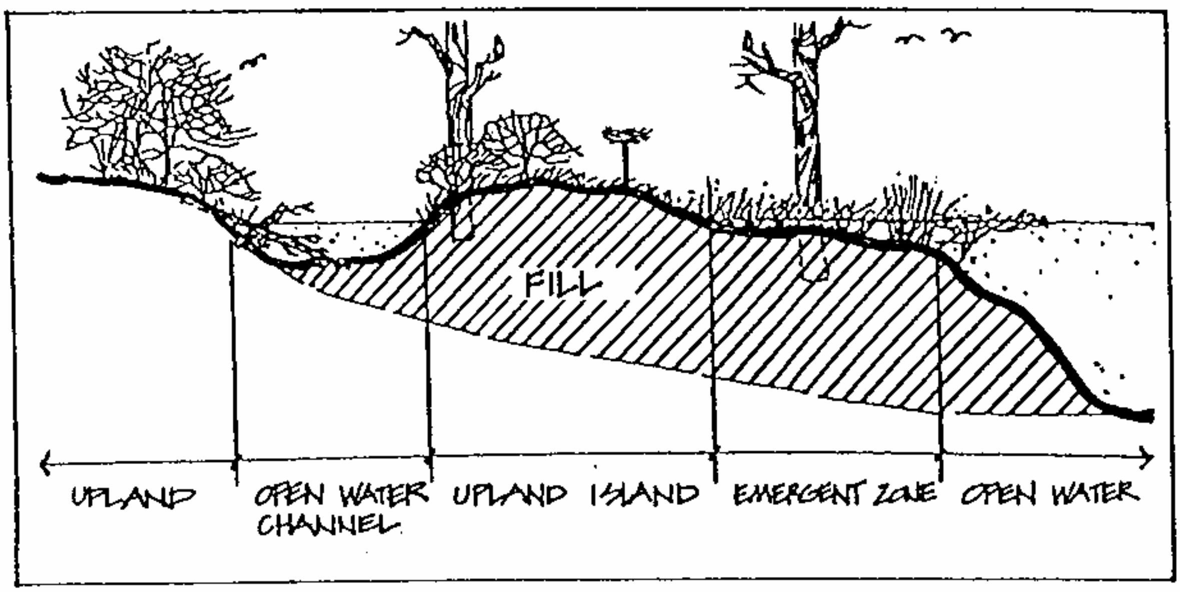


Figure 6.b. Section View Through Island. The addition of habitat features may be either an enhancement or an effort to restore features which may be assumed to have previously existed on site.

Snags. Snags provide food, habitat, and substrate for a variety of plants and animals. Cavity-nesting birds such as woodpeckers and chickadees use them for nesting, insects live under their bark (providing food sources for insectivorous animals), and the decaying wood provides substrate for mosses, liverworts, lichens, and fungi. Snags have the greatest value when they are part of or connected to a forest, offering woodpeckers the opportunity to excavate cavities.

Snags at the restoration site should be retained whenever possible. If snags are absent or additional snags are needed, they can be created by killing live trees, or by installing snags that have been imported from areas scheduled for clearing. It has not been conclusively demonstrated, however, that killing live trees produces snags that can be used by cavity-nesting birds. Moreover, the bases of snags that have been installed like giant fenceposts may rot fairly quickly, unlike snags that are rooted in place.

Snags imported to the restoration site can be installed by excavating holes with a backhoe or excavator, lowering the snags into the holes with a backhoe or crane, and then backfilling. The soil type and structure may determine the feasibility of installing snags. The soil replaced in each hole should be thoroughly compacted. To maximize their value to wildlife, snags of various species, heights, diameters, and states of decomposition should be provided. Snags should be installed both when the restoration project is constructed and also after construction as snags decompose and fall.

Thomas et al. (1979) provide information on the requirements of some snag-using birds and mammals in the Blue Mountains of Oregon and Washington, many of which occur in wetland and riparian communities. Their publication is especially useful for its recommendations concerning appropriate numbers and sizes of snags.

Nest Boxes and Platforms. Nest boxes and platforms are often used as substitutes for natural cavities in areas where such cavities are lacking or inadequate for the targeted species. Nest boxes must be properly sized and located for their target species. Publications of the Washington Department of Wildlife (WDW) and the United States Fish and Wildlife Service (USFWS) provide plans for constructing and installing nest boxes to attract a wide variety of cavity-nesting birds, and platforms for waterfowl and raptors. Plans for bat and flying squirrel nest boxes are available from several sources, presented in the *Resources* section of this document. Nest boxes can be constructed from hollow logs instead of milled lumber, allowing them to blend into the environment.

Nest boxes have certain limitations. They are generally insufficient for woodpeckers and other species that excavate cavities as part of their mating ritual. In addition, many types and sizes of nest boxes must be placed at various heights throughout the restoration site, with results that are likely to be less effective than if snags are present.

If protected nesting locations are desired, platforms for waterfowl can be provided. These can sometimes take the place of islands by providing protective nesting sites surrounded by water. Like nest boxes, platforms must be properly sized and located. Species such as Canada geese may use large platforms located many feet above the waters surface; other species need smaller platforms directly accessible from the water's surface. Again, WDW and USFWS publications may prove helpful. Platforms for raptors can also be included in the site design. Local resource agency staff should be consulted for guidance for targeted species and design specifications.

Nest boxes and platforms must be maintained to provide maximum value. They require yearly cleaning after nesting seasons and periodically need repairing or replacing. As a result, site management plans should include maintenance and repair schedules. Because of these requirements, nest boxes and platforms are not suitable for unmanaged sites. Installing or creating snags at these sites may provide greater long-term benefits.

Logs and Large Woody Debris. Logs also provide important habitat for a variety of wetland plants and animals. When anchored at the shore and floating out into aquatic bed or open water zones, logs provide pathways and haulout sites for waterfowl, reptiles, and amphibians, as well as substrate for wetland vegetation. Similarly, logs situated in emergent, scrub-shrub, and forested communities provide important structural features for wildlife, including perch sites, and cover and thermal refuge (escape from excessively warm waters) for fish.

To maximize their value to wildlife, logs of various species, lengths, diameters, and states of decomposition should be provided. As a general rule, the greater the log's diameter and length, the greater its value to wildlife. Logs placed within floodplains or intertidal areas may need to be anchored in place to prevent them from floating away during high water. Logs can be anchored with cables attached to buried concrete blocks, or, alternatively, portions of them can be buried.

While individual logs provide some important habitat structure, debris jams (accumulations of unsorted woody debris containing a significant fraction of large diameter logs) provide synergistic value. These habitat features are particularly important as sources of cover and thermal refuge for fish. Log diameters should be determined by balancing predicted decomposition rates with the anticipated rates of recruitment and replacement from adjoining or upstream timber stands. Decomposition rates are slower for coarse woody debris submerged or immersed in aquatic systems than they are for more terrestrial environments. In aquatic systems active decomposition is limited to the outer five millimeters of an immersed log, while in terrestrial settings wood boring insects will penetrate the core of a log and effectively increase the amount of exposed surface area, introducing additional decomposing organisms. Decomposition rates are also species dependent with tannin baring species (cedars) being the slowest, followed by hardwoods, and then softwoods. Some terrestrial values on decomposition rates have been sleuthed out for inclusion in this text. Complete decay of coniferous softwood species in western Oregon has been estimated at 20 years for a five inch diameter log, 60 years for a 13 inch diameter log, and approximately 150 years for a 39 inch log (all diameters are for mean breast height) (Ashkenas, 1993). A multiplier of 1.5 for logs immersed in aquatic ecosystems can be considered a conservative working "rule of thumb". Wetland or upland forest restoration designs that incorporate native coniferous species represent the best choices for restoration of mature ecosystems rather than designs that are more heavily weighted toward fast growing pioneering deciduous species.

Islands. Islands within the aquatic beds or open water zones of wetlands are often favored nesting sites of waterfowl. They can offer shelter from prevailing winds, and their shorelines can provide suitable conditions for emergent vegetation. A mosaic of islands also increases edge habitat and opportunities for community diversity. To maximize safety for nesting waterfowl, islands should be located far enough (300 feet or more) from shore to discourage predatory mammals from swimming to the islands (Ringelman, James, K 1991).

Islands can be created by placing fill in open water or, if excavating open water, by leaving islands of exposed earth. To maximize community diversity, the shorelines of islands should be as diverse as possible. A steep margin should be provided to maintain open water adjacent to each island's edge, and a shallow gradient from the edge into open water should be provided on other portions of each island (Figures 6 and 7). The shallow gradient will allow for variable zones of saturation, encouraging the establishment of diverse emergent vegetation. It is appropriate to establish the "top" of an island as an upland community. Islands can also be designed to be well-drained from the surface; this will provide an additional habitat/vegetation community type, thereby increasing diversity and available niches.

Trees. An inventory of the naturally occurring trees in the landscape should guide the selection of trees to be planted. Typically, a diversity of tree species will provide the most benefit. Trees along riparian corridors are particularly rich sources of insects, important foods for many bird species. Willows, cottonwoods and other shrubs provide valuable habitat for insects, caterpillars, and insectivorous birds. In addition, cavity nesters also benefit from these trees, which tend to have relatively short life spans and are susceptible to various heart rots. Some coniferous trees and shrubs provide vital winter habitat for certain wildlife species.

Buffers. Upland buffers are essential parts of wetland ecosystems. Especially when combined with implementation of best management practices for pre-treatment of stormwater, they can improve water quality of the wetland and water body.

