HOW SUCCESSFUL HAS WETLAND MITIGATION BEEN? AN EXAMINATION OF WETLAND COMPENSATORY MITIGATION SUCCESS IN THE COOS WATERSHED, OREGON

by

LAURA JEAN SHAFFER

A THESIS

Presented to the Environmental Studies Program
and the Graduate School of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Master of Science

June 1999

"How Successful Has Wetland Mitigation Been? An Examination of Wetland Compensatory Mitigation Success in the Coos Watershed, Oregon," a thesis prepared by Laura Jean Shaffer in partial fulfillment of the requirements for the Master of Science degree in the Environmental Studies Program. This thesis has been approved and accepted by:

Alan Shanks

Dr. Alan Shanks, Chair of the Examining Committee

26 May 1999

Date

Committee in charge:

Dr. Alan Shanks
Dr. Dennis Todd
Dr. Steven Rumrill
Dr. Jan Hodder

Accepted by:

Vice Provost and Dean of the Graduate School

An Abstract of the Thesis of

Laura Jean Shaffer for the degree of Master of Science

in the Environmental Studies Program to be taken March 1999

Title: HOW SUCCESSFUL HAS WETLAND MITIGATION BEEN? AN EXAMINATION OF WETLAND COMPENSATORY MITIGATION SUCCESS IN THE COOS WATERSHED, OREGON

Approved: ______________________________
Dr. Alan Shanks

Wetland compensatory mitigation (WCM) attempts to prevent further loss of wetland habitat to development, and where possible, increase wetland acreage. This study assessed the success of 35 WCM sites in the Coos Watershed of coastal southwestern Oregon. Permit reviews, field checks, vegetation surveys, and land-use and zoning data were used to determine wetland function and predict the potential of WCM sites in maintaining watershed functional integrity and creating long-term wetland viability.

WCM in the Coos Watershed has been successful in increasing acreage, but specific habitat types -- estuarine sand beach and rocky shore, forested wetland, and subtidal mudflat -- are still being lost. Fifty-four percent of all mitigation sites currently function successfully as wetlands. Increasing the spatial and temporal scales to include long-term wetland viability and maintenance of watershed integrity, site success drops to 37%, partial successes increase to 46%, and 17% of all projects are outright failures.

CURRICULUM VITA

NAME OF AUTHOR: Laura Jean Shaffer

PLACE OF BIRTH: Buffalo, New York

DATE OF BIRTH: April 16, 1972

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

University of Oregon
Cornell University

DEGREES AWARDED:

Master of Science in Environmental Studies, 1999, University of Oregon
Bachelor of Science in Biology *cum laude*, 1994, Cornell University

AREAS OF SPECIAL INTEREST:

Wetland Mitigation; Restoration Ecology; Habitat and Biodiversity Conservation; Water Quality Issues; Environmental Education

PROFESSIONAL EXPERIENCE:

Assistant Research Librarian, Northwest Coalition for Alternatives to Pesticides, Eugene, Oregon, 1996-99

Lecturer, Department of Environmental Studies, University of Oregon, Eugene, Spring 1998

Technical Assistant, American Samoa Territorial Energy Office, Pago Pago, American Samoa, Summer 1997

Teaching Assistant, Department of Biology, University of Oregon, Eugene, Fall 1996, Spring 1997

Teaching Assistant, Department of Environmental Studies, University of Oregon, Eugene, Winter 1997

Student Intern, South Slough National Estuarine Research Reserve, Charleston, Oregon, 1996

AWARDS AND HONORS:

Barker Fellowship, 1997-98

PUBLICATIONS:

Shaffer, J.. 1997. Promoting Energy Efficiency and Wise Water Use in American Samoa. A report to the American Samoa Territorial Energy Office, Pago Pago, American Samoa. University of Oregon Micronesia and South Pacific Program. 104 pp.

ACKNOWLEDGEMENTS

The author expresses sincere appreciation to Professors Hodder, Todd, Shanks, and Rumrill for their assistance in the preparation of this manuscript. In addition, special thanks are due to Mr. Michael McCabe at the Oregon Division of State Lands, who generously shared both his expertise with wetland mitigation in the Coos Watershed and time. I also thank the staff of South Slough National Estuarine Research Reserve for their expertise, valuable input, and use of their facilities for research. Finally, I would like to thank the McAlear family for providing a home away from home while I conducted my field work. The investigation was supported in part by a Barker Fellowship from the Environmental Studies Department at the University of Oregon.

DEDICATION

I would like to dedicate this work to my parents, Walter and Margaret Shaffer, who have always encouraged me to ask questions (especially "Why?") and to explore the world around me. I would also like to dedicate this to my husband, Christopher Hansen, for his unfailing support, encouragement, and love. I love you all.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

Table | Page

LIST OF MAPS

CHAPTER I

AN INTRODUCTION TO COASTAL WETLANDS AND WETLAND COMPENSATORY MITIGATION

Because wetlands occupy the transition zone between upland forests or grasslands and open water, wetland habitats share characteristics of both. This can make it difficult for a casual observer to determine a wetland's actual boundaries. Jurisdictional wetlands, as defined by Section 404 of the Federal Clean Water Act, are:

> [a]reas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions (p. 2, Federal Interagency Committee for Wetland Delineation 1989).

In practice, delineators, individuals who determine wetland boundaries, and government regulators recognize habitats having hydric soils, hydrophytic, or water-loving, plants, and standing water for at least two weeks during the growing season as wetlands.

Wetland compensatory mitigation (WCM) is an attempt to prevent further losses of wetland habitat, and where possible, increase wetland acreage. As areas are drained, dredged, or filled for development, a pre-agreed upon number of wetland acres are created, restored, and/or enhanced to balance the loss. Lack of knowledge about how wetland ecosystem components interconnect, poor funding, poor project design, and lack of a monitoring program may cause WCM project failure. In this study, I will attempt to determine how successful WCM has been within a single watershed, the Coos Watershed of coastal southwestern Oregon. I propose that current wetland mitigation practices have led to a loss of wetlands within the Coos Watershed, and that this loss has degraded watershed function and connectivity.

During a short field check, hydrology and hydric soils at a wetland site are difficult to measure and describe. Long-term monitoring is a better way of quantifying such parameters. However, vegetation health and species presence are useful indicators of habitat health and function. Wetland-dependent plants will only flourish in areas where specific conditions are present. Most plants are also easily identified in the field. Therefore, for this study I focused on vegetation as a means of describing and measuring WCM project success. I also reviewed wetland permits, checked for compliance in the field, and calculated WCM site acreages to compare with their associated impacts. Using these data, I then assessed individual WCM site success as a functioning wetland and as a successful contributor to watershed function.

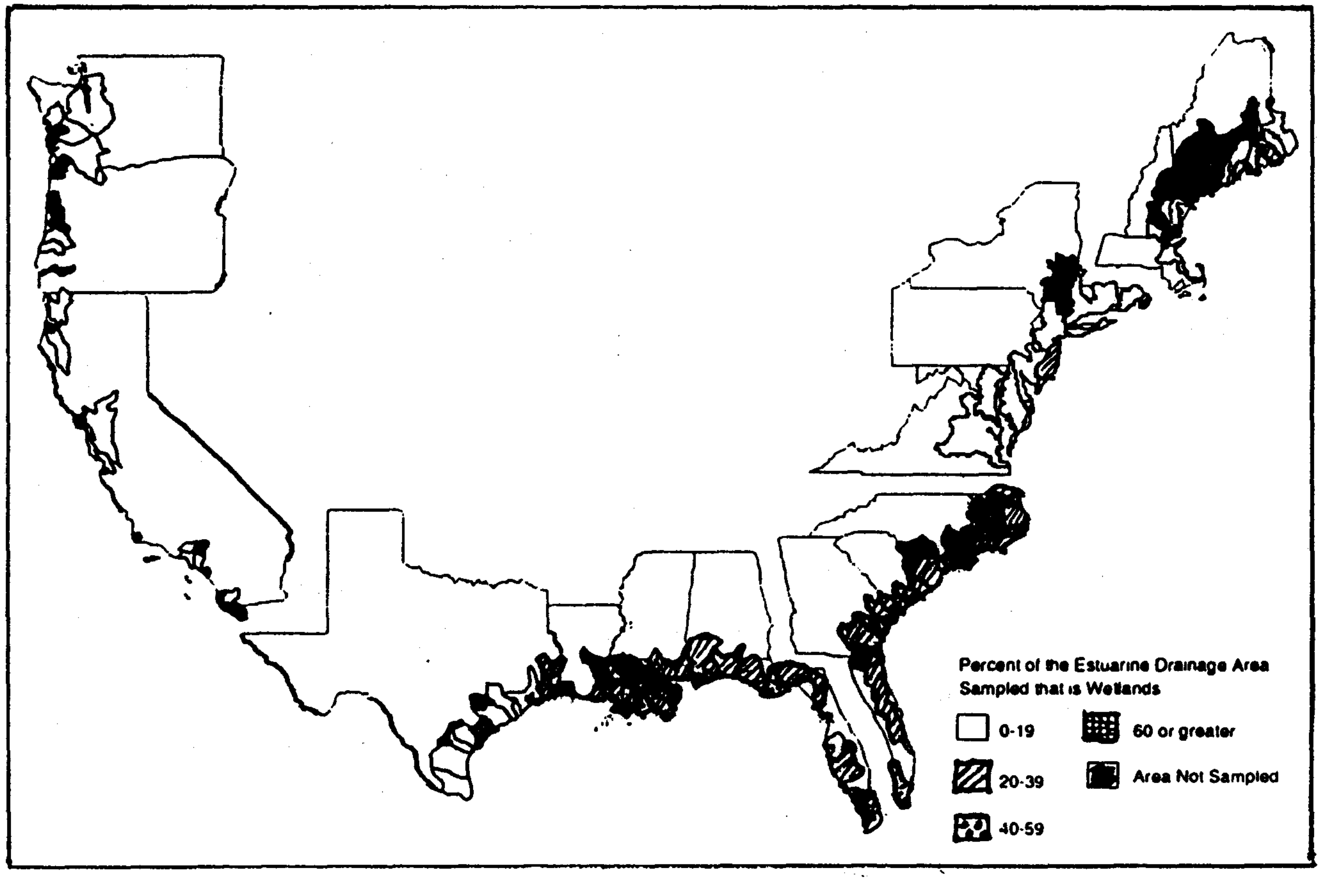
Wetland Status and Trends

Of the approximately 32,260 miles of United States coastline, only 5,200 miles of shore is wetland (Field *et al.* 1991). The 27.4 million acres of wetland adjacent to the ocean constitutes just 5% of all wetland acreage in the lower-48 states (Zedler 1996). Coastal wetland habitats in the United States include both freshwater and saltwater environments. Estuarine wetlands like salt marshes, mudflats, mangroves, and eelgrass beds contain plants and animals adapted for life under a tidal influence. Temperature, salinity, and air exposure change with the rise and fall of the tides. Freshwater wetlands include marshes, swamps, scrub/shrub wetlands, and bogs. These habitats may be tidally influenced. Plants and animals living in freshwater wetlands must adapt to waterlogged soils and inundation that vary seasonally. Map 1 shows the current extent of coastal wetlands and estuarine drainage areas in the United States.

Coastal areas have the highest population growth rate of any region in the United States. As a result, coastal wetland habitats are under frequent attack from development. In 1992, about 110 million people lived along the coast, roughly 108 persons per square mile (UN Conference 1992). Since the European settlement of Jamestown, Virginia in 1607, the United States has lost 53% of its original 221 million acres of wetlands in the lower 48 states -- approximately 117 million acres drained, filled, and paved (Dahl and Johnson 1991, Zedler 1996). Current figures show wetland habitats disappearing at an alarming rate. At about 300,000 acres impacted per year, human initiated losses far outpace natural rates of wetland growth.

Direct human action is responsible for most wetland loss and degradation along the coast. Resource management actions responsible for such wetland impacts include drainage for agriculture and mosquito control, dredging for navigation channels and flood control, filling for solid waste disposal and urban development, aquaculture conversion, and dike, dam, and levee construction (Boule and Bierly 1987). Natural losses from sea level rise, drought, erosion, and hurricanes are small compared to human impacts. Public opinion of wetlands is changing, as people slowly realize the inherent ecological, economic, and aesthetic functions of these areas.

In Oregon, 38% of all wetlands have been degraded or permanently lost (Boule and Bierly 1987, Ryan 1994). The two main historic causes of loss were agriculture and the siting of port and industrial facilities (Boule and Bierly 1987). While agricultural impacts decreased, urbanization expanded after W.W.II. Industrial and commercial



Map 1. Wetland distribution in coastal watersheds in the continental United States (p4, Field *et al.* 1991).

developments continue to impact Oregon's coastal wetlands. A 1992 study by scientists at the U.S. Environmental Protection Agency (USEPA) found that 90% of all mitigation projects in Oregon impacted coastal wetlands. Projects requiring compensatory mitigation increased over a ten year interval (1977-1987) and resulted in a net loss of about 79 wetland acres (Kentula *et al.* 1992a). Areas having the greatest amount of mitigation underwent significant population growth. This suggests that much of the development was residential, commercial, and industrial. Many of the restored and created wetland types were not those impacted -- there was no in-kind mitigation. Therefore, the original wetland functions and habitats were permanently lost.

The Importance of Coastal Wetlands

Coastal wetlands perform a number of functions benefiting both human and wild communities. Scientists calculate that, worldwide, coastal wetlands provide ecosystem services valued at approximately $ 212,975 per acre per year in 1994 U.S. dollars (Constanza *et al.* 1997). This figure does not include all ecosystem services or aesthetic values and uses. Coastal wetlands filter impurities from water, absorb flood waters and storm surges, retain sediments, slow erosion, and recharge aquifers (Beatley, Brower, and Schwab 1994, Constanza *et al.* 1997, Turner and Jones 1990, Williams 1996, Williams 1990). For example, when the U.S. Army Corps of Engineers (USACE) considered flood control alternatives for Boston, Massachusetts, they studied wetland contributions to flood water storage in the Charles River Watershed. The USACE determined that it was cheaper to buy and preserve wetlands in Charles River Watershed, than build a dam and levee system to protect Boston. The habitat preservation alternative has been estimated to save Boston $17.6 million annually (Dennison and Schmid 1997, Williams 1990).

Wetland productivity can exceed that of prime farmland in the Midwest, and some coastal wetlands have greater biological production than tropical rainforests (Constanza *et al.* 1996, Turner and Jones 1990). Like rainforests, coastal wetlands are home to an astonishing number of organisms. Forty-five percent of all endangered and threatened species use estuarine wetlands during some part of their life cycle, including 75% of federally listed birds and mammals (Glomb 1995). Migratory birds and waterfowl use coastal wetlands for feeding, resting, and breeding grounds. The U.S. Fish & Wildlife Service (USF&WS) recognizes Oregon's and Washington's coastal wetlands as national priority areas for preserving flyway and over-wintering habitat for birds, particularly waterfowl (Boule and Bierly 1987). These habitats also provide nursery and spawning grounds for 75% of all US commercial fish and shellfish catches, as well as non-commercially important organisms like amphibians, aquatic invertebrates, and fish (Stedman and Hanson 1997). Coastal wetlands fringing river mouths provide food, shelter from predators, and clean water for local populations of fish and other organisms. In Oregon, commercially important species like salmon, dungeness crabs, oysters, and clams depend on the 132,000 acres of Oregon's existing coastal wetlands (Akins and Jefferson 1973, Good 1987, Stedman and Hanson 1997). Development of Oregon's coastal wetlands is one of the many reasons that Coho salmon have been listed under the Endangered Species Act.

In addition to these regular ecosystem services, wetlands provide intangible benefits which cannot be adequately valued under our current economic system. Aesthetic aspects of wetlands are just as important to humans as the biological and physical services wetlands provide. Wetland open spaces allow humans a place to interact with nature. Frederick Law Olmstead, Sr. recognized this potential role for wetlands in the 1880s when he urged the city of Boston to set aside a stretch of marsh along the Muddy River as open space. Today, the Fens are a well-known and well-loved part of Boston's city park system (Platt 1996). Despite our cultural obsession with technology, we will always need quiet places to rest and reflect. Natural places, like wetlands, can fulfill this role. In Oregon, where else can one listen to the arguments of the frogs at night, spot a snowy egret standing in the river shallows waiting for the silver flash of dinner, or find a field of camas lilies reflecting the clear blue sky of morning?

Watershed Level Impacts

Wetlands are ecosystems, but they also act as ecotones. These habitats play an important role in maintaining watershed function and connectivity. Healthy watersheds need wetland bridges linking uplands and open water to sustain hydrological regimes (Ochoco National Forest 1997, Satterlund and Adams 1992, Williams 1990). Poor land management significantly alters watershed function. Wetland loss changes the quantity, quality, and timing of water moving through a watershed. Development paves over wetlands, strips vegetation, and fragments habitat. Bare and impermeable surfaces move water quickly to stream channels. The energy created by this movement provides greater potential for eroding soil and rock. Wetland vegetation slows erosion by trapping sediments in and around roots, stems, and leaves. In addition, the plants slow the water's movement and allow the water to sink into the soil. This process helps wetlands absorb flood waters, store groundwater for later release, and recharge aquifers. Slowing erosion and trapping sediments improves water quality within a watershed by preventing the addition of sediments to stream channels (Ochoco National Forest 1997, Satterlund and Adams 1992, Williams 1990).

One of main reasons that many plant and animal species are threatened with extinction is the loss of their primary habitat (Chadwick 1991). Small-scale development by a landowner may not have a noticeable effect, but cumulatively, development by many individuals will. Cumulative impacts contribute to habitat loss. In a heavily impacted watershed, the remaining, fragmented habitat is too small and isolated to sustain healthy populations over time. With no place to find food or reproduce, plants and animals die out. Isolation, like a pocket wetland in an urban area, is the ultimate fragmentation (Csuti 1991). While large wetland impacts permanently remove huge chunks of habitat out of a watershed, the small impacts of 1 acre or less eventually fragment the landscape so much that the effect is approximately the same. Natural disturbances create habitat fragmentation, but human caused fragmentation occurs at a faster rate and is more permanent (Csuti 1991).

Cumulative wetland impacts also contribute to degraded watersheds. Wetlands help maintain watershed connectivity by providing wildlife corridors. Species living within watersheds need corridors for three reasons: "to facilitate periodic migrations to breeding or birthing sites", "to forage or roost or follow seasonally moving resources," and because "populations must receive immigrants if they are to survive in isolated patches" (p 93, Soule 1991). Extinction vulnerability within isolated patches is inversely related to size -- the smaller the patch, the greater the chance of extinction (Soule 1991). If patches are very large, corridor links to transport small, abundant plant and animal species are unnecessary. Small patches can sustain large animals if movement among patches is possible. For example, isolated chaparral habitats in southern California support *Canis latrans* (coyote) populations because movement between these small patches is possible (Soule 1991).

Coastal wetlands once formed a band of unbroken, productive corridor between watershed uplands and estuary/ocean in some places in North America. Urban and rural development have fragmented this landscape, leaving isolated habitats surrounded by roads, houses, and industrial development. Migratory birds, weedy plants, deer, and the occasional coyote may be able to move successfully between fragmented wetlands, but what about other species? A few isolated wetland acres cannot sustain a herd of foraging elk. Genetic exchange between small, isolated populations of rare species is necessary (Good 1987, Mitsch and Gosselink 1993). Without the ability to exchange genetic material, populations of species like *Cordylanthus maritimus* (saltmarsh bird's beak) or *Rana aurora aurora* (red-legged frog) will die off. Fragmenting and degrading wetland habitat destroys a watershed's ability to provide adequate salmon spawning and rearing habitat.

Wetlands are fast becoming small preserves surrounded by human development. One of the main lessons of island biogeography is that species cannot survive in little preserves.

> "Organisms are constantly growing, interacting, adapting, evolving. Their numbers and distribution across the landscape fluctuate in cycles linked to climatic patterns and to other, less well understood patterns (p xviii, Chadwick 1991)."

All the processes of an ecosystem, and at the larger scale the watershed, must be preserved in order to save the community members that live within the system because of interconnections between the two. Leopold (1966) described this conservation land ethic succinctly. Every component of a system plays an important role in preserving the integrity of that system. Continued wetland losses from impacts and poor wetland mitigation practices further degrade watershed systems.

Historic Wetland Losses

Prior to European settlement, Native Americans took advantage of the highly productive coastal wetlands in the United States as hunting and fishing grounds. Wetland plants provided foods and medicines, as well as construction materials for homes, tools, and clothing (Siry 1984). Dredging, draining, and filling in this country began with European arrival and their establishment of settlements (UN Conference 1992). The wetland "wastelands" were viewed as obstacles to other more productive uses of land and water, like agriculture and shipping.

The majority of wetland alteration in the 17th and 18th Centuries consisted of reclaiming "wastelands" for economic use. Although colonists caught fish and shellfish in estuaries, they also grazed their animals on marsh grasses, and grew crops like rice, corn, hemp, and tobacco on the rich soils (Siry 1984). Northern colonists were more likely to drain, dredge, and dike their coastal wetlands than southerners, despite an act passed in 1712 by the House of Burgesses encouraging drainage and cultivation. Most southern marshes became seasonal pasturelands, rice paddies, and fields for poorer grades of tobacco (Siry 1984). In 1763, George Washington set up a company to drain the Great Dismal Swamp of Virginia and North Carolina and construct a canal connecting Albemarle Sound to the Chesapeake Bay. The canal was built, but most of the Great Dismal Swamp remained undrained (Dahl, Larson, and Scheidt 1993, Siry 1984).

Americans in the 19th Century continued the war against wetlands. As people moved west, they drained and filled in wetlands to create farmland and build settlements like Chicago (Mitsch and Gosselink 1993). The federal Swampland Acts of 1849, 1850, and 1860 gave away federal lands in states along the Gulf and Pacific coasts on the condition that the land would be drained (UN Conference 1992). The 1860 Swampland

Act particularly affected Oregon's wetlands by opening them to agriculture and settlement (Boule and Bierly 1987). People abused this act in Oregon. For example, if more than 50% of a township section (1 square mile) could be proved wetland, the whole parcel was declared wetland and thus open to free land grants. In some places, Oregon pioneers pushed boats across dry land in order to claim the land as swamp (Beckham 1996).

Epidemics of malaria, cholera, diphtheria, and typhoid caused the formation of public health boards in the 1860s and 1870s. At the time, city sewage was dumped into estuaries. The sewage often accumulated in the water and on tidal wetlands due to poor tidal flushing. Many of the health commissions recognized that the sewage accumulation created health problems, not the presence of swamp gases and air. However, promoters of tideland reclamation used the idea that wetlands bred disease to increase conversion of these areas for agriculture, residential, and commercial purposes (Siry 1984). Despite recommendations to drain wetlands to prevent malaria, most public health boards did not encourage reclamation (Siry 1984).

One individual who called for the preservation of wetlands was the geographer George Perkins Marsh. He pointed to water pollution from urban and industrial sources, the cutting of upland forests, drainage, canal building, and other human impacts on the landscape as causes of plant and animal extinction. In his 1864 work Man and Nature, Marsh urged "geographical regeneration" of habitat to prevent the downfall of civilization. His chapter on water discussed siltation and estuary destruction through human alteration of the land. Scientists today echo Marsh's sentiments by calling for wetland and watershed restoration, and assessments of wetland function and wetland mitigation within a watershed context and regional landscape scale (Bedford and Preston 1988, Zedler 1996). The work of Marsh and the sanitary commissions gave impetus to the preservation movement of the late 19^{th} and early 20^{th} Centuries.

Federally funded water projects in the first half of this century altered millions of coastal wetland acres for flood control, hurricane protection, navigation, and agriculture. While some individuals like Aldo Leopold and Rachel Carson raised their voices for environmental protection and conservation, until the late 1960s few people were concerned enough to act. Increased awareness of environmental problems such as poor water and air quality, pollution, and species extinction, brought about a push for protective federal and state legislation. The federal Clean Water Act (1972), Endangered Species Act (1973), and Coastal Zone Management Act (1972) were a result of environmental activism and awareness. Oregon's Removal-Fill Law (1971) and Statewide Planning Goals (1973) were written and passed for similar reasons.

Policy in the United States, especially environmental policy, during most of the 20^{th} Century has been mainly a reactionary process. As a society, the United States seems to act only at the very last moment. In protecting environmental integrity, reactionary policy is often too little or too late. Despite protective legislation, the net area of wetlands in the United States decreased by 404,700 acres from 1974 to 1983 (UN Conference 1992). Industry and agriculture still impact these habitats, and urban and residential development along the coast is increasing. People like to live near the water and overcrowding in some areas encroaches on coastal wetlands.

Federal Wetland Mitigation Regulation

Rising concerns about water quality and point-source pollution control culminated in the Clean Water Act of 1972 -- the most important federal law concerning wetland compensatory mitigation. This document assigned the USEPA responsibility to "... restore the physical, chemical, and biological integrity of the nation's waters...(p44, National Research Council 1991)." The USEPA began in earnest to reduce chemical inputs and concentrations in the nation's waters. At this time, though, little attention was paid to overall watershed management or functional restoration of ecosystems.

One provision of the Clean Water Act, Section 404, gave the USACE authority over the dredging and filling of any navigable waterway within the United States (Mitsch and Gosselink 1993, Weinmann *et al.* 1984, Williams 1996). A 1975 court case, *Natural Resources Defense Council v. Callaway*, definitively established that navigable waterways were to include wetlands. Before this decision, USACE regulated dredge and fill permits only on waters that allowed for boat passage (Mitsch and Gosselink 1993, National Research Council 1991). Now, USACE uses Section 404 to discourage unnecessary alteration and destruction of wetlands as well.

Around 1975, USEPA and USACE began applying Section 404 to encourage whole watershed management. This reflects a change in the attitude by the American public of viewing wetlands as "wastelands" to that of an important functioning ecosystem and the recognition of the role of wetlands in watersheds. Wetlands legally described by characteristic soils, vegetation, and hydrology require permits and usually mitigation for any impact which would destroy or degrade these ecosystems (Federal Interagency Committee for Wetland Delineation 1989). Both the USACE and USEPA have the authority to permit dredge and fill activity, but USEPA rarely uses its privilege -- only in cases of blatant USACE misjudgment (National Research Council 1991, Williams 1996). USF&WS and the National Marine Fisheries Service advise the USACE in permit review, as they have regulatory control over wildlife and wildlife habitat.

Wetland mitigation, under the Clean Water Act, is more than just a trade-off of wetlands destruction for wetland acres that have been restored, enhanced, or created. The permitting process includes an environmental assessment of project impacts and a discussion of possible alternative sites for project development. Developers must show that they have attempted to avoid wetland destruction, and then minimized their impacts when avoidance is impossible. For any remaining wetland impacts, developers compensate for wetland losses by creating, enhancing, and/or restoring other wetlands on-site or nearby the development project.

Oregon Wetland Mitigation Regulation

Oregon was one of the first states to adopt laws protecting coastal wetlands. Statewide planning goals 16 and 17 specifically direct planners to protect and conserve estuarine and coastal shoreland resources, including wetlands (Department of Planning, Public Policy, and Management 1997). Planning goal 5 provides a framework for communities to inventory and develop plans to maintain open space and protect natural resources (Leibowitz 1995). During the 1970s, coastal communities created estuarine management plans in conjunction with their comprehensive land use plans. Estuarine management plans, developed under goals 5, 16, and 17, set aside shorelands for protection under natural and conservation zoning designations. Other shorelands, with less natural value, were zoned for development. Some communities, like Coos County, designated all their priority sites for future wetland mitigation within the estuarine management plan's natural and conservation areas. In 1991, the Oregon Progress Board designated 1990 wetland acreage as a benchmark and adopted new goal of maintaining 100% of that acreage as part of the statewide planning goals (Leibowitz 1995).