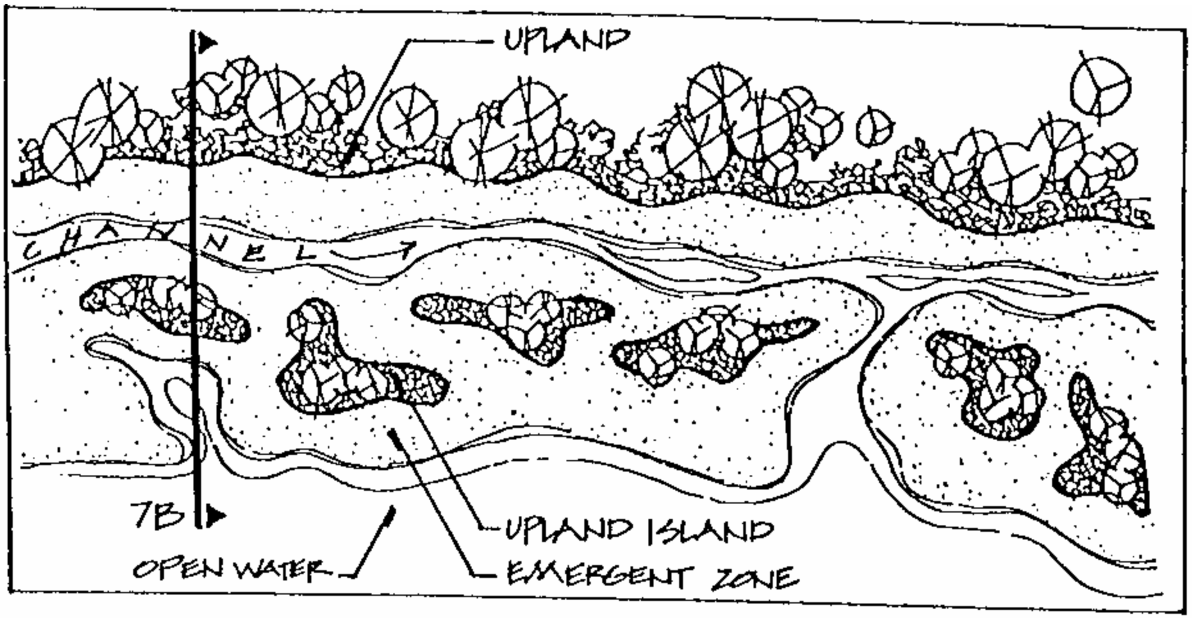


Figure 7.a. Plan View of Wetland/Upland Island Complex.

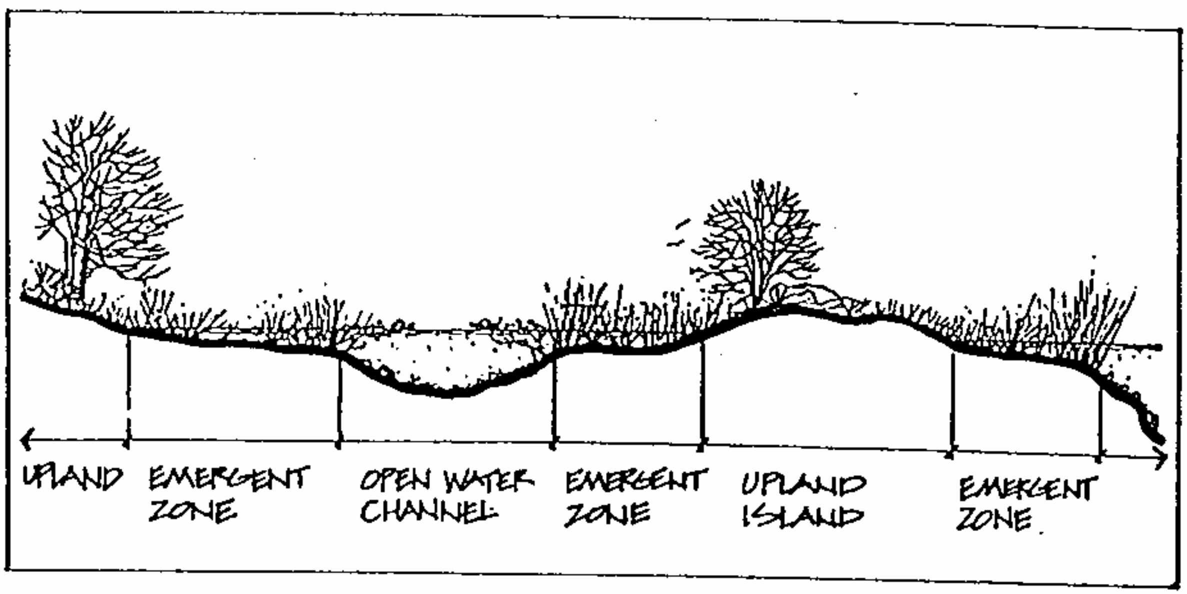


Figure 7.b. Section View of Wetland/Upland Island Complex.
Note the provisions for an upland plant community on the island and different land/water gradients present on the single island.

Wildlife buffers can extend up to 600 feet from the wetland's edge. To be effective in providing for wetland-associated species, most buffers should extend a minimum of 200 to 300 feet beyond the wetland's edge. The structural diversity and interspersion provided by well designed buffers significantly increases wildlife habitat value. In addition, the buffer area can be designed to create visual and noise barriers from offsite activities and to provide corridors or linkages to other habitats. These interconnections among communities are important, as they ensure habitat diversity for many species.

Impenetrable cover can be designed by using species that create visual and physical barriers, in accordance with site goals. If it is desirous to restrict access to humans, then a mix of dense stands of shrubs, particularly rose (Rosa sp.), crab apple (Pyrus fusca), salal (Gaultheria sp.), Douglas' spirea are appropriate barriers. If the barriers are to provide escape habitat for species, then cover may be composed of a variety of vegetation species planted in dense, extensive patterns. Fencing may be needed to exclude livestock or domestic pets.

Human Use

For some restoration projects, it may be appropriate to include human use in the design. Design elements to consider on a case-by-case basis include: trails adjacent or within the restoration site; views into parts of the restoration site; and uses of the site for interpretation, environmental education, passive recreation, or research.

It may also be necessary to place restrictions on or limits to human use at certain restoration sites. Design considerations should include the need for buffers, fencing, or blockage of views in all or only certain portions of sites. Consideration should also be given to limiting access or intrusion by domestic animals and livestock.

If the objectives of a project indicate that human use may be appropriate, the following design considerations should be addressed:

- Locations of trails within, overlooking, or adjacent to the site;
- Connecting trails to existing or proposed trail systems;
- Provisions for appropriate access for interpretation and education (ranging from informal self-guided brochures to formal ongoing environmental education programs); and
- Locations and functions of buffers.

Construction Considerations

Although it may seem premature to consider aspects of construction in the preliminary design phase, certain elements should nonetheless be considered at this stage of a project. Scheduling and timing of construction work can be critical if nearby wetlands are to be used for sources of hydric soils and seed banks or plant materials. The movement and storage of soils and plants must be timed so that restoration sites are available to accept these materials; otherwise consideration must be given to stockpiling soils and plants. The seasonal nature of many construction tasks should also be considered:

> Land clearing and movement of heavy equipment must be conducted to minimize the potential for downslope or downstream erosion. Ideally, site clearing should occur during dry months, minimizing sediment movement.
>
> Excavation of a restoration site is usually preferable during the driest season (late August through the beginning of October), minimizing the need for working under saturated conditions with perched water tables. Depending on site hydrology, even dry seasons may require work under saturated conditions and the use of all available best management practices.
>
> Schedules for excavation and other site work greatly affects the appropriate times for installing plant materials. Some species are best placed during the winter dormant season, others in the early spring growing season. The landscape designer should provide information regarding optimum times and scheduling of plant installation. The availability of water supplies may impose additional timing constraints in systems associated with fisheries resources.
>
> Irrigation may be required (at least temporarily) to increase the survival of young plants during dry periods. Mulching can help retain soil moisture, reduce invasive species, and provide organic debris for decomposition into the soils. In some instances, hay gathered from wetland meadow communities can be used as mulch and a seed source, but only if those communities do not contain reed canary grass or other exotic plant species. The landscape designer should provide guidance on the need, design, and timing for irrigation and mulching.

CHAPTER 5: Final Restoration Design And Implementation

Development of a final design involves the translation of conceptual ideas and information developed in the preliminary design into detailed plans, drawings, and specifications. Whereas initial designs may be portrayed with diagrams to indicate where features will be located, final plans usually include topographic surveys, engineered hydrologic analyses, grading plans with cross-sections showing all proposed grades and contours, and planting specifications (including quantities of each species required, planting locations, and installation specifications). It is vital to convey specific instructions to the individuals who will be implementing these designs. In addition, a final plan should include a plan for monitoring the restoration project over time and a contingency plan in case the proposed restoration is not initially successful.

The work required between preliminary and final designs can be unpredictable, both in the complexity of tasks and amounts of time expended. Any restoration projects conducted as part of a regulatory process must be reviewed by the appropriate resource and regulatory agencies. Agency staff who review preliminary design concepts may suggest or require design changes based on their goals and objectives of relevant laws and regulations. For example, USFWS staff may request additional design work focusing on fisheries resource enhancement, or Ecology staff may request further design modifications in response to water quality issues.