In addition to land-use zoning, the state has its own version of Section 404 -- the Removal-Fill Law (1971). One of the reasons for the law's passage was the protection of salmon habitat and spawning beds. In Oregon, the Division of State Lands (DSL) regulates fill and removal activity on coastal wetlands for impacts of 50 yds.[3] or more. The Removal-Fill Law applies to both tidal and nontidal wetlands, but contains stricter mitigation measures for estuarine wetlands (Glomb 1995, Salvesen 1994). This may be because the law's authors assumed that freshwater wetlands could be mitigated for anywhere, while saltwater wetlands can only be replaced in coastal areas. Interference from timber and agriculture interests is another possibility for reduced restrictions on freshwater mitigation. Mitigation must occur within the same watershed as the fill or removal, but not necessarily the same subbasin within the watershed. All permit applications must be accompanied by a mitigation plan. In-kind mitigation, such as the exchange of a salt marsh for another salt marsh elsewhere in the estuary, is not required. DSL may ask that the replacement vegetation be different from the plants destroyed, especially if the filled wetland contained mostly non-native species like reed canary grass or smooth cordgrass (Salvesen 1994).

DSL analyzes the adverse affects of fill and removal activity and the extent for which these activities must be mitigated. The state agency reviews permits using criteria established by the state legislature. DSL is required to notify applicants if mitigation is necessary or if information from the permit is missing (Hamilton 1984). Wetland mitigation proposals must be consistent with existing land-use zoning, occur within the same estuary as the development activity, restore or create equal or greater areas of wetland, and "replace" the biological productivity and species diversity of the lost habitat.

What is Wetland Compensatory Mitigation?

In most cases, just adding water will not restore a coastal wetland. Other, often complex, interactions must be considered. Many estuarine plant and animals are very sensitive to changes in salinity and temperature. Elevation regulates exposure to tidal fluctuations in salinity and temperature (Frenkel and Morlan 1991, Mitsch and Gosselink 1993). As a result, elevation becomes important in determining vegetation, and thus faunal diversity and health. Freshwater wetland organisms must be able to survive seasonal temperature changes and wet/dry cycles. In addition, scientists still do not understand many of the biological interactions that occur between organisms in wetlands.

To fulfill the national goal of "no net loss" of wetlands, the USACE requires at least a 1 : 1 mitigation trade ratio in wetland acreage and functional value. DSL maintains a similar goal, but requires different trade ratios for different methods of mitigation and types of habitat impact. To aid developers in figuring out ratios for estuarine replacement, DSL created a series of tables based on acreage and the relative value of the estuarine habitats lost to development and gained through mitigation (Hamilton 1984, Mitsch and Gosselink 1993). Mitigation involving freshwater wetlands uses set ratios based on the type of mitigatory action. For every acre of freshwater habitat lost to development, 3 acres may be enhanced (3 : 1), 1 acre restored (1 : 1), or 1.5 acres created (1.5 : 1) .

The mitigation process begins by considering impact avoidance. Developers attempt to relocate the proposed development and avoid building on the wetland. For example, natural areas could be incorporated into design plans as open space for recreation and educational opportunities (Salvesen 1994). If avoidance is impossible, a developer must then try to minimize the size of the impact. Cluster development is one way to minimize impact. Clustering structures on a lot allows developers to gain greater design creativity, create greenspace, minimize impacts to delicate natural systems, and save money by building fewer streets and shorter utility lines (Salvesen 994). Only as a last resort is compensation through restoration, enhancement, or creation considered for wetland loss (Kukoy and Canter 1995). However, a restored, created, or enhanced wetland can never adequately replace natural wetland ecosystem values and functions.

Although acreage exchanges may be equal, past mitigation projects include creation/restoration of wetlands in a different watershed, exchanges for a different type of wetland habitat (i.e., the creation of a freshwater pond for the destruction of a salt marsh), and creation at the expense of an upland forested system (Kentula *et al.* 1992a). Some mitigation projects fail because much remains unknown about the relationships between the biological, chemical, and physical aspects of wetlands and how to recreate that interconnectedness. The dynamic and temporal nature of wetlands makes it difficult to determine if a project is, or ever will be, successful. Other WCM wetlands fail because the project is never fully completed or monitored after completion (Mitsch and Gosselink 1993).

Wetland restoration is one of the most commonly used tools of mitigation. It is the process by which degraded or historic wetlands are altered to return them to a naturally functioning state. Most restoration projects in Oregon try to attain the species diversity and biological, physical and aesthetic characteristics of the original wetland prior to major human disturbance -- circa 1850 (Leibowitz 1995, Hamilton 1984). If avoidance and minimization are impossible, permit reviewers recommend restoration as a means to mitigate for wetland destruction because there is a greater guarantee of success (Leibowitz 1995). This mitigation technique salvages degraded sites rather than creating new ecosystems from scratch, often in areas that have not been historically wetlands.

In addition to a greater guarantee of success, restoration projects may require minimal human involvement. After 15 years of monitoring, researchers concluded that plantings were unnecessary on a 52 acre salt marsh restoration in the Salmon River Estuary, Oregon (Frenkel and Morlan 1991). The scientists found that dike removal and the re-establishment of an historic hydrological regime brought vegetative propagules onto the site and encouraged old seed banks to sprout. They recommended that plantings might be warranted if seed banks were absent or small, or the hydrological conditions were marginal for natural establishment (Frenkel and Morlan 1991). A restoration project at South Slough National Estuarine Research Reserve in Charleston, Oregon has had similar plant colonization results after dike removal (personal observation, Rumrill and Cornu 1993, 1995).

Creation is a popular choice for developers in Oregon (Kentula *et al.* 1992a, Shaich and Franklin 1995). To create wetlands, developers convert upland -- forest, meadow, or dune habitat -- into wetland. To achieve some measure of success, developers try to keep site design simple. From nature, we know that sustainable, successful ecosystems are complex, diverse, and interesting (Salvesen 1994, Zedler and Powell 1993). Simplicity may work for a developer, but it is a disaster for the ecosystem (Salvesen 1994, Zedler 1996). Duplicating a wetland ecosystem requires establishing both structure and function -- hydrology, hydric soils, and hydrophytic vegetation and fauna (Zedler 1996). Some developers are trying to recreate natural complexity, and succeeding, but adaptive management and regular monitoring remain necessary to ensure created wetlands thrive.

Enhancement is usually one of the last alternatives recommended as it ultimately results in a net loss of wetland acreage (Leibowitz 1995, Hamilton 1984). Enhanced wetlands are previously established wetlands which have been altered or managed for long-term improvement of certain functions and values (Leibowitz 1995). For example, an enhancement mitigation project might involve planting certain plant species or deepening a water channel to attract waterfowl. Even with a 3 : 1 mitigation trade ratio, impacted wetlands are lost forever to development with no compensation for the loss. No new wetland acres are created or restored through enhancement. In the Pacific Northwest, enhancement WCM is common (Kentula *et al.* 1992a, Shaich and Franklin 1995).

Has Mitigation Been Successful Elsewhere?

WCM success is usually assessed on a site by site basis. Few studies look at WCM success for an entire region or watershed. Published research focuses mainly on acreage exchanges/ratios, permit compliance, why WCM sites fail, and why WCM is necessary. Success assessments have occurred in Florida, Ohio, Washington, and Oregon. Considering the lack of knowledge surrounding the creation of a successful wetland mitigation and the developer's demand for a wetland mitigation "cookbook," it is surprising that more comprehensive assessments have not been published.

A Florida study reviewed 40 mitigation projects involving wetland creation, restoration, and preservation (Erwin 1991). On average, WCM sites were only three years old (these sites would be assessed as incomplete in my Coos Watershed study). Only half of the required mitigation acreage had actually been completed. Erwin (1991) defined successful WCM projects as meeting all state goals and being functionally equivalent to a reference wetland. Only 10% of all sites succeeded in meeting these criteria. Erwin (1991) judged 60% of the sites (24 out of 40) as incomplete or failures. Improper hydrology caused many of these failures and incompletes (Erwin 1991).

Another study in Ohio compared the function of seven natural wetlands to ten mitigated habitats (Fennessy and Roehrs 1997). These researchers looked at permit compliance, acreage ratios, plant species diversity, and wetland function for sites two to five years old. WCM occurred for all wetland impacts. The researchers found an average replacement ratio of 1.26 : 1. Fennessy and Roehrs (1997) point out that the ratio may be viewed as either a shortfall of 0.24 acres for the goal of 1.5 : 1 mitigation ratio, or a surplus of 0.26 acres generated through mitigation for every wetland acre lost. They also found that native plant diversity decreased with WCM in the early stages of site development, but overall no significant differences in vegetation diversity between natural and mitigated sites were found. An USACE review of wetland function for the ten sites found that the mitigated sites were not yet equivalent with respect to flood water retention, water quality improvement, and habitat provision (Fennessy and Roehrs 1997). Even though sites may comply with permit goals and provide habitat, they may still not function like natural wetlands.

A 1992 review of Section 404 permits in Washington and Oregon found a loss of wetlands to development. The group of USEPA scientists reviewed 58 Oregon permits (1977-1987) and 35 Washington permits (1980-1986). Most impacts and WCM sites were less than or equal to 0.2 acres. These cumulative impacts add up. Oregon lost 13 acres and Washington lost 6.5 acres (Kentula *et al.* 1992a). The greatest losses were to freshwater marsh, subtidal mudflat, and river bottom habitat west of the Cascade Range and near urban centers (Seattle, WA, Grays Harbor, WA, Portland, OR, and Coos Bay, OR). The number of permits requiring mitigation increased during the period of study (Kentula *et al.* 1992a). If this permit trend continues, without measures to ensure trades of equal or better habitat, losses of wetland acreage will increase too. Continued small wetland impacts and losses within specific watersheds contribute to degraded water quality and watershed function, altered local hydrology, species loss, and habitat fragmentation.

In 1995, DSL reviewed their WCM permitting program in Portland, Oregon. DSL issued a total of 72 permits between 1980 and 1990 for 52 acres of wetland impact

(Shaich and Franklin 1995). While all of the required WCM had been completed, there was a net loss of 14.5 acres of wetland. Approximately 35 acres of freshwater emergent wetlands were lost and 29 acres of open water gained. Shaich and Franklin (1995) found that creation and enhancement were the only types of wetland mitigation techniques used. Enhancement mitigation resulted in net losses of wetlands for 54% of the projects. Sixty-four percent of WCM projects had one or more compliance violations. Discrepancies between permitted and as-built impacts and mitigations contributed to the compliance problems and wetland losses. Shaich and Franklin (1995) found that WCM projects were successful in some ways but not others. They did not attempt to determine the significance of these WCM projects to the Tualatin Watershed, where the impacts and mitigation occurred. However, the researchers indicated that ecological concerns should be considered for future permitting, as cumulative impacts, such as those in Portland will impair wetland function and watershed function (Shaich and Franklin 1995).

From these four examples, several themes emerge. Hydrological problems developed on sites within at least three of the studies (Kentula *et al.* 1992a did not review this). Wetland organisms will not thrive and hydric soils form without proper hydrology. In order for WCM sites to compare favorably to natural wetlands, develop into successful wetland habitats, and thus be defined as wetlands, they must have functional hydrological regimes.

Certain types of habitats are still being lost, despite a federal order for "no net loss." Specific habitats -- restored salt marshes, created ponds, enhanced wetlands of any type -- will always be easier to create through mitigation. Forested wetlands, freshwater marshes, and subtidal mudflats are not recreated when impacted. Uplands converted to wetlands through mitigation are not recreated either.

While one of the studies mentioned above discussed potential watershed problems associated with wetland loss and another referred to wetland contributions to watershed hydrology, none specifically addressed such problems with their research. Habitat and species diversity contribute to healthy watersheds. Greater discussion and research looking at the role of wetlands in creating healthy watersheds should be expected, considering the problems arising from dysfunctional watersheds and fragmented landscapes. Watershed and regional scales are large and complicated, but each study adds to the baseline of knowledge (Bedford and Preston 1988, Zedler 1996). This Coos Watershed wetland mitigation research can contribute to a greater understanding of function at the watershed scale and provide a baseline for future study.

Mitigated wetlands take time to develop. Mitsch and Wilson (1996) suggest a 15 to 20 year development period for freshwater marshes -- longer for forested wetlands, coastal wetlands, and peatlands -- before attempting to assess WCM success. None of the sites in the four studies reviewed above looked at sites ten years or older. Older site assessment would also be useful for a watershed scale study of the effectiveness of WCM in contributing to improved watershed function and connectivity. However, based on what the researchers found and knew from watershed science, more predictions of the effectiveness could have been made.

In Chapter I, I reviewed wetland trends and history in the United States, the importance of wetlands, and their role in watershed function. A discussion of federal and Oregon regulations concerning mitigation followed. I then described wetland compensatory mitigation and four studies of mitigation success. Chapter II continues this introduction to wetland compensatory mitigation and relates the process to past, present, and future land use in the Coos Watershed of southwestern Oregon.

CHAPTER II

AN INTRODUCTION TO THE PHYSICAL AND BIOLOGICAL FEATURES OF THE COOS WATERSHED

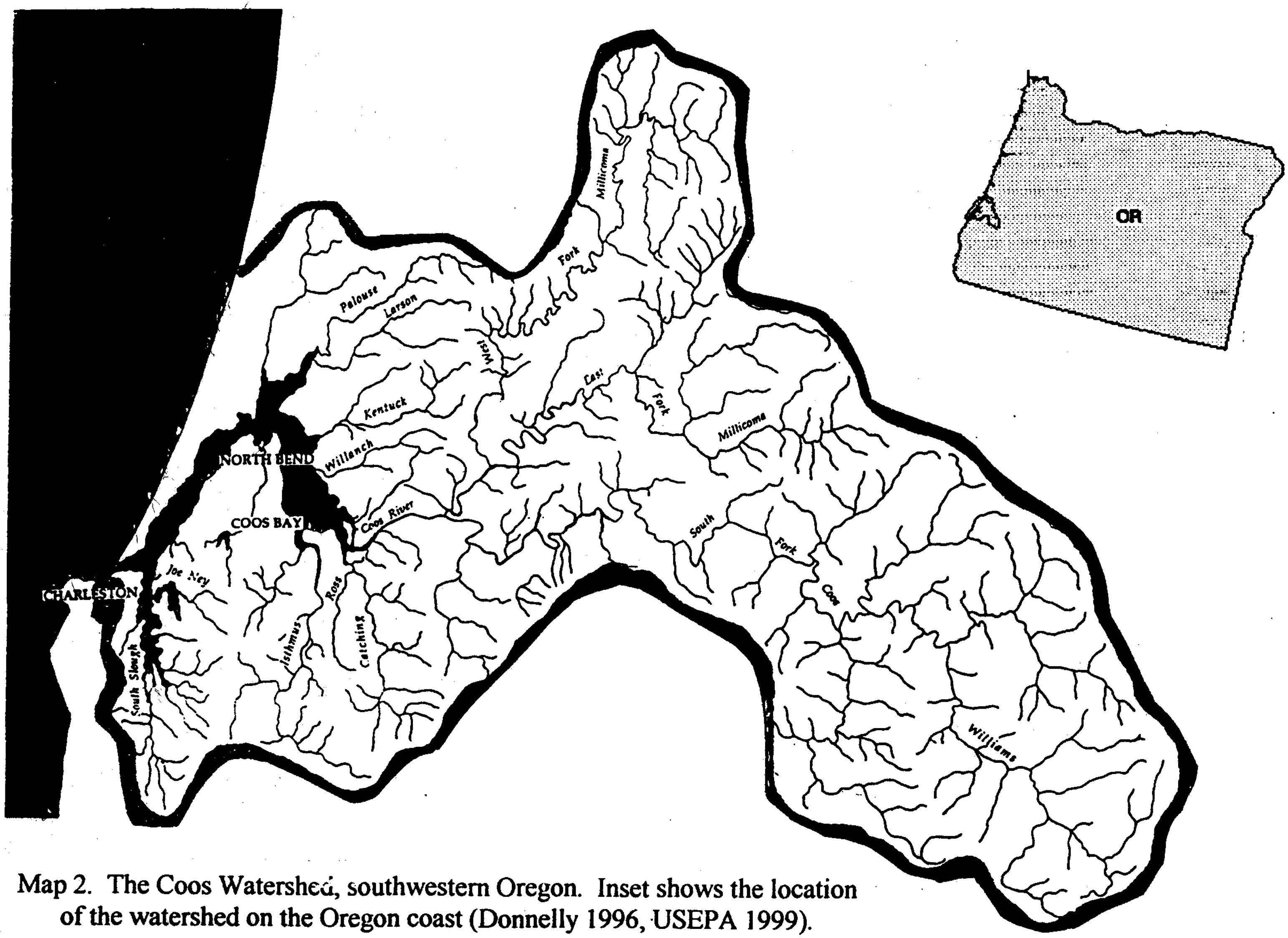
In order to better understand the current management, development, and condition of wetlands in the Coos Watershed of southwestern Oregon, it is necessary to know something of the physical features, biological components, and human history of this region. Landscape -- topography, climate, geology, and biological communities -- affects how people will live within and utilize the resources of an area. Human action, in turn, shapes the landscape and the action of future generations on such land. The success of wetland compensatory mitigation in the Coos Watershed is tied to past, present, and future uses of wetlands, uplands, and water. Chapter II describes the physical and biological features of the Coos Watershed, relates some of the local human history which impacted wetlands, and discusses some of the current environmental problems that affect wetlands within the watershed.

Topography

Located in southwestern Oregon, the Coos Watershed drains 605 square miles of Pacific Coast Range, coastal dunes, and marine terraces in Coos County, and 225 square miles of Coast Range within Douglas County (Hoffnagle 1976). The Coos and Millicoma Rivers are the two main drainages of this watershed. Other small streams also empty directly into the estuary. Along its western edge, the North Spit borders the estuarine portion of the watershed. Rugged hills interspersed with marshes surround the rest of the bay. Moving up into the watershed, rivers and streams cut deep valleys between Douglas-fir, Western hemlock, and Sitka spruce covered slopes. Ridgetops within the watershed are narrow and sharply defined with very steep slopes (Haagen 1989). The Coos Watershed has a drowned river mouth estuary. The only flat lands available for development are freshwater and salt marsh wetlands, because most of the Coos River's floodplain is either intertidal mudflat or ocean floor (Hoffnagle 1976). Map 2 depicts the Coos Watershed.

Wetlands are temporary features on the landscape. Eventually most wetlands become uplands. They progress from mud flat to marsh to forest as silt, clay, and sand are trapped in estuarine areas, along river banks, and in ponds. Sea level changes can affect marsh succession though. Glacial melt at the end of the last Ice Age caused sea level to rise, drowning established marshes, and causing new marshes to form at the water's edge. An earthquake, several hundred years ago, lowered marsh benches and required the process of sediment accumulation to begin again along Coos Bay's shores.

Today, most of the Coos River's floodplain is covered by open ocean and estuary waters (Hoffnagle 1976). The estuary is considered a drowned river mouth estuary. Estuarine wetlands formed through a combination of river mouth sedimentation at the ocean's edge and post-glacial sea level rise (Atkins and Jefferson 1973). Freshwater wetlands line streams and rivers above the head of the tide. Some freshwater marshes, however, have developed behind dikes separating former estuarine marshes from tidal



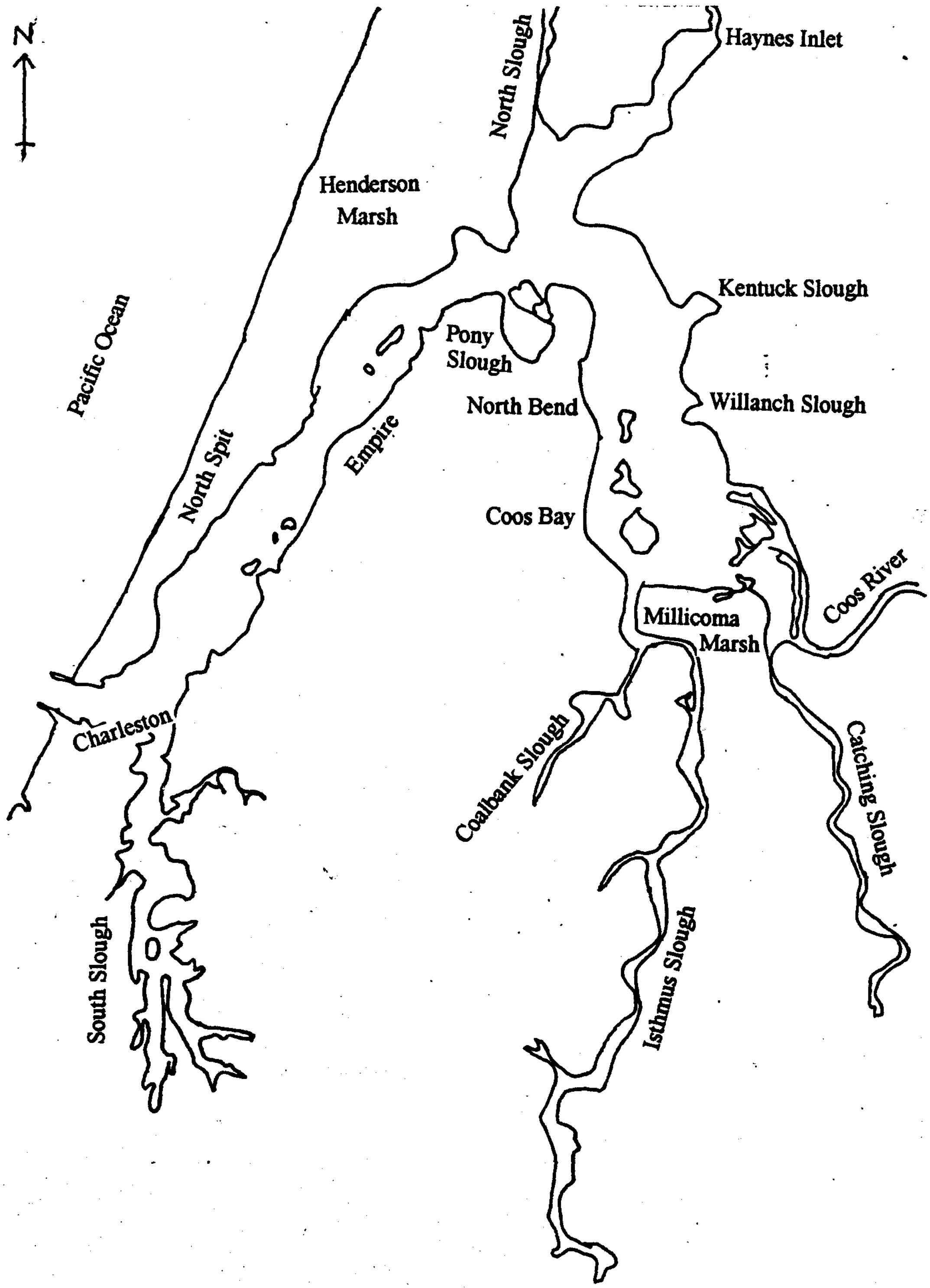
Map 2. The Coos Watershed, southwestern Oregon. Inset shows the location of the watershed on the Oregon coast (Donnelly 1996, USEPA 1999).

influence. Wetlands surrounding the Empire Lakes and on North spit consist of scrub/shrub marsh, pond, and lake habitats.

Coos Bay, the estuarine part of the watershed, is the largest estuary totally contained within the state of Oregon (Atkins and Jefferson 1973, Hoffnagle 1976). Tidelands cover 6,200 acres of the estuary's 12,380 acres, and include 2,738 acres of tidal marshes (Atkins and Jefferson 1973). Most of these marshes are located along the ten rivers and sloughs entering the bay -- South Slough, North Slough, Haynes Inlet, Kentuck Slough, Pony Slough, Willanch Slough, Isthmus Slough, Coalbank Slough, Catching Slough, and the Coos River. Map 3 shows the Coos estuary and surrounding sloughs and tributaries. From the estuary's mouth, the head of the tide extends 10 miles up Catching Slough, 12 miles up Isthmus Slough, 32 miles up the South Fork of the Coos River, and 34 miles up the Millicoma River (Roye 1979). With the exception of a few sites in the Upper Pony Slough watershed, North Spit, Henderson Marsh, and the Coos Country Club, the majority of wetland compensatory mitigations (WCM) in this study are tidally influenced. All 35 sites described in this study may be found within one mile of the estuary.

Climate

The area receives cool, wet winters and warm summers, with high humidity throughout the year. Precipitation mainly falls from late fall to early spring. Snow is rare below 1000 feet of elevation. Rainfall averages 60-70 inches per year at lower elevations within the watershed (City of Coos Bay 1998, Haagen 1989). Temperatures range from an average 40°F in January to 57°F in July (City of Coos Bay 1998, Haagen 1989). In the summer, marine fog commonly shrouds the coast and major drainages. It moves inland



Map 3. The Coos Estuary, Oregon.

during the night, and may not dissipate until late morning the following day. This fog, combined with steady winds, moderates summer temperatures. Winter temperatures stay above freezing because the relatively warm-watered California Current warms air masses offshore before they move inland during the winter months. Winds buffet the area from the south-southwest in winter and blow out of the north-northwest in summer (Hoffnagle 1976, Siuslaw National Forest 1993). Each year, two or more major winter storms bring strong winds, with gusts of 100 mph, which can damage both natural areas and human settlements (City of Coos Bay 1998). The rains accompanying these storms may create serious flooding problems (Haagen 1989).

Geology and Soils

Easily eroded sedimentary sandstones and siltstones compose most of the Coos Watershed bedrock. The eroded rock supplies both the sand dunes along the coast and the soils that cover watershed hillsides and fill river valleys (Siuslaw National Forest 1994). Like their parent bedrock, soils of sedimentary origin also erode easily. The U.S. Forest Service (USFS) rates the stability of the various soils on the steep slopes throughout the watershed as moderately unstable (Hoffnagle 1976). Past estimates of soil runoff in the Coos Watershed are at 72,000 tons annually (Atkins and Jefferson 1973).

A lack of vegetative cover, combined with heavy seasonal rain, can speed up and worsen the natural siltation processes in the watershed. Although natural siltation, combined with marine sedimentation, builds marshes in tide flat areas, it also clogs salmon spawning beds and necessitates dredging of the ship channel and marinas by USACE. USACE dredges some areas only once every ten years, while others are attended to annually, depending on the channel's use and sediment input. As a natural watershed process, landslides have always been important contributors of gravel and woody debris to streams. However, logging practices in this century, such as clear-cutting, combined with heavy rainfall on unstable soil have probably increased the rate of such debris flows.

Wetland and Associated Communities

Upper Watershed Forests and Wetlands

The Coos Watershed sits in the middle Pacific section of the North American Columbian biogeographic region (Donnelly 1994). The mild, maritime climate encourages almost year-round growth of forests that cover the slopes of the Pacific Coast Range. Sitka spruce, western hemlock, and mixed evergreen (Douglas-fir, Western hemlock, Red cedar, Pacific yew) zones naturally cover these slopes (City of Coos Bay 1998, Pojar and MacKinnon 1994). Large mammals like black bear, cougar, Roosevelt elk, and deer make their homes among the dense undergrowth. Huge numbers of chinook, coho, and chum salmon and steelhead and cutthroat trout have swum upstream -- until recently -- to spawn in gravel beds shaded by thick forest canopy (Atkins and Jefferson 1973).

The upper Coos Watershed is managed by the Coos Bay Bureau of Land Management (BLM), Coos County Forestry Department, and Oregon Department of Forestry (ODF), as well as private timber companies such as Weyerhaeuser, Menasha, and Georgia Pacific. Currently, timber managed lands dominate 75% of the watershed. The majority of these lands are located in the upper portions of the watershed (Donnelly 1996). For example, much of the Millicoma River subbasin is managed by Weyerhaeuser as a Douglas-fir plantation.