If a restoration project is being undertaken voluntarily, it is strongly recommended that applicable resource agency staff be encouraged to review and comment on the proposed design. Agency staff represent a wealth of information available on wetland resource issues.

The plans, drawings, and specifications outlined below are usually produced by more than one person. Typically, the plans for the hydrology analysis are produced by a project engineer, planting plans and plant materials specification sheets are produced by a landscape designer or botanist, and grading plans are produced by either a project engineer, landscape designer, or another member of the project team. For licensed contracting work, the grading plans usually must be signed and stamped by either a certified engineer or a licensed landscape architect.

Project Plans

For restoration projects that are undertaken voluntarily, the degree of specificity of plans usually reflects the project's complexity and budget. However even for voluntary projects, detailed restoration plans should be drafted to the level of construction drawings and detailed planting plans, giving hired contractors and plant installers sufficient information from which to perform their tasks.

Plans And Specifications

Preliminary and final restoration plans are usually accompanied by written reports describing the necessary steps to implement the restoration project. If the restoration project is being conducted to compensate for the loss or degradation of an existing wetland, such reports should also contain impact assessments.

The following sections describe plans, drawings, and other planning tools that may be necessary for a final restoration plan. The specifics of each site, the complexity of the proposed restoration, and any regulatory requirements will determine which of the following items will be necessary. Before any work on the final plan is begun, the various agencies involved in its review should be consulted to determine which of these items will be needed.

Accurate and thorough plans and specifications may be the most essential element of restoration success. They may also be instrumental in avoiding unnecessary change orders during the construction process. Change orders typically delay progress and require additional project funds. Plans and specifications should not allow any discretionary decisions to be made by the contractor.

Hydrologic Analysis. A wetland restoration plan should include a description of all planned water regimes, especially those regulated by water control structures. This helps ensure that the water regimes will be correctly maintained by those charged with its operation and maintenance. In most cases, the responsible individuals are neither wetland scientists nor involved in the original planning and design of the project. By providing these persons with maps of the contributing watershed, existing on-site hydrologic patterns, and proposed hydrologic conditions, project plans can be accurately replicated at the restoration site. If appropriate, a cross-sectional view of surface water or perched groundwater locations under existing and proposed conditions should also be provided.

Grading Plans. The elevation contours required in the plan are relative to the scale of the project. When projects are complex, detailed contours may be necessary (for example, 1- or 2-inch contours). All channelization requirements for water circulation and import and export of nutrients and particulate matter should be addressed in this plan, as well as any stormwater management and sedimentation control requirements. Detailed engineering designs must be drafted and approved before any ponds, dams, spillways, breakwaters, erosion control structures, and water level control structures are constructed. The grading plan should identify:

- Existing topography of the site, surveyed at appropriate intervals, including stable benchmarks that can be relocated throughout construction and monitoring phases;
- Proposed topography for the proposed site conditions;
- Areas to be excavated, filled, or graded;
- Wetlands at the restoration site that will be altered by excavation, filling, or grading;
- Estimated quantities of soil involved in these operations;

- Appropriate locations for disposal or placement of materials removed from the site;
- Cross-sections at critical locations or areas;
- Any proposed islands
- Any proposed islands and areas of shallow grade to be inundated for emergent target communities; and

- Construction details for any engineered elements such as weirs, dams, dikes, infiltration systems, or swales.

(Note: If the total restoration site is a cut and fill project, locations of both cut and fill should be indicated on site plans.)

Excluding water from the site during construction, grading, channelizing, and, occasionally, planting are major considerations. Construction specifications must be detailed in addressing construction options, erosion control measures, establishment of staging areas, and site restoration. In some instances, plans may require that a certain portion of the land be retained as a dike to exclude water. In tidal areas, earthen dikes could be temporarily opened at low tide to release accumulated groundwater and surface waters. In non-tidal areas, water may have to be continually or periodically pumped out of temporary collection basins (Garbisch, 1986). Alternatively, site dewatering could be achieved by establishing a network of shallow wells or deep percolation holes equipped with appropriate pumps. Water removal and discharge related activities may require special permits from Ecology's Water Resources and Water Quality Programs. It may not be practical or even feasible to exclude water from a site. In such instances, precision grading of the site may not be possible. Underwater grading is seldom acceptable to regulatory agencies or successful at achieving site specifications.

Before a contractor can perform work, temporary construction staging areas may be required. As much as possible, this work should be done in upland areas, as specified in the plans. The original contours of impacted areas should be restored and their surfaces reseeded. Significant soil compaction of uplands occurs following the third pass from heavy equipment such as bull dozers and skidders. Plant growth rates in compacted areas are significantly slower than in non-compacted areas. Wherever possible designated transit routes should be established in order to minimize overall site impacts. All compacted soils should be scarified (mechanically agitated and loosened) prior to revegetation.

Planting Plans and Specifications. Final planting plans should include:

- A schematic planting plan for the entire restoration site, locating each of the targeted vegetation groups in relation to the entire project;
- Cross-sections of targeted vegetation groups in relation to anticipated elevations and water levels; and
- A detailed planting plan for each targeted vegetation group for each area of the restoration. (Such plans should identify the relative spacing of species and planting patterns for each group, where appropriate.)

For each target group, a list specifying quantities of each species to be planted should be prepared. If a proposed species will appear in more than one target group, it must be specified by quantity for each target group. When a vegetation group is proposed for more than one location of a restoration site, each separate location must be clearly identified (mapped) and the specifications for each location provided.

Minimum stem sizes or plant heights, sizes of containers in gallons, and form of plant material (whether it is to be bare-root, balled and wrapped in burlap, or unrooted cuttings or whips) should be indicated. Detailed planting descriptions should also be provided, either written or as graphic representations. Final planting plans should also indicate any soil amendments that will be used, where these amendments will be used, and if specific applications of fertilizer will be needed at the time of planting. Locations and types of irrigation systems should also be noted.

Because site conditions and project goals will determine spacing needs for a specific project, a range of spacings is provided for most species. Those provided in the previous chapter were compiled from planting plans and other published planting guides that assume regular planting patterns will be used throughout a defined area.

When planting species that spread by rhizomes to form monotypic stands, growth during the first two growing seasons will generally obscure the original pattern. However, plantings of species that do not spread rapidly will look artificial if spaced regularly; they will not mimic natural distribution patterns. To establish plants and communities in patterns that mimic natural stands, many restoration designs randomly locate individual plants within areas that meet growth requirements.

Using Reference Sites To Guide Revegetation

The California Department of Transportation's ecosystem approach to restoration design uses reference sites to determine plant sizes, spacings, and quantities. Described in a recent issue of Restoration and Management Notes (Baird, 1989), the department's methods are summarized below.

Identify reference sites.

Determine reference site plant species composition, size classes, and spacing. For forested systems, saplings should be planted at about three to six times the density of mature trees, allowing for mortality and also providing additional cover.

Produce a scale map of the reference site.

Determine restoration site plant layout based on the entire reference site or a portion of the site. For example, 100 x 100-foot cells could be replicated to accommodate areas of any size or shape.

Minimize invasion and spread of undesirable species with dense plantings of groundcover species.

In consideration of cost and the large quantities often required for wetland restoration plantings, most projects tend to use small, bare-root material such as sprigs or rhizomes for establishing herbaceous species. Containerized, bare-root, or balled and burlapped material is generally used for establishing shrubs and trees in buffer areas.

Timetables and Schedules. As part of the final design, a construction timetable should be established, with schedules and milestones for coordinating all elements of construction. Because restoration involves working with natural systems and live materials, certain activities (such as excavation and planting) cannot always be delayed for indeterminate time periods. Time constraints are also imposed by the permitting process, specifically in relation to fisheries resources or breeding seasons. All foreseeable factors affecting the timing of construction and subsequent installation of plant materials should be identified before a realistic, detailed time line can be drawn up.

Construction Management

Prior to construction, one or more individuals should be identified to oversee the project. Although it may be appropriate to have several experts onsite at various times during construction, it is usually most effective to have one project manager, thus ensuring clear communications and efficient operations. By identifying one project manager, all contractors and nursery staff with the project will know to whom they should direct questions. If the project is associated with a regulatory program, agency staff will also have one person to contact with questions.

A project manager must have a complete understanding of the complexities of the project and be able to communicate well with all associated parties. Such a person could be a wetland ecologist, landscape designer, or engineer from the design team.

It is the project manager's responsibility to make sure that project goals and objectives are understood by everyone involved in the project. The success of a project can, in part, be measured by the commitment of all workers to excel at their jobs. Everyone can contribute; however, site plans must be adequately communicated to construction and revegetation crews. Often the skills of heavy equipment operators are keys to successful restoration. Whenever possible during construction, a biologist should be assigned to the site, offering immediate project supervision and facilitating any modifications of plans according to site or construction constraints.

Additional Construction Details

Close attention to construction details will help ensure that restoration plans are successfully implemented. The following discussion is not intended to be a comprehensive overview but rather a highlight of some of those details that must be considered before and during actual construction.

Contractors. Implementation of project construction begins with the selection of one or more licensed contractors for each construction task. Restoration often requires earth moving, plant materials propagation, and plant installation. It is preferable to select contractors and nursery people who have previously worked on successful wetlands restoration projects. Local agency staff, professional wetland consultants, or staff of nurseries that specialize in native habitat restoration should be contacted for recommendations of contractors with whom they have worked and are considered appropriate for the scale of project to be undertaken.

According to Garbisch (1986), it is most desirable to issue separate contracts for the performance of restoration work. Such contracts must be sufficiently detailed and include performance bonds.

Erosion Control. Excessive erosion is a common cause of project failure (Munro, 1991). If a site is heavily degraded, some type of geotextile (e.g., a permeable filter fabric) should be used, and vegetation with high soil-holding capabilities and rapid growth should be planted. Frequently, willows are used in this type of situation. If non-native grasses or forbs such as legumes are to be used, non-aggressive species should be chosen. Other protective measures include:

- Using logs, large rocks, or other materials to protect the emergent zone from wave action;
- Installing wattling or shrub plantings for bank stabilization;
- Stabilizing uplands to prevent offsite sedimentation through use of best management practices such as silt fences, hay bales, grass-lined swales, vegetated buffers, and sedimentation basins;
- Following procedures to protect the site from impacts during construction (for example, using wide-wheeled vehicles to minimize soil compaction **(restricting transit as much as possible to designated routes)** and cultipackers to tamp planted seed into prepared seedbeds);
- Planting an annual cover crop such as barley (<u>Hordeum</u> <u>vulgare</u>) or Italian ryegrass (<u>Lolium multiflorum</u>), which provides erosion control for the first year but does not compete with native plants over extended periods.

Stockpiled Wetland Soils and Vegetation. Incorporating or applying a surface layer of hydric soils that have been salvaged from another wetland site is a common restoration technique. Application of hydric soil not only provides a layer of nutrient-rich topsoil but may also accelerate plant establishment by introducing seed, rhizomes, or entire plants. Soils should only be salvaged from wetlands that are being destroyed.

How salvaged topsoil is handled may affect the survival of seeds and other plant propagules. Stockpiled wetland materials will deteriorate from aeration, desiccation, decomposition, freezing, or salt buildup during storage. To maximize the chances for successful restoration and minimize wetland impacts, Garbisch (1986) recommends stockpiling soils in upland areas for less than four weeks. Covering stockpiled soils with plastic sheeting may help reduce drying and contamination with wind-borne weed seeds. However, Garbisch also points out that time restrictions, difficulty in bringing wetland soils to final grade, and greater expense may make excavated wetland soils less attractive for restoration projects than non-hydric soils.

Seed Germination From Borrowed Soils

In a recent study comparing seed germination rates in undisturbed wetland soil versus soil that was collected from a donor wetland and spread in a wetland creation site, fewer plant species and individuals germinated and grew in the disturbed soil (Warne, 1990). Topsoil from the donor wetland was removed and thoroughly mixed before respreading, burying a large fraction of the seedbank too deeply for seeds to germinate and survive. This factor may account for the difference in germination rates.

Efforts must be taken to determine the sources of all imported soils. Caution must be taken to assure that a functional wetland is not used as a "borrow" site. Moreover, soils from wetlands that are contaminated with reed canary grass, purple loosestrife, or other aggressive species should be avoided.

Fertilizer and Other Soil Amendments. Most biologists and landscapers do not typically specify or install commercial fertilizer for wetland plantings. Instead, some workers adjust soil Ph into the optimum range for the targeted wetland community or incorporate salvaged wetland soils to introduce nutrients and mycorrhizal fungi. Although concerns over potential threats to water quality have been frequently cited, hesitance to use fertilizers also stems from the belief that native species are generally adapted to low-nutrient conditions, and that high-nutrient conditions tend to favor weedy species.

Sawdust, straw, hay, or other organic matter can be mixed with mineral soils, increasing the soil's capability to retain moisture. Sterile straw has also been added to non-wetland soils that were being inundated to increase organic content (Hashisaki, personal communication). The straw must be sterile, or it may introduce a weedy seed component to the restoration site. In at least one instance in western Washington, the use of marsh hay bales for erosion control resulted in introduction of reed canary grass to a site.

If fertilizers are needed in addition to other soil amendments, fertilization requirements can be determined in two ways: 1) by monitoring plant growth and fertilizing if plants show signs of nutrient or mineral deficiency; and 2) by conducting soil fertility tests. With proper planning, containerized plants can be grown in soil mix containing slow-release fertilizer that will provide nutrients throughout the establishment period. Incorporating fertilizer in the soil mix may also eliminate the need for surface applications and reduce the chances of algal blooms, surface feeding of annual weeds, or other water quality problems created by nutrients released into the water column.

Fertilizers that have been used successfully in wetland plantings include several formulations of Osmocote® controlled-release pellets and Agriform® controlled-release tablets. Both products supply nutrients from 4 months to 2 years, depending on release times inherent to each formulation. Because of their large size, Agriform® tablets are easier to handle in shallow water areas. Individual tablets can be pushed into the soil and buried. Enclosing several pellets in a small burlap sack before burying will simplify handling of Osmocote®. Recommended application rates for wetland emergent plantings are presented in Table 3.

TABLE 3: Fertilizer Application Rates for Wetland Emergent Plantings (source: Garbisch, 1986; Francis, 1987)

Product	**Rate**
Osmocote® 18-5-11 (12- to 14-month release)	1 fluid ounce per peat-pot, tuber, bulb or plug; 1/2 fluid ounce per sprig or rhizome
Osmocote® 18-6-12 (8- to 9-month release)	1 fluid ounce per peat-pot, tuber, bulb, or plug; 1/2 fluid ounce per sprig or rhizome
Osmocote® 19-6-12 (3- to 4-month release)	1 fluid ounce per peat pot, tuber, bulb, or plug; 1/2 fluid ounce per sprig or rhizome
Agriform® 20-10-5, 10-gram tablets (2-year release)	4 tablets per plant

Seeds. Although seeds provide the cheapest cost per plant, several factors limit their use, including lack of control over density and location of seeded species, lack of availability of many native wetland species, and the relatively long time before uniform vegetation cover is achieved. In addition, seed germination requirements are unknown for many wetland species. The resulting lack of control over plant establishment makes seeding the riskiest method of establishing target communities. Collecting seed from donor wetlands and introducing them to restoration sites may help to increase species richness but should not be the principal method for establishing dominant species or communities.

It is a standard practice to seed buffer areas adjacent to wetlands with non-native grass and forb mixtures for erosion control and quick cover, and many prepared seed mixes are available (Randy Akada, personal communication). Because this practice may introduce exotic species into the wetland, native upland species or annual non-native mixtures are preferred.

Although reed canary grass has been widely planted and is still available for streambank, wet pasture, and wetland swale plantings, it should not be used in restoration work because it is invasive, out-competes native wetland forbs and grasses, provides poor wildlife habitat, and forms dense monotypic stands. A related species, Harding grass (Phalaris aquatica), should also be avoided as it may hybridize with reed canary grass, incorporating many of the latter's undesirable characteristics.

Native grass mixtures using species such as tufted hairgrass (Deschampsia cespitosa) and mannagrasses should be developed to reduce the need for seeding with non-native species. The SCS's Plant Materials Center in Corvallis, Oregon is working to develop native cultivars of tufted hairgrass and other locally adapted grasses. The center's tufted hairgrass is scheduled to be released in 1995.

Hardstem bulrush (Scirpus acutus) and other wetland forbs are occasionally specified for seeding restoration sites. However, lack of a consistent commercial source has limited their use (Akada, personal communication). Wetland forbs that frequently pioneer new sites in western Washington include ovoid spikerush (Eleocharis ovata), tapered rush (Juncus acuminatus), baltic rush , Juncus balticus), woolgrass Scirpus cyperinus), sawbeak sedge (Carex stipata), slough sedge (Carex obnupta), and mannagrasses. These species seed prolifically and grow quickly, making them good candidates for experimental seed mixes.

Additional native plant species to consider for seeding wetlands include:

- Spike bentgrass (Agrostis exarata), Oregon bentgrass (A. oregonensis), and winter bentgrass (A. scabra)
- Common spikerush (Eleocharis palustris) and neeedle spikerush (E. acicularis)
- Giant wild rye (Elymus cinereus)
- Bog deervetch (Lotus pinnatus)
- Knotweed/Smartweed Polygonum spp.

Recommended seeding time on both sides of the Cascades (assuming adequate moisture is available through the summer) is mid-April to October (Woods, Baune, personal communications). To ensure enough moisture for germination and growth but not so much that seeds float away, seasonally flooded areas should be seeded after water levels have dropped but the soils remain moist. Commercial suppliers of native seed mixes are presented in the *Resources* section of this document.

Sprigs, Plugs, Rhizomes, and Tubers. Sprigs are divisions of herbaceous species (generally sedges and rushes) that include a single stem or cluster of leaves and associated (soilless) roots. Slough sedge and small-fruited bulrush (Scirpus microcarpus) are examples of species that are typically planted as sprigs. Planting sprigs during the spring and fall has resulted in good survival rates. Summer plantings in areas with adequate moisture have also been successful.

Plugs are similar to sprigs except they include small amounts of the soil in which they were growing. Because plugs are usually dug from natural wetlands, soil flora and fauna imported with the plug will help inoculate new wetland sites with soil microorganisms. However, their retrieval also impacts the natural wetlands from which they were collected. Plugs may be obtained using a 4-inch or 6-inch PVC pipe modified to include a handle.

Given sufficient lead time, plugs can also be produced in a nursery by growing sprigs in peat-pots, which can then be planted directly at restoration sites. Unfortunately, this method does not reduce impacts to natural wetlands, because most sprigs provided by commercial nurseries are collected from the wild. However, it does allow planting an undisturbed root mass, which may result in a higher rate of survival than by installing sprigs.