Wetlands in this part of the watershed are mainly riverine and palustrine. Riverine habitats are found within a creek or river channel and generally have flowing water. There may be some nonpersistent vegetation, but the habitat is usually unvegetated (Morlan 1990). Palustrine habitats in the upper watershed are often adjacent to, or form as islands within, riverine wetlands. These freshwater swamps, bogs, and marshes may be dominated by alders, willows, sedges, rushes, cattails, herbs, and grasses (Morlan 1990). Many of these freshwater wetland habitats are found in the flats of canyon bottoms and within the narrow strips adjacent to creeks.

Coastal Dunes and Deflation Plain Wetlands

The western edge of the Coos Watershed (North Spit) includes the southernmost part of the coastal dunes that stretch from Heceta Head near Florence, Oregon to Cape Arago, Oregon. The North Spit forms an effective barrier separating the Pacific Ocean and the Coos Estuary. Different areas of the North Spit are managed by the Coos Bay BLM, USACE, USFS, and Weyerhaeuser. Intentional plantings of European beachgrass (*Ammophila arenaria*) in the 1930s, and the construction of jetties at Charleston, Oregon (1890-1900) stabilized the sand dunes on the North Spit and the mouth of the Coos River (Beckham 1996, Hodder 1998). These changes have also impacted the ecological processes on the North Spit.

Steep foredunes face the cold Pacific waters on the western edge of the North Spit. Once covered by native American dunegrass (*Elymus mollis*), the 20'-30' tall foredune is now thickly covered by non-native *A. arenaria* (Siuslaw National Forest 1993). *A. arenaria* outcompetes native plant species for space and nutrients, and decreases the habitat available for species like snowy plovers, an endangered shorebird.

Moving inland, the sand behind the foredune slopes down into the deflation plain. This wet habitat has been slowly increasing in size in the past century (Hodder 1998).

In an area without *A. arenaria*, wind blows off the ocean, across the beach, and over the top of the foredune transporting sand inland. Some of this sand gets trapped behind the foredune in the deflation plain. Depending upon the time of the year and recent precipitation, the sand may stick or, if the area is dry, blow further inland . Overall, the deflation plain should remain a narrow strip of wetlands in this scenario. However, *A. arenaria* has stabilized the foredune, and the plant's structure is designed to trap sand (thus the plantings in the 1930s). The more the plant is buried by sand the better it grows. On the North Spit, *A. arenaria* traps sand as it moves over the foredune preventing the input of sand to the deflation plain. The wind scours out sand from behind the foredune in the deflation plain during drier periods of the year (Hodder 1998). With no replacement sand, the deflation plain grows in size.

Moving past the palustrine wetlands of the deflation plain, transverse and oblique dunes surround tree islands -- remnants of early coastal forests (Siuslaw National Forest 1994). On the mainland, transition forests mark the ecotone between the ocean-based dune ecosystems and land-based forests, but on the North Spit the transition forest habitat is missing. In some places, the deflation plain covers the entire width of this peninsula. On the east side of the North Spit the palustrine wetlands slope down into salt marshes and mudflats bordering the Coos Estuary.

The deflation plain within the Coos Watershed supports both palustrine and lacustrine wetland communities. Shorebirds, waterfowl, raptors, songbirds, and other migratory birds nest, rest, and feed in the productive deflation plain wetlands. The palustrine wetlands of this area are characterized by willows, sedges, small herbs, rushes, cattails, and various grasses. Small fish, raccoons, river otters, red-legged frogs, snowy egrets, great blue herons, ducks, Canada geese, and deer live and feed in this highly productive scrub/shrub habitat (personal observation). Human hunters also use this habitat, as evidenced by the many shotgun shells found throughout the area (personal observation).

Lacustrine wetlands -- small, shallow lakes and deep ponds -- form in the troughs between transverse and oblique dunes and tree islands (Morlan 1990, Siuslaw National Forest 1994). Winds blast the sands out of these low spots, thus exposing the water table. Stabilization of dunes by the sand-trapping *A. arenaria* has prevented the input of sand to these low spots. Deep ponds have also been created in the scrub/shrub wetlands of the Henderson Marsh area with heavy equipment as a result of wetland compensatory mitigation. Newer lakes and ponds may have little vegetation, but older lacustrine habitats typically support water lilies, duckweed, pondweeds, cattails, and rushes. Some lakes may even be large enough to support small fish populations. Many of these fish populations have been introduced by Oregon Department of Fish and Wildlife (ODF&W) for the benefit of sport fishermen. However, each introduced plant or animal species displaces a native species and/or changes the natural functioning of a habitat through its actions.

<u>Henderson Marsh</u>

Henderson Marsh is a large parcel of land on the North Spit. Weyerhaeuser, Inc. owns and manages the land as an unofficial wetland mitigation bank. The company operates an industrial waste lagoon to the southwest of the marsh and a containerboard plant to the northeast. In 1979, Weyerhaeuser began the process of developing a wetland mitigation bank by creating an interagency task force in conjunction with the ODF&W, USF&WS, Menasha Corporation (another timber company with land holdings in

Henderson Marsh at that time), and a private consultant. The group evaluated the marsh habitat's quality and quantity, and developed a comprehensive mitigation action plan. Turning Henderson Marsh into a mitigation bank would concentrate mitigation efforts and projects into one area, and offset any wetland habitat losses prior to their development on other lands owned by Weyerhaeuser. Also, a wetland bank could prove to be a great investment for the company, as they retained the option to sell banked acreage credits to outside groups that needed to do wetland mitigation. DSL has never granted wetland mitigation bank status to Henderson Marsh. However, as of 1998, five WCM projects had been completed in the marsh -- three by Weyerhaeuser, one by the Port of Coos Bay, and a project by the Coos County Urban Renewal agency which relied on banked credits from one of the Weyerhaeuser projects.

Several of the mitigation actions in Henderson Marsh remain questionable. Wetland habitats were analyzed for quality and quantity before and after wetland sites were enhanced or created. The habitat received a higher value rating prior to mitigation. WCM *decreased* the value of the wetland habitat in Henderson Marsh. Also, some of the habitat types created through WCM were inappropriate for the area. For example, more than 250 acres of scrub/shrub wetlands were enhanced in the deflation plain north of the waste lagoon. The mitigation consisted of creating small, shallow ponds to attract waterfowl by punching roads through the deflation plain, scooping out swales, and removing vegetation. While the deflation plain may flood during winter and spring, permanent small ponds are not a natural feature of this densely vegetated scrub/shrub wetland habitat. These ponds decreased the value of the scrub/shrub habitat and increased access for hunters and ATV users.

Estuarine Marshes and Mudflats

Between the upland forests and estuary waters, low-lying marshes fringe the confluence of rivers, streams, and sloughs that make up Coos Bay. These estuarine wetlands are tidally influenced salt marshes, mudflats, and eelgrass beds (Morlan 1990). Freshwater runoff dilutes salinity, and solar radiation warms plant and soil surfaces at low tide. Flooding tides rapidly cool surfaces and increase salinity. Estuarine wetland flora and fauna must be highly tolerant to these rapid temperature and salinity changes, possess adaptations to survive these conditions, and/or be able to move as the tides change (Castro and Huber 1997). While most of the marsh and mudflat habitats are privately owned, all submerged lands in the Coos Watershed, including the estuarine areas, are owned and managed by Oregon DSL.

Estuarine wetlands are some of the most productive habitats on Earth, and those in the Coos Watershed are no exception (Castro and Huber 1997, Donnelly 1994, Gaskill 1997, Mitsch and Gosselink 1993). High primary productivity supports a diverse array of mammals, birds, fish, and invertebrates (Gaskill 1997). While upper watershed mammals like bears, raccoons, and river otters will come down to the salt marshes to feed, other mammals such as harbor seals and sea lions will enter the estuary at Charleston chasing fish dinners. Brown pelicans, bald eagles, osprey, egrets, and great blue herons also fish the waters of the estuary. All the Coos Watershed sea-run salmonid fishes travel through the estuary on their way to spawning and feeding grounds. Tide channels in salt marshes provide hiding and feeding places for juvenile salmonids during the period in which they adjust to oceanic salinities (Miller and Simenstad 1997, USF&WS 1994). Dungeness crabs, clams, oysters, ghost shrimp, and other marine and estuarine invertebrates live in and on estuarine wetlands in the Coos Watershed (Atkins and Jefferson 1973, City of

Coos Bay 1998, Donnelly 1994, Gaskill 1997). Humans take advantage of this productivity through fishing, hunting, clamming, birding, and hiking.

At the base of this vast, interconnected web are the plants. Typical salt marsh plant species in the Coos Watershed include tufted hairgrass, saltgrass, pickleweed, fleshy jaumea, seaside arrowgrass, and Lyngby's sedge (Jefferson 1974). Two rarer species, sea lavender (*Limonium californicum*) and saltmarsh bird's beak (*Cordylanthus maritimus*) thrive in high salt marsh habitats. Due to habitat losses of high salt marsh cuased by human development and pollution, *C. maritimus* is listed as threatened in Oregon and rare and endangered in California. This small, undistinguished plant has been found on only one site in Tillamook County, a few places in California, and Coos Bay (Eastman 1990).

Other types of estuarine wetland habitats found in this part of the watershed include intertidal and subtidal mudflats. Subtidal areas are dominated by eelgrass beds containing both *Zostera marina* and non-native *Z. japonica*. Eelgrass beds sustain large numbers of fish and estuarine/marine invertebrates (Gaskill 1997), although *Z. marina* probably supports healthier native faunal populations. Although intertidal mudflats may appear bare of vegetation, they are covered by algal mats and often support some eelgrass. As the mudflat grows out towards the water, the landward edge slowly matures into vegetated marsh. The first macrophytes to appear on the mudflat can include fleshy jaumea, pickleweed, and brass buttons, a non-native species. Appendix C contains a plant list of all species found on wetland study sites in the Coos Watershed.

<u>South Slough National Estuarine Research Reserve</u>

About 5000 acres of tidal wetlands, freshwater wetlands, and forest in South Slough have been set aside for protection in the Coos Watershed (Gaskill 1997). South

Slough National Estuarine Research Reserve (SSNERR) stretches from Valino Island up onto the steep hillsides of the watershed. Timber companies, farms, ranches, a speak-easy, and even a coal mine once operated within SSNERR's boundaries. Many "permanent" structures have already disappeared, and the few remaining have been left to decompose. In addition to conservation of natural resources, SSNERR is restoring habitat by removing dikes, planting trees, and placing woody debris in degraded stream channels.

SSNERR is important because it is the largest parcel of land within the Coos Watershed dedicated to the preservation of natural resources -- future development will not occur within the reserve's boundaries (Donnelly 1994, Gaskill 1997). Also, due to an amendment of the Coos Bay Estuary Management Plan (CBEMP) none of the wetland restoration projects located in SSNERR can be used for wetland compensatory mitigation (Cornu 1996). Part of the mission of SSNERR is to restore the land within it's boundaries to pre-European settlement conditions where possible (Donnelly 1994). If restored acreage within SSNERR were used to offset development in another part of the Coos Watershed, watershed integrity and function could erode further. Wetland function and watershed integrity are lost when WCM occurs outside the subbasin where development has impacted a wetland.

History, Economics, and Wetland Loss in the Coos Watershed

Humans have been using the wetland resources -- indicated by shell middens, old settlements, and fire remains -- of Oregon's south coast for thousands of years. One of the earliest confirmed sites (8900 B.P.) is about 50 miles southeast of the Coos Watershed at Mule Creek on the Rogue River (Douthit 1986). Another site, about 2900 years old, was found at the mouth of the Umpqua River near Reedsport, Oregon -- 18 miles north of

North Bend, Oregon. Archaeological excavations show the Miluk people, a branch of the Coos tribe, living in the South Slough subbasin during the 16th and 17th centuries C.E.. Due to the evidence from Reedsport and Mule Creek, researchers believe that native peoples may have been calling the Coos Watershed home as many as five thousand years ago (Giles 1993).

The first Europeans camped at the harbor of Coos Bay -- probably on marshes -- in October 1826. A small band of Hudson Bay Company trappers were guided to the area by Umpqua River natives (Beckham 1973). The next visitor was also a trapper. Jedediah Smith, of Smith River fame, waded across the bay at low tide with a group of California men in 1828 while searching for a coastal route north. Coos Watershed's first white settlers arrived in 1853 and founded Empire City (Douthit 1981).

Gold and coal drew these settlers to the area, but the gold of Coos Bay's black sands soon ran out. Coal mines opened near Haynes Inlet, Kentuck Slough, and Coalbank Slough (Beckham 1996, Beckham 1973, Douthit 1981). By 1854, landings and railways built on salt marshes near these water bodies allowed for the transfer of coal to barges and ships bound for San Francisco, California (Beckham 1973). However, other commercially-minded men eyed the magnificent stands of spruce, fir, cedar, and hemlock.

At first, small lumber operations supplied local gold mines. In 1856, Henry Luse and Asa Simpson began mass production of lumber. Their timber was soon supplying construction materials to San Francisco and other growing western ports. Luse opened the first sawmill in the watershed in Marshfield (now Coos Bay) in 1867. At this time, most logs were transported to the mills by water. The logs were often stored nearby on landings created by filling in marshes with sawdust or dredge spoils, but the common practice was to raft the logs together and tie them to pilings along sloughs and rivers (Atkins and Jefferson 1973). As the tides rose and fell, rafted logs compacted mudflat soils, and their flora and fauna. This log rafting practice is still in use today (personal observation).