The underground stems and storage organs produced by some plant species, rhizomes and tubers can be used to establish wetland plant populations. Advantages of rhizomes or tubers include ease of handling and, with proper installation, increased growing success. Wapato (Sagittaria latifolia) and seaside bulrush (Scirpus maritimus) are examples of species producing tubers that can be used to establish populations. Common cattail and hardstem bulrush are other examples, typically planted during the spring, fall, or winter as pieces of dormant rhizomes. Each piece should contain two to three new buds or shoots, formed at the base of old stems and at the tips of rhizomes. The rhizomes are planted just below the soil surface and the soil firmed down over each piece. Planting in shallow water areas should be completed before the area is flooded, making planting easier and reducing the chances of rhizomes floating away.

Cuttings. Rooted or unrooted hardwood cuttings of woody species have been successfully used to revegetate streambanks, and much information on their collection, preparation, installation, and use is available (Schiechtl, 1980; SCS, various Technical Notes). To ensure the survival and growth of cuttings in the field, competition with other plants must be minimized, browsing or grazing controlled, and adequate soil moisture maintained until the plants are established.

Sitka willow (Salix sitchensis), Pacific willow (Salix lasiandra), black cottonwood [Populus balsamifera (P. trichocarpa)], red osier dogwood (Cornus stolonifera), and Douglas' spiraea (Spiraea douglasii)are easily rooted from cuttings and are probably the most frequently used species for direct sticking in the field. Cuttings of these species are ideally obtained from 1-year-old wood at least 3/8 inch in diameter. They are best planted in areas with adequate soil moisture throughout the growing season and where competing vegetation will be controlled. The size of cuttings should be determined by the proposed hydrology; for example, cuttings should be 18 inches or longer where fluctuating surface and ground water levels are present. Longer cuttings are used in areas where groundwater fluctuation and plant competition may limit growth. SCS field tests have shown that willow and black cottonwood whips (4 to 5-foot long cuttings, 2 to 6 inches in diameter) had significantly higher survival and growth rates than shorter cuttings (Lambert et al, 1990). From these tests, SCS has concluded that the whips' greater length helps insure rooting in perennially moist soil, enabling these cuttings to compete with established herbaceous plants.

Cuttings or whips can be taken in the fall after plants become dormant and stored outdoors in moist sand or sawdust until the following spring. They can also be taken in the spring before growth begins and planted directly in the field. Cuttings should be kept out of direct sunlight and drying winds during planting. A hole should be dug for each cutting, avoiding any damage caused by pushing it into the soil.

Sitka willow cuttings, collected and planted 4 feet apart in June at a western Washington restoration site, had a 62% survival rate at the end of the first growing season (Schaefer, personal communication). The cuttings were planted in an area with perennially moist soil that had been cleared of vegetation.

Container-Grown, Balled and Burlapped, and Bare-Root Plants. Most of the plant species commonly specified for restoration plantings can be grown in containers, enabling larger plants to be installed onsite. Using containerized plants during the growing season optimizes chances for survival because the plants can be transported and held at the job site and installed with well-developed and intact root systems. In addition, container-grown plants often include fertilizer reserves in their growing media that can help the plants become established. Not all plants are well suited for transplanting from containers. Exceptions include vigorous species that spread by rhizomes such as small-fruited bulrush and common cattail. Although these species thrive in containers, the rhizomes quickly grow through the container's drainage holes. When the plants are removed from their containers, the protruding rhizomes generally break off, resulting in wasted plant materials or extra efforts to retrieve and plant the broken pieces.

Field-grown shrubs or trees (or those collected during the growing season) are generally supplied balled and burlapped. The plants are dug and their root masses with attached soil wrapped with burlap for ease in storage and transport. Balled and burlapped plants that will be stored at restoration sites should be placed in shady locations and their root balls covered with moist wood chips.

Many tree and shrub species are available as bare-root materials during the dormant season (generally October through March), minimizing plant material costs. Bare-root materials should be stored onsite in moist wood chips, as described above for balled and burlapped materials.

PLANT CULTURE AND PREPARATION

As a general rule, plants obtained from local sources will be best adapted to conditions at the project site. The conditions under which plants have been grown will also influence their chances for survival at the restoration site. Conditions at a nursery should mirror as closely as possible the conditions of the planting site. Specifically, some species will grow in shallow standing water, saturated soil, or moist soil. Containerized plants that have been kept moist (but not saturated) before being planted in saturated soils may not survive as well as plants that have been kept under saturated conditions.

Planting Considerations

Wetland areas can be planted whenever there is adequate moisture to ensure plant survival. Planting times will vary, depending on the requirements for successful establishment of each species. Wetland areas created by irrigation runoff and snowmelt in eastern Washington tend to be wettest during the summer and fall, making these the optimum seasons for planting.

Bare-root plant materials should be planted during dormant seasons (fall, winter, and early spring). Containerized materials can be planted year-round. Because plants installed during the height of the growing season may require extra care until they become established, most restoration plantings are scheduled for the early spring or late fall, when the plants are just beginning or ending their yearly growth.

The rooting zones of transplants and cuttings must remain in the permanent water table or be irrigated until the plants are established, often a period of 3 years or more. In eastern Washington, riparian vegetation is permanently watered along many reservoir margins on federal projects. Native species adapted to local water tables should be used, minimizing maintenance costs and maximizing longterm establishment of vegetation.

Planting efforts along rivers must take flooding duration and planting dates into account, ensuring plant survival and preventing physical erosion. Flooding of trees or shrubs by stagnant water is more injurious than flooding by flowing water, which contains more oxygen. However, fast-flowing water may cause rapid soil erosion, undermining vegetation (particularly those plants in light, sandy soils). A combination of high-velocity waters and shallow root systems may result in blowdowns.

Planting emergent or aquatic species may present special problems. Turbid water obscures vision, deep water limits access, and moving water can wash out recent plantings. Two methods to overcome these problems are enclosing rhizomes or tubers in mesh bags weighted with stones, or pushing nails or fence staples into tubers to sink them. To firmly install tubers, rhizomes, or roots of emergent species, these materials should be planted before the planting area is flooded, or, alternatively, the planting area could be drained. To minimize the chances of planting at incorrect depths, community boundaries should be clearly staked.

CHAPTER 6: Monitoring

Monitoring provides a framework for systematic and quantitative measurements of change over time. Through monitoring, timely information about the progress of a wetland restoration project can be obtained. Problems can be identified and the appropriate modifications made to better achieve the goals and objectives of restoration efforts. Following planning, construction, and planting, evaluation of monitoring data provides the opportunity to critique the restoration project. Successes and failures can be analyzed and experience transformed into knowledge that can better serve subsequent restoration efforts.

Many attempts have been made to define sampling methods and describe parameters and analytical techniques for studying wetlands (Horner & Raedeke, 1989; Cooke et al, 1988; Simenstad et al, 1989; Platts et al, 1987; Franklin and Frenkel, 1987). In general, the specific parameters and analytical techniques to be used should be based on the amounts of detail and degrees of precision required for each individual restoration project. As with any data collection effort, goals and objectives need to be clearly identified. This ensures that proper parameters are selected and that sampling designs, data collection activities, and analytical methods are appropriate to the scope of the project.

BASELINE MONITORING

All monitoring requires a "baseline" or standard for comparison. Several sources can be used to establish a baseline of information for wetland restoration. These include:

Information about onsite conditions prior to construction of the restoration project;

Data collected in the first year following the restoration project;

Information from a reference site;

Information gathered from literature reviews of similar situations; and

Information from studies of existing, undisturbed wetlands.

Development of a comprehensive and cost-effective monitoring program requires forethought and careful planning. At a minimum, monitoring should be directed at evaluating the success of restoration efforts relative to the goals and performance standards established at the outset of each project. This would involve determining whether certain characteristics or conditions were achieved within a specified time frame.

To be adequate, baseline data should be collected over a period of at least one full year. Therefore, it is important to begin collecting data early in the project and continue data collection for as long as possible. Data collected only once or during one season will not be sufficient to characterize the wetland system under investigation.

Replicating the functions and values of complex ecosystems requires years and, in some instances, decades of effort. Within the short time frames defined by most monitoring plans (usually less than 5 years), evaluations of progress are based on measurement of more tangible indicators that identify established, functioning systems. These include hydrology, vegetation, and water quality. Other indicators of a new wetland's health and stability include wildlife habitat and usage, biogeochemical relationships (e.g., the interactions between plants and soils), below-ground biomass, and mycorrhizal restoration. The following sections briefly address the primary components of a monitoring plan that can be used to address these indicators.

Hydrology

Hydrologic monitoring is useful in the initial planning phase to evaluate design constraints resulting from the water regime. It may also be necessary to establish a baseline for monitoring hydrologic stability in adjacent wetland systems if an objective of the restoration plan is to preserve the integrity of existing wetlands. Post-construction monitoring then confirms the adequacy of the hydroperiod to support the wetland ecosystem.

Groundwater wells and piezometers measure the elevations of the water table. Properly used, they provide information about groundwater inflows and outflows that might be expected at different seasons. Such information is also important in establishing the hydrologic regime in wetlands that do not maintain surface water at all times. Groundwater information can also be collected from an open pit or by installing a perforated tube that can be read by inserting a chalk- marked measuring tape. A plastic cap should cover the tube to prevent debris and rainwater from entering (Horner & Raedeke, 1989).