Since the European settlement of Coos County in 1853, roughly 86% of the tidal wetlands in the watershed have been lost to agricultural land conversion, urbanization, and filling associated with transportation (Cornu 1996, Graybill 1996, Hoffnagle 1976). Past logging and mining practices destroyed tidal marshes; however, logging operations had other major impacts on Coos Watershed wetlands. Logging helped to open up the landscape for agriculture. The federal Swamp Act of 1860 opened Oregon's coastal wetlands to settlement by promoting filling and draining for agricultural purposes in exchange for free land (Turner and Jones 1990). Most of the hillside slopes were too difficult to farm, so Coos pioneers diked and drained the flat salt marshes along the sloughs and freshwater marshes further up in the watershed. Marsh hay became feed for dairy and beef cattle, and vegetables grew well in the fertile wetland soils. Much of the produce was sold to local loggers in exchange for money or more cleared land (Douthit 1986). By the 1890s, agriculture -- cropping and dairies -- accounted for 42% of all economic production in the Coos Watershed. Timber production lagged at 22%, but not for long (Douthit 1981).

To create Marshfield's urban waterfront, estuarine marshes, the only available flat land in the watershed, were permanently filled to build streets, docks, and houses. Sawdust, from Luse's mill and others, was used to fill in soggy tidal marshes and mudflats to depths of greater than ten feet above the original wetland in some places. Later, Mill Slough, a main thoroughfare for boats, was boxed in and buried beneath the city of Marshfield to make way for paved streets . Marshfield -- now Coos Bay -- incorporated in 1874. Louis Simpson, Asa's son, designed, founded, and incorporated North Bend 39 years later in 1903 (Douthit 1981). By then Coos Bay/North Bend had metamorphosed into a timber boomtown, developed a ship-building industry, and become the major port between San Francisco, California and Portland, Oregon (Beckham 1996, Beckham 1973, Douthit 1981).

Until the 1930s, most transportation in the Coos Watershed involved boating along the rivers, sloughs, and streams (Douthit 1981). Charged with the creation and maintenance of navigable waterways, the USACE dredged sloughs, rivers, and streams throughout the Coos Watershed to keep navigation channels clear for the transport of logs and people (Atkins and Jefferson 1973). In the past, the USACE filled marshes and mudflats with dredge spoils, dumped dredged sediments in the bay creating upland spoil islands, and helped construct dikes to dry out wetlands throughout the lower watershed. Today, the USACE dumps dredge spoils offshore in the Pacific Ocean.

Current Economic Development in the Coos Watershed

Approximately 30,000 people currently live in Coos Bay, North Bend, Empire, and Charleston, the four main towns on the estuary. Another 10,000 may live in the surrounding areas on farms or small, unincorporated communities within the Coos Watershed (NOAA 1996). Humans share the watershed with a variety of common and rare flora and fauna. The majority of land directly adjacent to the estuary is privately owned, although large sections of the North Spit, part of South Slough, and submerged lands are publicly owned and managed.

Local economics still depend upon exploiting the region's natural resources. Outside the urban areas, farmers still ranch cattle on diked wetlands and floodplains. Agricultural crop production has all but disappeared. Commercial oyster farmers raise introduced Pacific oysters on the mudflats leased from the DSL in South Slough, Haynes

Slough, and the main bay near McCullough Bridge (Hwy. 101). Locals fish for dungeness crabs off the docks in Charleston and Empire, and put out crab pots in other less accessible areas. Fish are also caught in the estuary and nearby ocean. Several fish processing plants are located in Charleston, but fish populations are declining and fishing restrictions increasing.

Until the mid-1980s, timber production dominated the economy of this watershed. Timber companies still ship raw logs and wood chips out of Coos Bay, but production levels have severely decreased since the heyday of the timber industry (Beckham 1996). An economic prediction in the early 1970s stated that Coos Bay, unlike other Oregon estuaries, would continue to be dominated by marine industrial, not residential or recreational, activity (Atkins and Jefferson 1973). To a certain extent this is true. However, while many people in the watershed hold out for a renaissance of the fishing and timber industries, degradation of ocean and forest habitats ensure a long wait. Tourism, light industry, and high tech business have been suggested as a way to boost the sagging economy (City of Coos Bay 1998). Tourism in the Coos Watershed depends heavily on natural resources for activities like boating, fishing, sight-seeing, birding, hiking, and mountain-biking. Also, people enjoy living in areas with beautiful surroundings. Past resource exploitation has degraded the areas where such activities are usually conducted.

Drawing new business and industry to the Coos Bay/North Bend area will require developable land for office and factory construction. Some brownfields --land previously used for industrial or commercial purposes -- are available, but history shows that previously untouched land is usually desirable for new construction. In the Coos Watershed, such lands are often wetlands or previously diked and drained wetlands. However, Section 404 of the Clean Water Act requires mitigation for any development that destroys wetlands. Past land use and development have left little room for future economic growth and wetland mitigation.

Coos Bay Estuary Management Plan and Wetland Mitigation

In 1977, Oregon's Land Conservation and Development Commission classified the Coos Estuary as a deep draft development estuary under statewide planning goal 16 (Roye 1979). The Coos Estuary is one of only three estuaries that qualify for deep draft designation. Yaquina Bay and the Columbia River are the other two so designated. The classification required nominating specific estuarine areas for distinct water use management units -- including natural, conservation, shallow draft, and deep draft development units (Donnelly 1994, Roye 1979). These areas were zoned as CBEMP (Coos Bay Estuarine Management Plan) throughout the estuary and are indicated on both county and city maps.

Natural management units designate large tracts of marsh, tide flat, eelgrass bed, and algal beds for protection. Bridge construction, aquaculture, and passive habitat restoration are a few of the limited activities allowed in this zone. A conservation designation is similar to that of natural zoning, but the areas are smaller. These areas may have been modified in the past by humans, and water dependent recreation, minor dredging, and wetland compensatory mitigation are allowed. Shallow draft and deep draft development zones include areas with little biological significance, navigation channels, or deep water areas adjacent to the shore. The Coos Estuary has maintained jetties and a navigation channel at least 22 ft. deep within deep draft zones. CBEMP permits activities in these zoned areas that will provide for navigation, public, commercial, and industrial water dependent uses (Cortright, Weber, and Bailey 1987).

Coos County and the Land Conservation and Development Commission developed CBEMP in an effort to create a comprehensive plan for the estuary. This plan ties statewide planning goal 2, land use planning, to goals 16 and 17, estuarine resources and coastal shorelands, respectively. Wetland compensatory mitigation (WCM) is part of this comprehensive planning. Historic loss of tidal wetlands in the Coos Watershed rendered preservation, conservation, and restoration of estuarine and shoreland habitats a top priority for the region (Cortright, Weber, and Bailey 1987). The federal Clean Water Act of 1972 (Section 404) mandated that wetland losses caused by development impacts be offset by compensatory mitigation. Oregon's own Removal-Fill Act of 1971 had similar requirements. Although these rules were not consistently enforced until the late 1970s - early 1980s, the new regulations sent Coos County scrambling. Coos County wants to preserve agricultural lands while pursuing increases to their economic base through industrial and commercial development. Projections indicate that population densities will only increase in the next century (NOAA 1996), but new land available for development is limited. One result of trying to preserve agricultural lands, conservation areas, and provide room for development is the placement of 16 WCM sites within CBEMP areas.

Coos County needed to balance WCM compliance with cost. Mitigation can be costly because of permanent land dedication, actual construction fees, and the uncertainty of success. Large, private landowners grumble quietly about mitigation costs, but they usually comply with the federal and state regulations because of the great publicity and the high costs of noncompliance. By contrast, small landowners become very defensive when asked to dedicate a portion of their land to a WCM project, even though they may agree with long-term mitigation goals. Dedicated land is unusable for pasture or construction. Conservation easements -- payments made to a landowner for not using a wetland -- help, but distrust of government runs high in the Coos Watershed (Donnelly 1996). People want to be able to do as they wish on their property without interference. Coos County planners had to find land to set aside for mitigation that the county already owned, or was already permanently dedicated to conservation and preservation of natural resources, to avoid raising the ire of these smaller landowners. CBEMP zones share these characteristics. Almost half of the mitigation sites are located within CBEMP zones, while the rest are located on privately owned property specially bought or set aside for mitigation purposes.

Environmental Problems Affecting Coos Watershed Wetlands

Point and non-point source pollution and the introduction of non-native species into the area have probably restructured the biota, and presumably the ecology, of the Coos Estuary (Graybill 1996, Turner and Jones 1990). In recent years, scientists have begun to document many biological threats to the Coos Watershed. In one study, Carlton and Geller (1993) described a total of 367 identifiably different species imported in ballast water from Japan to Coos Bay in 159 ships. Most of these are marine and estuarine invertebrate larvae, although some plants and fish are included. If they are able to survive the trip, grow to adulthood, and reproduce, these organisms have the potential to completely change the ecological community into which they have been introduced.

Estuarine ecosystems weakened by human disturbances, like extensive urbanization, are more susceptible to biological invasions (Carlton and Geller 1993). For example, although San Francisco Bay retains some native species in deeper, saltier waters, more than 150 estuarine and marine plants and animals compose the common and dominant species in this community (Carlton 1993). The Coos Estuary may not be as urbanized as San Francisco Bay , but historic and current human impacts have touched every part of the estuary. Other species have been imported into the Coos watershed from all over the world via commercial oystering (*Crassostrea gigas* - Japanese oyster), ship fouling (*Halichondria bowerbanki* - yellow bread crumb sponge), and intentional plantings (*A. arenaria, Gambusia affinis* - mosquitofish) (Carlton 1995). At least 80 species of invasive flora and fauna have established documented populations in the Coos Watershed (Carlton 1995).

Water quality issues play an important role in both human and non-human communities. A 1998 USEPA survey of water quality rated the Coos Watershed a three on a six-point scale. A score of six indicates serious water quality problems and low vulnerability to pollutant loading stressors (USEPA 1999). The score was calculated by reviewing data for specific categories, as shown in Table 1. A score of three indicates less serious problems and low vulnerability to future problems compared to watersheds across the United States. Clean up efforts, monitoring, and environmental regulations are having a positive effect on the water quality in the Coos Watershed. However, any water quality problems decrease the effectiveness of wetland mitigation and habitat restoration for salmon and other aquatically dependent species. The fishing industry, oyster culture, agricultural and forestry practices, and potentially the drinking water supply within the watershed are also impacted.

Specific water quality related problems in the Coos Watershed include bank erosion, elevated water temperatures, degraded commercial shellfish beds, high bacteria loads (fecal coliform), toxics contamination (ex. TBT contamination from ship paint), degraded salmonid spawning gravel areas, and high rates of juvenile salmon mortality (USEPA 1999). Some of these problems can be directly linked to poor logging and agricultural practices. Because the economy of the watershed is tied heavily to natural resources, and salmon have been recently listed under the Endangered Species Act, major changes must occur in all facets of the economy. Healthy forest and wetland ecosystems

Table 1. Coos Watershed water quality indicators (USEPA 1999).

Condition Indicators

are designed to show existing water quality across the country.

Designated Use Attainment -- (*More Serious*)

Fish And Wildlife Consumption Advisories -- (*More Serious*)

Source Water Condition -- (*More Serious*)

Contaminated Sediments -- (*Better*)

Ambient Water Quality Data Four Toxic Pollutants -- (*More Serious*)

Ambient Water Quality Data Four Conventional Pollutants -- (*Better*)

Wetland Loss Index -- (*Less Serious*)

Vulnerability Indicators

are designed to indicate where pollution discharges and other activities put pressure on the watershed. These could cause future problems to occur.

Aquatic/Wetland Species at Risk -- (*High*)

Pollutant Loads Discharged Above Permitted Discharge Limits - Toxic Pollutants -- (*Low*)

Pollutant Loads Discharged Above Permitted Discharge Limits - Conventional Pollutants -- (*Low*)

Urban Runoff Potential -- (*Low*)

Index of Agricultural Runoff Potential -- (*Moderate*)

Population Change -- (*Low*)

normally help to cool water, filter toxins, and decrease soil erosion. With 86% of the wetlands lost to agricultural and urban conversion and until recently a timber-driven economy, water quality problems will not disappear overnight. However, given time, concentrated, thoughtful effort, and money, to open dikes and restore habitat, such problems should lessen.

In February 1999, the *New Carissa*, a chip transport tanker, ran aground 150 yards offshore of the North Spit. The ship broke apart before it could be moved to deeper water and spilled over 70,000 gallons of fuel into the ocean. Oil washed up as tar balls on beaches from Bandon, Oregon to Reedsport, Oregon, and moved into the Coos Estuary. The spill also coated and killed birds. At the time of this writing, the Oregon Department of Environmental Quality (DEQ) had closed commercial oyster beds to harvesting because of potential oil contamination. Many state agency biologists believe that ecosystem damage seems limited (Bishop 1999). However, only the passage of time will allow scientists to make a final judgment on the extent of impact the oil spill had on the ecology of the Coos Watershed and coastal beaches.

The success of wetland compensatory mitigation depends on past, present, and future use of natural resources -- forest, water, and land -- in the Coos Watershed. In this chapter I have attempted to describe the physical features, biological components, and human history of this region. This information will hopefully contribute to greater understanding of the following study of wetland compensatory mitigation success in the Coos Watershed.

CHAPTER III

METHODOLOGY

Chapter III reviews the methods used to determine the success of WCM projects in creating functional wetlands and maintaining watershed function and connectivity. Descriptions of permit reviews, zoning assessments, site visits, acreage calculations, in-depth field reviews, and my success matrix are included.

Choosing Wetland Compensatory Mitigation Study Sites

Both the USACE and DSL have jurisdiction over wetland permitting in Oregon. However, for the purposes of this study I reviewed only those sites permitted by DSL. Thirty-six wetland compensatory mitigation (WCM) projects located in the Coos Watershed of southwestern Oregon were available for review at the beginning of fieldwork during the summer of 1998. All project sites are located within one mile of the Coos Bay estuary and include both freshwater and saltwater influenced habitats. WCM sites were at least one year old by the summer of 1998. The mitigation sites were completed between 1982 and 1997. Although each site has a DSL permit number, I gave each WCM project a separate study number to make it easier to follow a particular site through the course of analysis. Maps 4 through 11 depict the locations of the WCM projects reviewed in this study.