Information about depth, frequency, and duration of inundation is useful in evaluating plant community development. Surface water gauging stakes are used to measure water depth and are useful in characterizing the hydroperiods of wetlands. A staff gauge for reading water elevations can be assembled from any object that can be held vertically in place in the water and marked with water elevation lines.

Water Quality

Water quality includes both surface water quality and the quality of the interstitial groundwater of the wetland. Water quality in wetlands is influenced by a number of factors including the annual, seasonal, and diurnal variations in water quantity, velocity, and chemistry of hydrologic sources. Because of this variability, it is difficult to establish criteria against which changes can be measured. Great care must be taken to design a sampling program that meets an acceptable level of statistical rigor.

To establish baseline data for water quality:

> Reference wetlands in a geographic region should be monitored and general mean reference values estimated for the different parameters measured, as was done for the Puget Lowland ecoregion by the Puget Sound Wetlands and Stormwater Management Research Program (Reinelt and Horner, 1990).

> National data derived from a review of the literature may be used if regional data are unavailable.
>
> Baseline information on particular wetlands can be collected. Given the scarcity of data that can be applied to wetlands in most regions of Washington, such characterizations are often the most meaningful. To establish a baseline for an individual wetland, a full year of sampling is required, from which a water quality "signature" can be compiled. Horner and Raedeke (1989) recommend that a minimum of 8 samples be taken, distributed throughout the year: 2 during the early growing season (March 1 - May 15), 3 during the dry season (May 15 - September 30) and 3 during the wet season (October 1 - February 28). A general rule of data collection and analysis requires a minimum population size of three data points in any set or subset. Therefore, an additional sampling point during the March 1 - May 15 interval is recommended (Christian Fromuth, Personal Communication).

Water quality monitoring in wetlands involves measuring both the soluble and insoluble elements present in the water column and interstitial water. Depending on the area of concern, many different parameters can be used to characterize water quality. The Puget Sound Wetlands and Stormwater Management Research Program has provided data for pH, total suspended solids, nitrogen (NH3-N, NO3-N, TKN), phosphorus (SRP and total P), and fecal coliform (Reinelt and Horner, 1990). A detailed discussion of the significance of temperature, pH, dissolved oxygen, specific conductivity, and pollutant removal and retention is contained in *Guide for Wetland Mitigation Project Monitoring* (Horner and Raedeke, 1989), a publication of the Washington State Department of Transportation. Additional guidance can be found in Franklin and Frenkel (1987). Sampling analysis, detection limits, and procedures for quality assurance/quality control should be based on *Recommended Protocols for Measuring Conventional Water Quality Variables and Metals in Fresh Water of the Puget Sound Region*, a publication of the Puget Sound Estuaries Program. Recommended sampling methods for dissolved oxygen, pH, turbidity, suspended solids, sediment accretion, nutrients (such as phosphorus and nitrogen), fecal coliform bacteria, and heavy metals are summarized in Appendix G.

Additionally, chloride is a useful and often included parameter in water monitoring programs where discerning groundwater influences is an objective. Once baseline data have been established, criteria must be developed for identifying if a change from background conditions represents a significant deviation from the natural variability of wetland water quality. Although no numeric water quality standards for wetlands currently exist, several methods can be used to identify significant deviations. For example, a standardized Coefficient of Variation (C.V.) for each water quality parameter has been used by the King County Stormwater Research Program to evaluate their data (Horner, 1990).

The following are examples of criteria that can be used to determine changes in water quality:

- The mean of observations from baseline monitoring shall not increase (or decrease in the case of pH) from the baseline mean by more than the C.V., expressed as a percent.

- If a wetland is associated with a surface water body, the water quality criteria for that surface water body shall apply.

Use of the C.V. as a threshold value for change in water quality depends on securing adequate background information about an individual wetland or a number of similar wetlands from the same ecoregion. If no previous data have been collected for a wetland or its region, two full years of data would give a more accurate estimate of the mean. This would provide a better water quality baseline for determining the acceptable threshold for change.

Soils

Soil pH, heavy metal content, particle size, organic content, redox potential, nutrient regime, and microbial activity were monitored as part of the Puget Sound Wetlands and Stormwater Management Research Program to quantify the changes to soils and vegetation communities resulting from urban stormwater runoff (Cooke, Richter, and Horner, 1989). Based on the results of this study, it is recommended that these parameters also be measured in any wetland restoration work. Sampling methodologies included soil cores to assess physical and chemical characteristics, microtox analysis to determine acute toxicity in aqueous samples, and a litter decomposition study to determine soil microbial activity.

By trapping sediment, wetlands help to reduce downstream impacts from sediment transport. However, an excessive rate of sediment accumulation can affect the water storage capacity of a wetland and alter the characteristics of its benthic habitats. Horner and Raedeke (1990) report several techniques for measuring sediment accretion and provide information about assembly and installation of sediment traps, sampling design, and data analysis for different objectives. They also report sediment accretion rates for different types of natural wetlands based on a review of the literature.

The formation of hydric soils may be monitored as part of a set of performance standards in restored wetlands. This would involve the same methods used to identify hydric soils for wetland determinations.

Vegetation

Determining percentages of dominance and rates of establishment for plants are valuable insights for evaluating the success of restoration efforts. Performance standards for the vegetation component of a restoration plan are generally directed at achieving a distribution and density of vegetation similar to the conditions at a nearby reference site. Other objectives may require information about changes in vegetation composition and structure in response to flooding or other predicted impacts. Monitoring for the presence of invading weeds should be a high priority. If weeds are found, control efforts should be implemented immediately and continuously until the species are eradicated. Without effective action, the restoration site could be overwhelmed.

Vegetation monitoring generally involves counting transplanted materials, estimating cover and biomass production, and measuring species diversity and plant density. Many methods have been developed for taking vegetation measurements. Horner and Raedeke (1989) discuss a number of these, including the canopy coverage method of Daubenmire (1959) for herbaceous plants, small shrubs, and trees less than three feet tall; the line-intercept method of Canfield (1941) for use with shrubs and trees less than six feet tall; and the belt transect technique of Phillips (1959) for use in evaluating trees greater than six feet tall in forested sites. Franklin and Frenkel (1987) have developed a method for sampling herbaceous vegetation using nested frequency quadrants similar to the approaches of Hironaka (1985) and Smith et al. (1986) for studying rangeland vegetation. This method yielded data similar to those mentioned earlier in this paragraph and was faster and easier to complete. The choice of specific sampling method will depend on the type and density of vegetation that is being restored. A wetland ecologist should be consulted before designing a sampling method that will meet project objectives.

In undertaking vegetation monitoring, it is important to prepare an as-built drawing of each plant installation. Sampling plots should be located along permanent transects, with vegetation, elevations, water levels, and special features labeled and mapped so that data can be collected quickly and consistently from year to year. Data should be collected when plants are at maximum growth, generally from July to August.

Wildlife

Wildlife should be sampled directly. If this is not feasible, special features of wetland habitats should be assessed to gauge the potential of the site to support wildlife. The Habitat Evaluation Procedure (HEP) developed by USFWS describes specific habitat parameters for individual wildlife species. Assessed habitat characteristics may include open water, structural diversity, snags, large organic debris, presence of single or colonial nests, convoluted micro-topography, buffer characteristics, and continuity of habitat features. WDW is currently developing a method for sampling wildlife in wetlands, expected to be available in 1993.

The Puget Sound Wetlands and Stormwater Management Research Program has similarly developed protocols for monitoring macroinvertebrate, amphibian, bird, and mammal populations in wetlands (Cooke, Richter, and Horner, 1989; Horner and Raedeke, 1989) that are also applicable for wetland restoration projects. As part of these protocols:

> Emergent traps are installed to capture emerging aquatic macroinvertebrates. Traps are emptied semi-monthly except during winter months (November to March), when emergence is expected to be low or nonexistent.
>
> Distribution and relative abundance of amphibians is determined from coffee can pitfall traps and Sherman live traps. Counts of amphibian egg masses are conducted in spring in palustrine open water wetlands. A "life form rating," based on the plant community and successional stage in which amphibians reproduce and feed, and a "versatility rating," based on the sensitivity of an identified amphibian to habitat change, can also be used (Brown, 1985). In addition, life history phenomena are recorded, as indicated by Nussbaum et al. (1983).

Birds are identified by calls, territorial songs, pecking and drumming patterns, visual sightings, and flyovers during 15-minute observations at permanent census stations. Relative abundance can be determined according to Orians as adapted by Gracz in Appendix C3 of the *1989 Puget Sound Wetlands and Stormwater Management Research Program Report*. As with amphibians, life form ratings and versatility ratings can also be used, as indicated by Brown (1985).

Sampling protocols for mammals are similar to those established for amphibians, according to (West, Cooke, Richter, and Horner, 1989; Horner and Raedeke, 1989). Mammal populations are low in spring and, following the breeding season, increase in fall. For this reason, mammal populations should be monitored in both the fall and spring, encompassing the seasonal dynamic. Information about coffee can pitfalls, Sherman live traps, and data collection and analysis are provided in Appendix C4 of the *1989 Puget Sound Wetlands and Stormwater Management Research Program Report*.

Photographic Monitoring

Photographic monitoring provides a visual record of the restoration effort and is an excellent way of qualitatively documenting plant community changes. As recommended by Horner and Raedeke (1990), a sufficient number of photographic stations should be established to provide photographic coverage of each plant community type and vegetation layer. These stations can be located in conjunction with plant sampling transects. Each station should be identified and permanently labelled in the field.