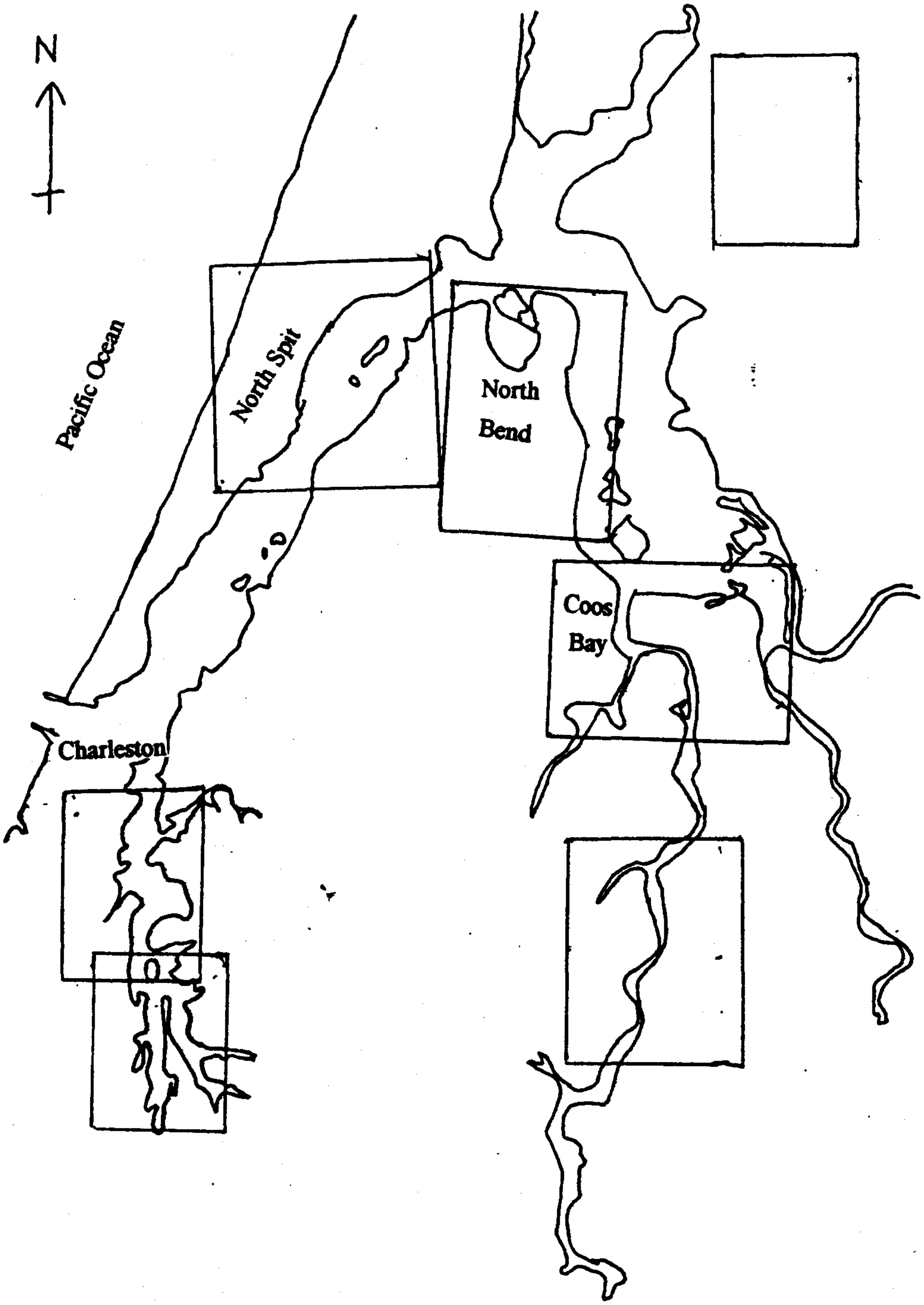
After initial permit reviews and attempts to locate each WCM project, site # 23 (Henderson Marsh) was pulled from the analysis. The permittee relied on banked mitigation credits in the Henderson Marsh area and failed to give a location for the banked WCM acreage. As I could not visit the site to verify permit compliance, survey vegetation, and later calculate acreage, I did not include site # 23 my the results.

Many of the WCM projects in Henderson Marsh on North Spit dwarfed other mitigation sites in the Coos Watershed in size. Therefore, in some cases I created two figures of the same information with the Henderson Marsh data removed from one of the figures to help clarify results for analysis. Summaries of WCM project descriptions may be found in Appendices B, D, and E.

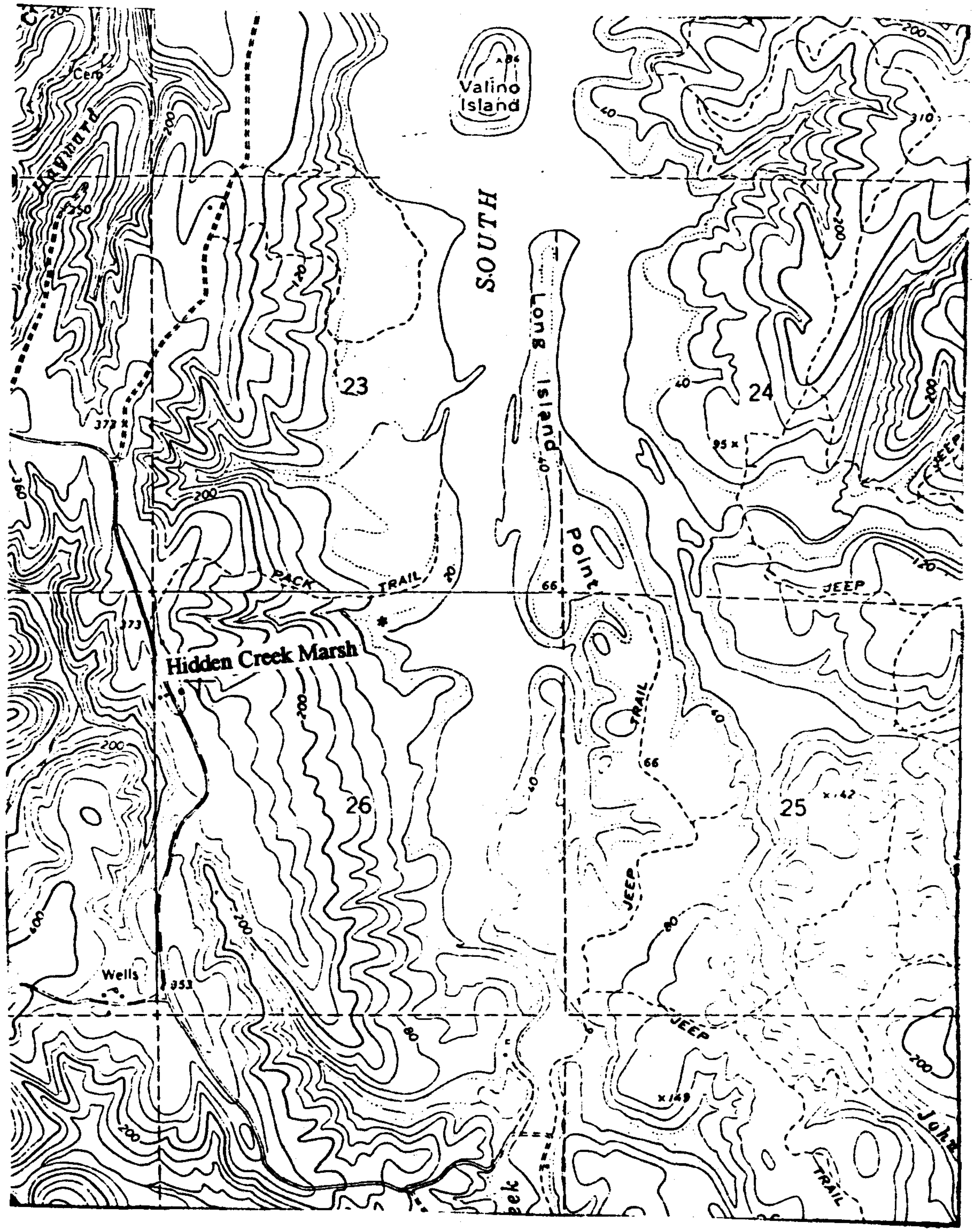
Permit Reviews

Prior to site visits during the summer of 1998, I borrowed Coos Watershed WCM permit files, approved between 1982 and 1997, from the DSL in Salem, Oregon. For each permit, information concerning the development project, the proposed compensatory mitigation, and DSL wetland specialist comments -- made during previous on-site visits -- was copied onto a data sheet for future analysis and on-site review (See Appendix A.). The sheet's format was similar to that used by DSL wetland specialists for their review of WCM sites.

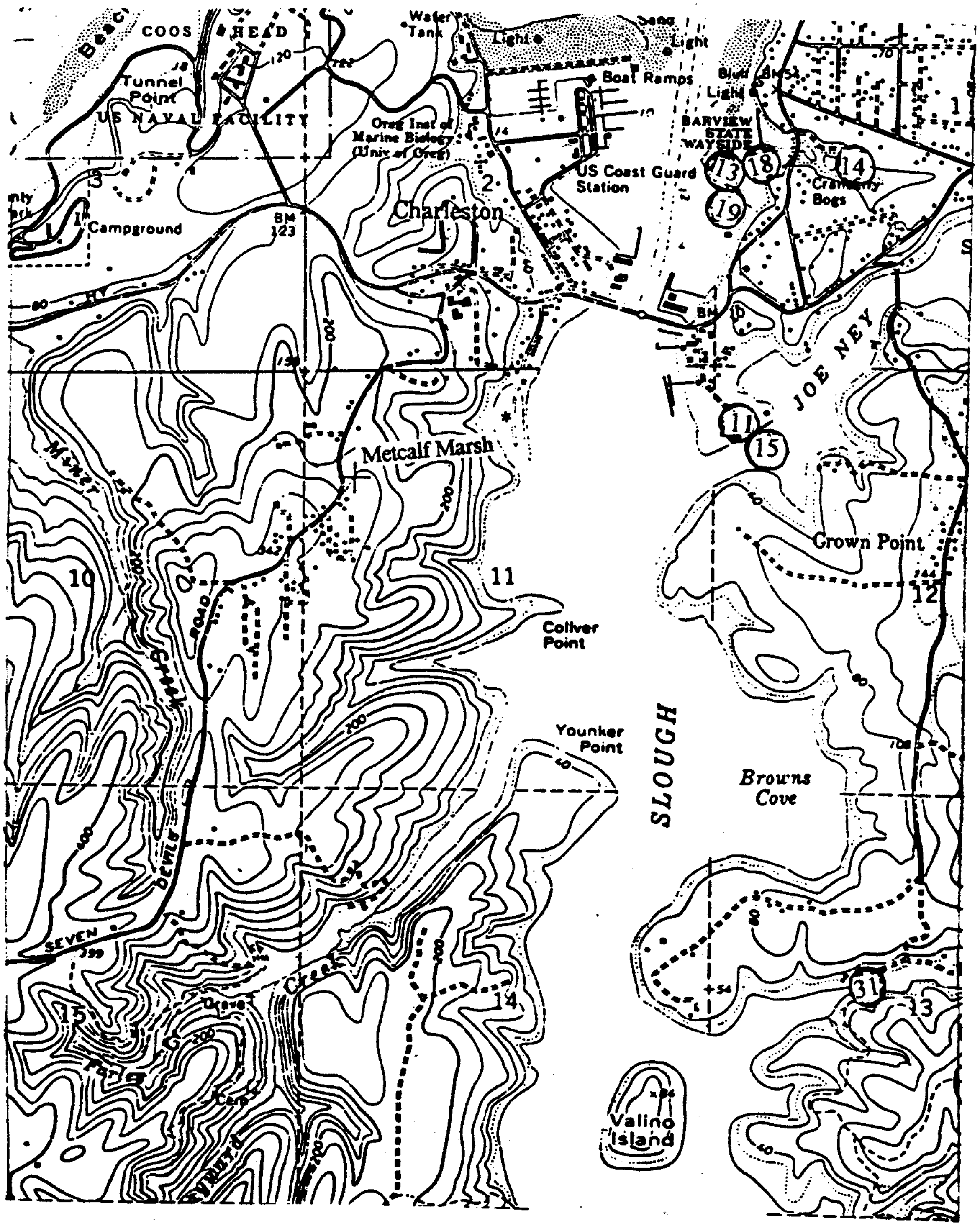
Development project information included the type, location, and impact size of the proposed action, the developer, and, if possible, a description of the impacted wetland's hydrology, vegetation, and functional value prior to construction. The type,