Photographs should be taken at approximately the same date each year, preferably during peak vegetation growth. A reference stake should be included to evaluate vegetation growth, and each photograph should be labeled with photo point designation, compass bearing, frame number, date, and time. Aerial photographs can also be used to provide a measure of the change in distribution of plant communities over time.

Citizens' Monitoring

Citizens' monitoring programs can be extremely valuable to a restoration program. Through such programs, the public can be educated about the value of wetland resources, long-term stewardship of wetlands can be encouraged, and local governments and agencies can obtain assistance with monitoring projects. In addition, the vigilance of involved citizens can serve as an early warning system, informing program participants about disturbances and detrimental changes occurring in wetlands.

Citizens' monitoring of basic wetland indicators can be especially valuable after baseline data have been collected. Citizens can be trained to take measurements and make observations on a regular basis, helping to track changes in wetland conditions. Measurement methods should be easy to learn and involve inexpensive materials. Many monitoring techniques are simply a matter of directed observations. Instruction sheets can be provided to citizens to guide observation and data collection in the field. Several monitoring tasks can be easily performed by citizens. These include:

Photo documentation. Photo stations can be established to regularly document vegetation, water levels, habitat features, and surrounding land uses.

Hydrologic studies. Citizens can be trained to observe and document the hydrology of the wetland. Water sources can be identified, inlets and outlets located, and the condition of surrounding watershed tracked. Marked dowels or rods can be permanently installed to measure water depths. Citizens can monitor daily, weekly, or seasonal water changes and observe changes in surrounding drainage patterns. By installing a backyard rain gauge, water levels in the wetland can be correlated with ambient rainfall.

Water quality monitoring. Water temperature, Ph, Dissolved Oxygen, and visual quality can be easily assessed by citizens with minimal training.

Plant and animal observation. Citizens can check for encroachment of invasive species and other changes in vegetation. Field observers should be encouraged to learn plant names and to identify the different plant communities. Their observations of wildlife species can provide valuable insights that might otherwise go unnoticed. Similarly, citizens can be trained to identify basic habitat features and to note seasonal use by wildlife.

Land use documentation. Citizens can alert local agencies of impacts to wetlands such as filling, dredging, soil erosion, and increased runoff. Observations can be made about the impacts of human intrusion and domestic animals on wetland systems.

A citizen's guide to wetland restoration assessment is being prepared by the U.S. Environmental Protection Agency in cooperation with the U.S. Army Corps of Engineers. This guide will be available in the spring of 1993.

CHAPTER 7: Management Of Restoration Sites

Long-term management and ownership of restoration sites are the final aspects of restoration planning that must be addressed. A wetland's position in the landscape makes it more prone to natural disasters than its surrounding upland communities. Wildfire, flooding, or drought can limit restoration success by altering vegetation, soils, and hydrology. Project managers must monitor and be able to respond to impacts created by these and other events that threaten project goals.

Management of restoration sites should begin during the construction phase. Early concerns include controlling erosion with sediment fencing, straw bales, or temporary vegetation covers; identifying access routes and boundaries for equipment operation; and supervising planting to ensure plants are handled properly and installed correctly. Surface water runoff containing pesticides, petroleum products, large amounts of sediment, or other contaminants should be directed away from wetlands or treated before entering a wetland. Ecology's *Stormwater Management Manual for the Puget Sound Basin*, #91-75, provides detailed information on controlling and treating stormwater runoff.

Certain long-term management issues, such as the need to control grazing by livestock and other animals, may become obvious during the site assessment phase. In these instances, strategies to maximize plant survival and growth should be developed before any plants are placed. However, some factors limiting successful establishment, however, are not always immediately evident, requiring project managers to address any factors that threaten restoration success as they arise.

Long Term Site Management

Who should manage and own the restored wetland? Usually the simplest answer is for the project proponent to own and manage the sites. However, this may not be the most effective way to ensure restoration goals will be met. For example, under many regulatory programs, management of mitigation sites by project proponents has often been inadequate, making it necessary to determine an appropriate party or parties to take over management and ownership of these sites.

If a project is part of an overall restoration program, the program's administrator may be the appropriate candidate to assume the responsibilities of ownership and management. If the project is not likely to further program goals, another government entity or a local land trust may be a likely candidate. In some instances, it may be most effective for one party to own and another to manage a site. This may well be the case if a conservation easement is placed on the land, with specific restrictions covering changes in use. The holder of the conservation easement is responsible for enforcing any terms identified in the agreement and, if specified, may also take over management responsibilities for the land.

Additional information on conservation easements, other preservation options, and wetland preservation programs in general is contained in Ecology publication #90-05, Wetlands Preservation: An Information and Action Guide.

Controlling Grazing And Browsing

Grazing or browsing by domestic and wild animals can prevent or severely limit the establishment of wetland plant populations. Beaver, muskrat, nutria, deer, waterfowl, and livestock have all caused serious problems at restoration sites in Washington State. Conditions at each site will determine how to best control grazing and browsing. In general, if suitable feeding areas are available nearby, animals will be more easily deterred than if they are dependent on feeding areas in or around the restoration site. Structural controls of grazing or browsing must be kept in good working condition and used persistently until new plants are well established.

By fencing sites, plant communities, or individual plants, access to large animals such as deer or cows can be restricted. Fences must be tall enough (at least 8 feet high) to prevent deer from jumping over them and sturdy enough to thwart animals from pushing them over. Battery-powered electric fencing has been effective in preventing deer access in some cases.

Building fences of chicken wire or nylon line can also deter geese and ducks from feeding on plantings of emergent species. Rhizomes and tubers are especially vulnerable when planted in emergent areas before water levels are established. Built around the perimeter of the planting area, fences can prevent waterfowl from feeding on materials within the fences. However in large planted areas, waterfowl can often fly over these barriers, requiring a cover of fencing or string over the entire area.

Effective goose fencing can be built by driving posts into the soil and connecting them with 1/8-inch nylon line rails spaced 6 inches apart (Garbisch 1986). The rails should extend from 6 inches above the low water mark to 6 inches above the high water mark. Fences should be built out of highly visible materials. If wire is used, surveyor's flagging should be hung to increase its visibility.

To discourage animals from excavating tubers or rhizomes, chicken wire can be fastened directly to the soil after planting. Wire or other physical barriers should be removed once the plants become established.

Plants can also be individually protected from grazing or browsing by installing physical barriers. Tubex® and Treehouse® tree shelters are translucent plastic tubes available in lengths that range from 8 inches to 6 feet. Tubes of rigid netting for protecting seedlings are also available, in heights ranging from 18 inches to 36 inches. Both types of tubes are placed around plants during installation to limit animal access. These products can be used with seedlings or single-stemmed trees, but multi-stemmed shrubs or trees may require the protection of individual fences constructed of wood or metal posts and chicken wire. To protect mature trees from beavers, individual tree trunks can be wrapped with fencing material such as chicken wire or hardware cloth. These wrappings must later be removed to prevent girdling of the tree.

Several chemical deterrents have been developed for the forestry industry to protect shrubs and trees. These products contain bitter-tasting or foul-smelling chemicals that can be applied directly to the plants. Most of these substances are water soluble and must be reapplied. By hanging surveyor's flagging on each treated plant, the effectiveness of the product may be increased. If animals learn to identify treated plants, they may avoid these plants even after the chemicals have lost their effectiveness.

Repellents

A recent study conducted in apple and yew plantations on the East Coast compared the effectiveness of Big Game Repellent®, Ropel®, and soap (Swihart and Conover, 1990). Soap was evaluated because it is commonly used by orchardists in the northeastern United States as a relatively inexpensive alternative to commercial repellents. In addition, soap tends to last longer than the commercial repellents.

For this study, researchers hung bars of soap by drilling a hole through the wrapper and bar, looping a piece of string through the hole, and hanging the bars (with their wrappers intact) in the trees. Several brands of bar soap, including Dial®, Irish Spring®, Coast®, Ivory®, and Safeguard®, proved more effective than Ropel® but less effective than Big Game Repellent® for limiting deer browsing. No brand of soap proved to be distinctly better or worse than others, and none of the repellents entirely prevented damage. The authors suggest 39 inches as a conservative estimate of the effective distance that soap will exhibit repellent properties.

Scarecrows are generally effective only for short periods, losing their effectiveness as animals become accustomed to them. Animal control cannons, available from forestry equipment suppliers, produce a harmless detonation similar to that of a 37-millimeter cannon. They can fire with regular or irregular rhythms and be operated unattended for up to 14 days with a timing device. At sites in the eastern United States, effectiveness was limited to areas near the cannons (Kraus, personal communication). To minimize disturbance to human populations, cannons should only be used in rural areas.

Trapping and relocating beavers was effective in a California riparian restoration project, despite the fact that trapping was conducted for only a few months (Oldham and Valentine, 1989). Buech (1985) provides an excellent discussion of beaver natural history and potential control methods (which include culvert installations to regulate water levels despite beaver activity).

Other control methods include keeping a dog at the site to discourage wildlife use and encouraging hunting to both reduce animal populations and alter foraging behaviors. It should be noted that many other problems may arise, making it necessary for managers of restored wetlands to remain in contact with wetland ecologists and hydrologists for at least 10 years following the restoration work.

Controlling Aggressive Plants

The relative success of a wetland restoration project is threatened when aggressive plant species invade or exist at a site. Once established, an aggressive plant population can outcompete other species, form dense monotypic stands, and eventually dominate entire water regimes and or plant communities if not controlled. While this kind of growth may be considered beneficial from a water quality functional perspective, other wetland functions and values can be dramatically impaired, for example wildlife habitat and ecosystem complexity. Restoration projects that involve earth moving or alterations to site hydrology are particularly vulnerable to the invasion or spread of aggressive plants.

There are both native and non-native species of plants which can form monocultures in Washington wetlands. Problem species include:

Non-native (exotic)	Native
reed canary grass	common cattail
purple loosestrife	Douglas spiraea
Eurasian milfoil	
soft rush	
creeping buttercup	
Canada thistle	
common reed	
Russian olive	

Limiting the spread of any of these species onto a project site will require careful planning, monitoring, and eradication of invading plants.

Different control measures have met with varying degrees of success and the base of experience with these techniques is limited. A collection of the available information on the control of some of Washington's aggressive wetland plants is presented below.

Soft rush and creeping buttercup. Soft rush and creeping buttercup seldom invade high-quality wetlands. Instead, these plants favor disturbed sites with compacted soils or exposed subsoil layers and frequently grow in seasonally wet pastures where livestock grazing has reduced plant competitors. Soft rush is shade-intolerant and can be controlled by establishing dense stands of shrubs and trees. This species can be a prolific seed producer. Creeping buttercup, although capable of forming long-lived monocultures, is usually more of a short-term nuisance than a long-term threat, and separate control strategies for this species are seldom needed. Planting shrubs and trees and removing livestock may be sufficient controls.

Reed canary grass and purple loosestrife. While developing a management plan for reed canary grass and purple loosestrife, the question is usually not how to eliminate but, rather, how to control these weeds. Once established at a site, both species require regular, long-term maintenance to control their spread and limit populations to acceptable levels. In addition, controlling the spread of these species is difficult because mechanical methods, herbicides, and burning may provide only short-term control, often with undesirable secondary impacts. Biological controls have been approved for use in Washington State, and, as of July 1992, one of three approved European insects has been released. A larger number of insects have been scheduled for release in spring of 1993. An interagency effort is underway in Washington State to write a programmatic environmental impact study on controlling emergent noxious plants. The goal of this study is to identify integrated pest management programs for each species, with particular emphasis on purple loosestrife and cordgrass (Civille, personal communication).

Reed canary grass. Because of its pernicious impact to Washington wetlands this species has received a relatively high degree of attention. Several separate control strategies for this plant have been outlined below.

Cut and cover. A single summer mowing, followed by the placement of 3-foot diameter circles of road felt around transplanted 2-gallon red osier dogwood, limited the spread of reed canary grass at one eastern Washington riparian zone, allowing the dogwood to overtop the canary grass in one growing season (Jurs, personal communication).

Physical removal. At individual sites eradication has been attempted by pulling plants up by hand or by cutting them out with heavy machinery. Although these methods may remove established plants, they are not very effective because canary grass seeds and rhizomes are usually left in the soil. Seed bank germination tests of soils from an Illinois wetland suggest that reed canary grass can completely dominate a seed bank: within eight days after placing soil samples in a greenhouse, thousands of canary grass seedlings per square yard emerged, and no other species grew (Fisher, personal communication).

Burning on a 1-year to 3-year rotation. This method appears to be effective at controlling canary grass at one Illinois prairie preserve, but it has not been effective in western Washington (ibid). Burning should be used with caution because it may result in undesirable changes in plant community composition. In western Washington, an area infested with reed canary grass was converted to smartweed through combined applications of Rodeo® herbicide and fire (Stephenson, personal communication).

Flooding. Permanently flooding areas with more than 5 feet of water for at least three growing seasons has successfully eliminated reed canary grass populations.

Heavy shading with red alder, black cottonwood or other fast-growing trees. Because reed canary grass grows sparsely in mature forest understories, planting trees that will eventually shade an area dominated by canary grass may be an effective control tactic. However, limited field observations indicate that planting trees to eventually shade out reed canary grass may be only partially effective and is, at best, only a long-term control tactic.

Herbicides. Reed canary grass may be controlled with the herbicide Rodeo®, as discussed in the following section on purple loosestrife.

Purple loosestrife. If purple loosestrife already exists at a site, any disturbance (including water level manipulation, exposing bare soil during site preparation, or construction of water control structures) may encourage its spread by creating seed beds, spreading seed, and spreading plant parts capable of regeneration.

Mechanical and chemical methods. In areas of heavy infestation, attempts to control purple loosestrife by mechanical or chemical means is often futile and may worsen the situation by damaging or destroying competing native vegetation (Henderson, 1987). If left in the soil, any roots that are larger than 1/8 of an inch in diameter can sprout. Severed stems that are left in the soil can also develop adventitious roots and form new plants. Moreover, ground disturbance from digging will provide new areas for seed germination.

Wetland "Triage". Without drastically altering an area through methods such as flooding or excavation, it is not possibles to eradicate large loosestrife populations. Presently, the most effective method for controlling loosestrife is to eradicate small populations and individual colonizers, thereby confining loosestrife to severely infested areas. Preventing the invasion of purple loosestrife into new areas is only possible with continual monitoring and control activities.

Salinity. Purple loosestrife does not tolerate brackish conditions (Stevens, personal communication). As a result, in coastal wetlands that have tide gates to prevent tidal inundation, loosestrife may be controlled by opening these gates for at least one full growing season. Impacts to desirable salt-intolerant wetland plants and the potential for flooding non-wetland areas should be evaluated before using this control method.

Herbicides. Although purple loosestrife can be controlled with repeated wick applications of the nonselective herbicide glyphosate, such applications only kill growing plants. Subsequent seedling growth must be controlled for at least 2 to 3 years. Rodeo® is the only glyphosate herbicide recommended in areas with surface water. Rodeo® must be applied by a state-licensed applicator, and its use requires a Short-term Water Quality Modification Permit from Ecology (Maynard, personal communication). A list of commercial applicators with Aquatic Licenses is available from:

> State of Washington Department of Agriculture
> Pesticide Management Division
> 406 General Administration Building AX-41
> Olympia, Washington 98504-0641

Assessment protocol. WDW biologists recommend the following steps for assessing purple loosestrife at revegetation sites (Perry, personal communication):

> Determine the age and density of the purple loosestrife population to assess the potential seed bank build-up in soils.
>
> Determine the rate of spread and identify suitable habitat areas within the restoration site that may support new populations.
>
> Begin control work, hand-pulling all plants that are less than two growing seasons old.

When purple loosestrife is present in or near a restoration site, spring and summer monitoring for loosestrife invasion should be included in the long-term management plan. Monitoring must include onsite inspections of the entire wetland, and control efforts must be initiated as soon as loosestrife is found.

Biological control. Biological control of purple loosestrife offers the greatest potential as a long-term, safe, economical, and effective control technique. Two leaf-mining and one root-mining beetle species are undergoing final screenings before they can be approved for field release. There is no scheduled date for their release in Washington (Dolstad, personal communication).

Additional control measures. Additional loosestrife control methods reported in studies from the eastern United States include competitive plantings with cattails and other emergent species (Wilcox, Jarman, personal communications) and mowing and covering plants with clear plastic (Dobberteen et al, 1989). The cut-and-cover treatment plots, conducted on a small experimental basis, had 6-38 percent fewer loosestrife stems than uncovered control plots, suggesting that this may be an effective method for dealing with small clusters of plants.

Common cattail and Douglas spiraea. Although native to Washington, common cattail and Douglas' spiraea can form vast monotypic stands in disturbed or created wetlands. As a result, these species should be introduced with caution at restoration sites, and may require control to minimize competition with other species. Common cattails and Douglas' spiraea both seed freely on bare, moist soil and spread by rhizomes.

Potential methods for controlling Douglas' spiraea include digging, mowing, flooding, and herbicides. Cattail growth and management techniques have been reviewed by Beule (1979), who favors the cutting of cattail stems when carbohydrate reserves are low (coinciding with the emergence of flower spikes) and maintaining several inches of water over the cut stems through the next growing season, thereby eliminating air supplies to the roots. Kunz (personal communication) has used a machine called a "cookie cutter" to control cattails in a large pond in western Washington. The machine requires about 1/2 foot of water in which to operate, and cuts and digs rhizomes to a depth of about 3 feet. At the western Washington site, no cattail regrowth occurred in the treated areas during the following growing season.

Common reed. By covering wetland soils with clear plastic sheeting, which can raise soil temperatures to levels that are lethal for plants, common reed has been controlled in one North Carolina salt marsh (Boone et al, 1988). This practice may also be effective in Washington. Plants in the North Carolina marsh were mowed or burned, then covered with clear plastic sheeting held in place with sandbags. Temperatures under the plastic reached 169° F when ambient temperatures were 100° F. Complete die-off of all species was evident after three or four days. Because ambient temperatures seldom reach 100° F in western Washington, and because minimum lethal temperatures for common reed have not been determined, this method should be applied experimentally before it is used locally to treat large-scale infestations.

As our collective knowledge of the control of aggressive wetland plants continues to grow so will our ability to adequately protect and manage the resource from this threat. To this end the Wetlands Section of WDOE will serve as a clearing house for information on successes and failures in the control of aggressive wetland plants. As practitioners in the field gain additional experience in this area, the information should be shared with staff at the WDOE Wetlands Section. *Appendix A* of this document contains information on sources of aquatic weed control supplies.