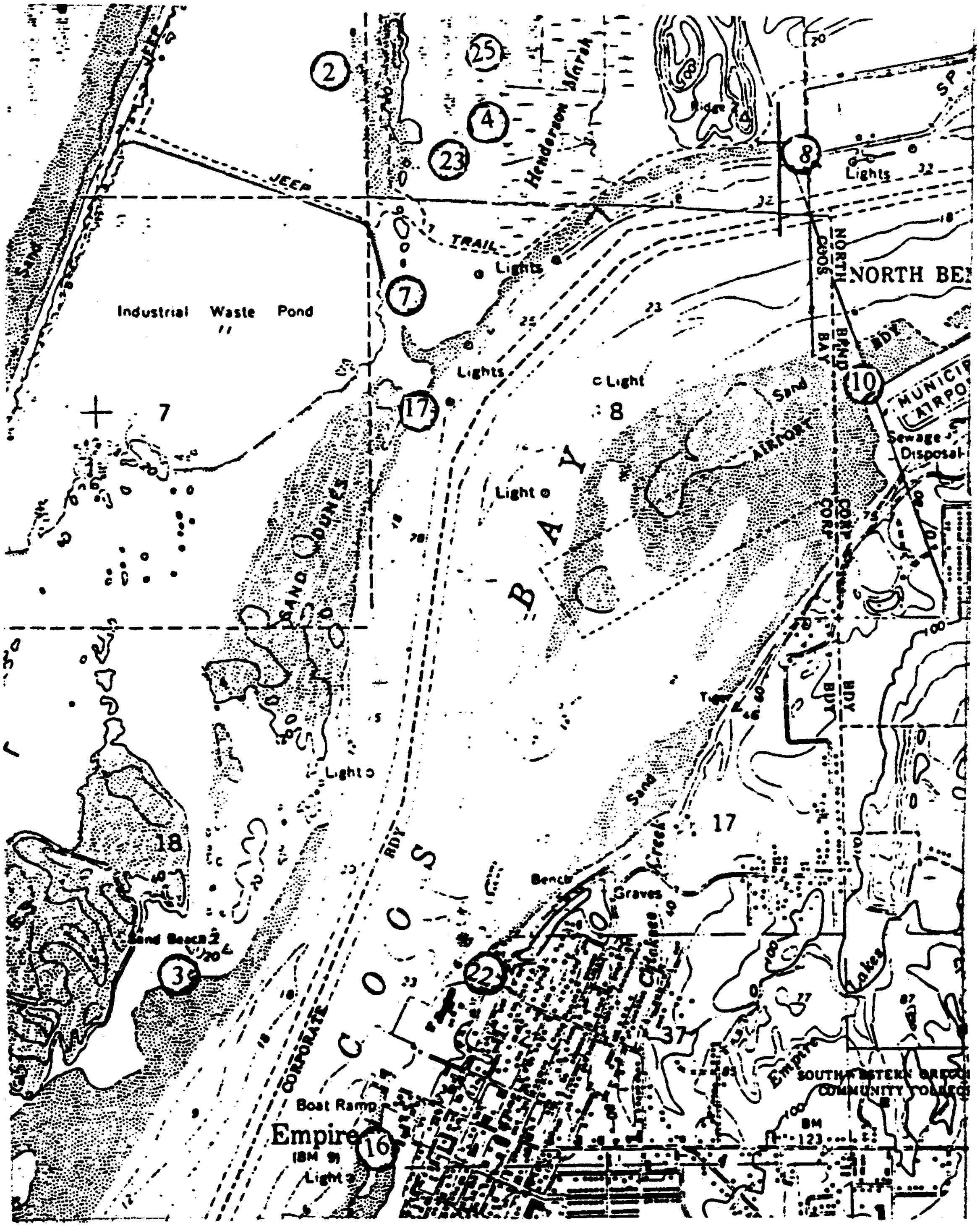
Map 4. The Coos Estuary, Oregon. Maps 5-11 following are enlargements of the boxed areas.



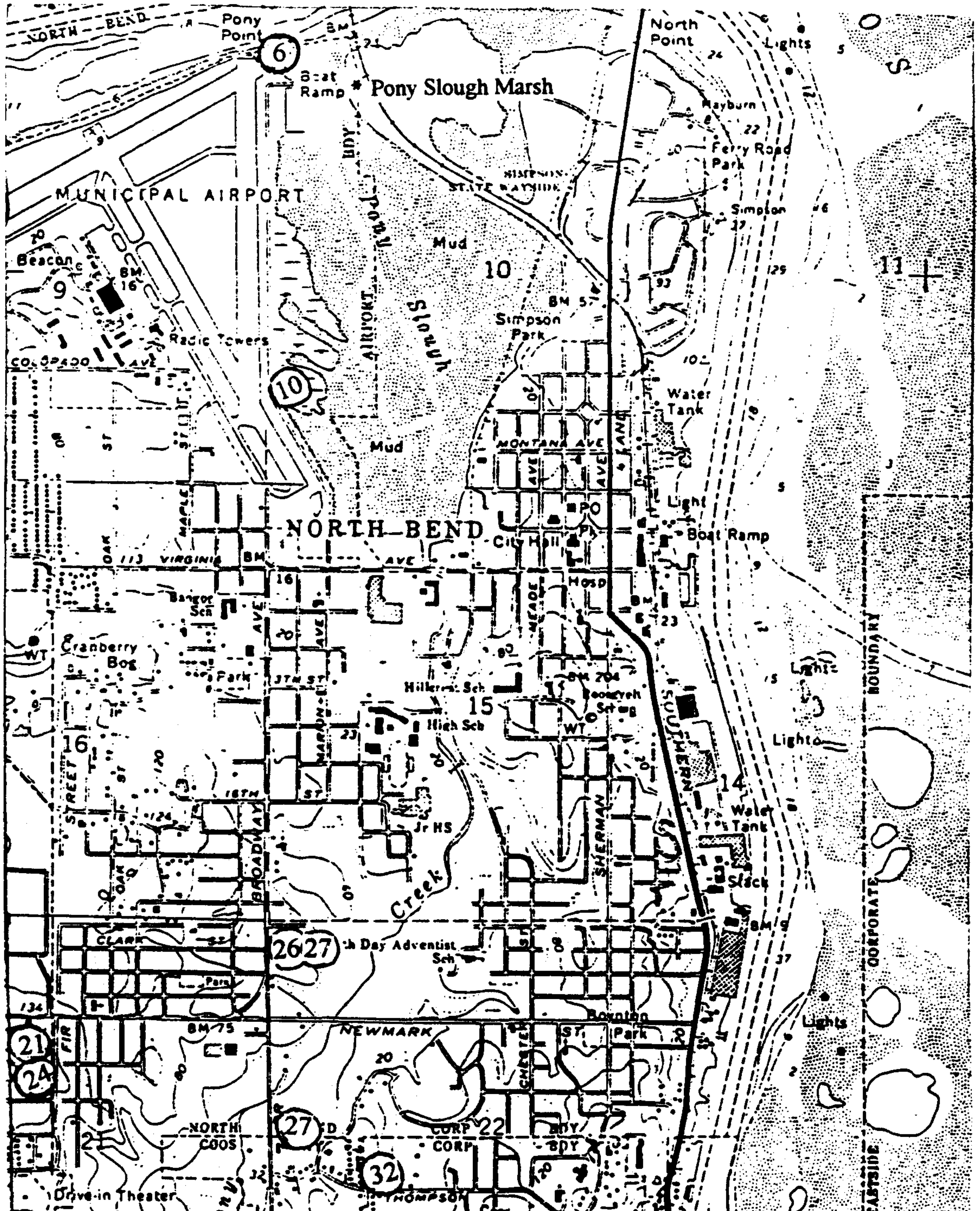
Map 5. South Slough, Oregon. A * provides the location of a reference marsh (USGS 1970a).



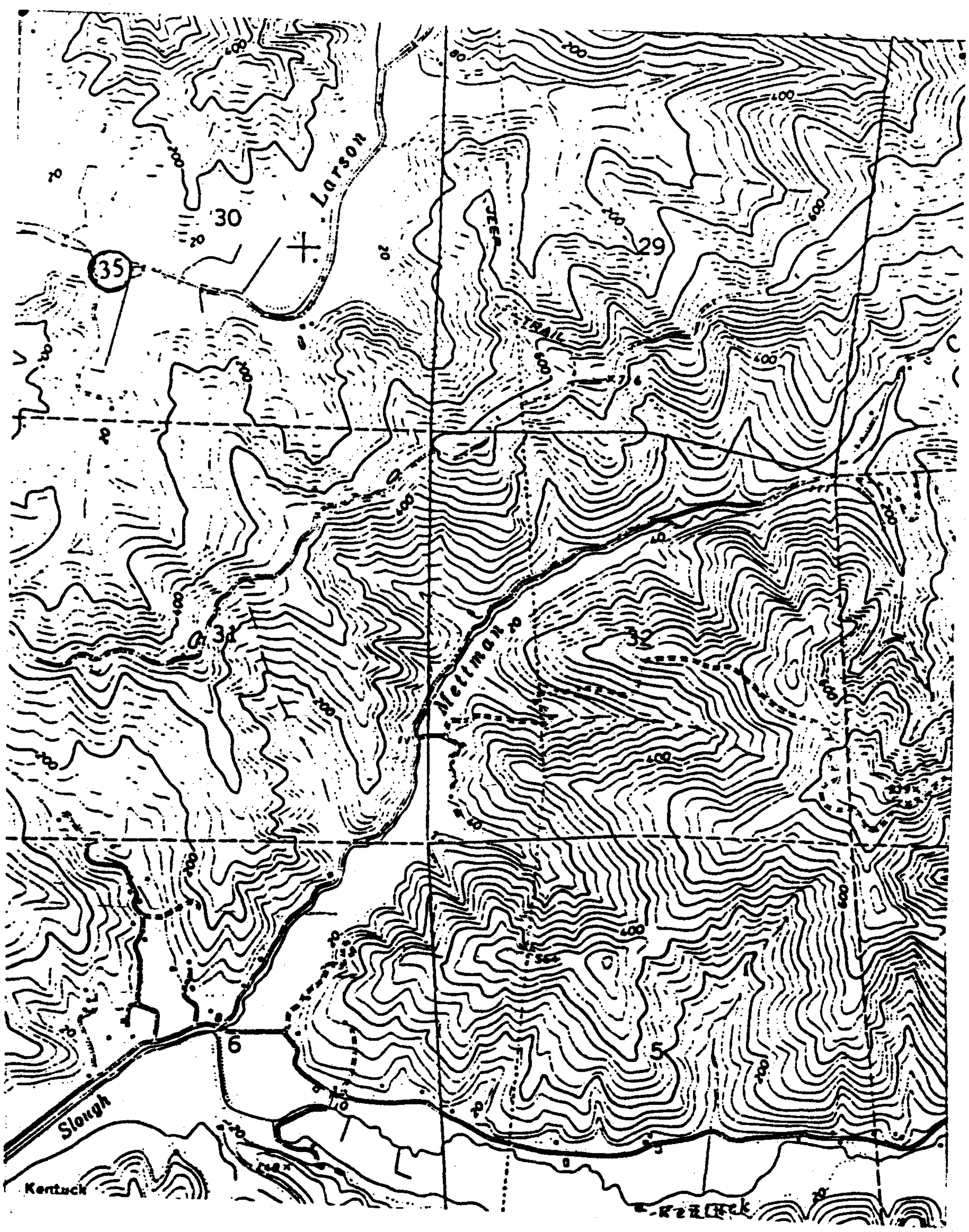
Map 6. Charleston, Oregon. Circled numbers indicate the locations of the wetland compensatory mitigation projects reviewed in this study. A * provides the location of a reference marsh (USGS 1970a).



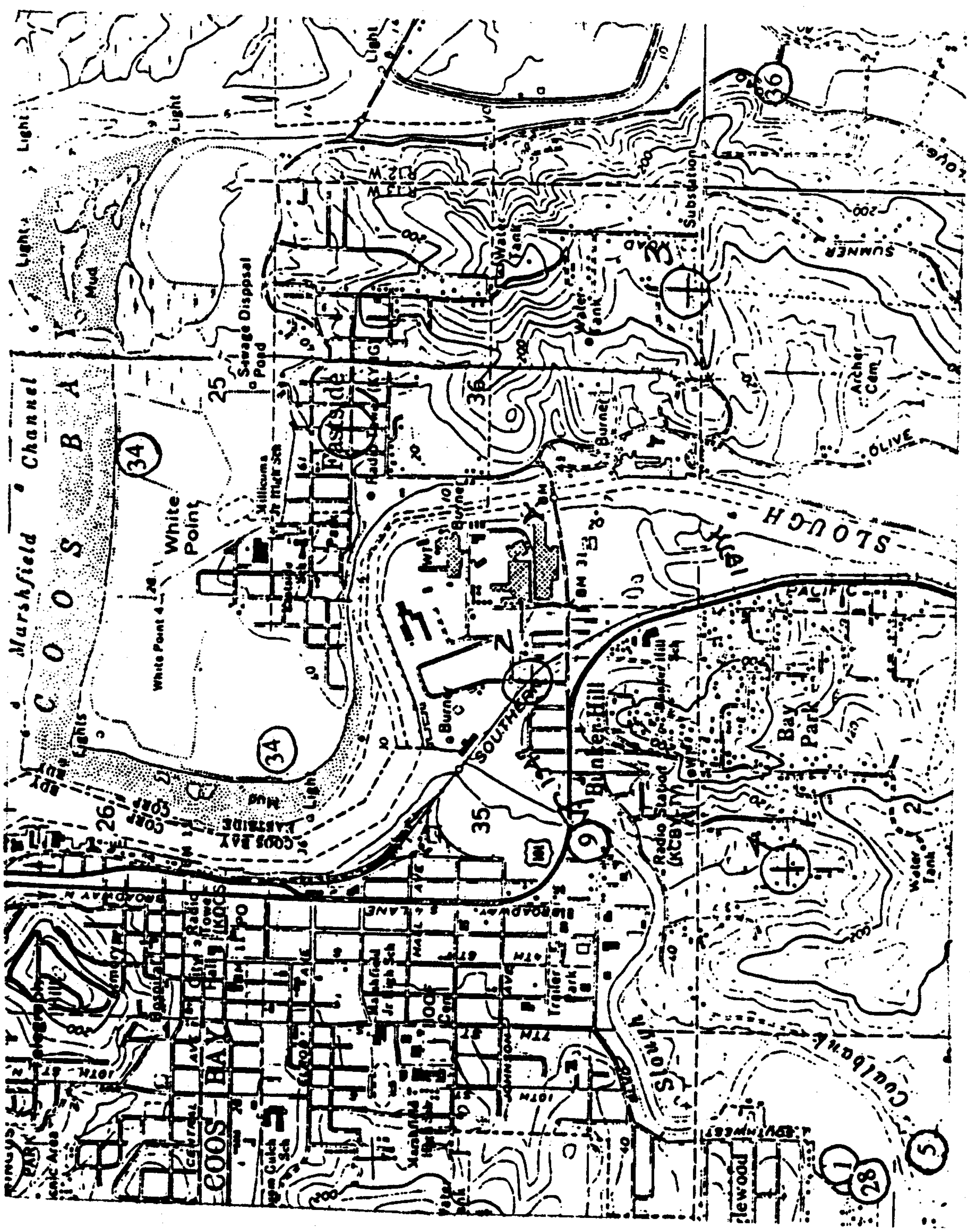
Map 7. Empire and North Spit, Oregon. Circled numbers indicate the locations of the wetland compensatory mitigation projects reviewed in this study (USGS 1970b).



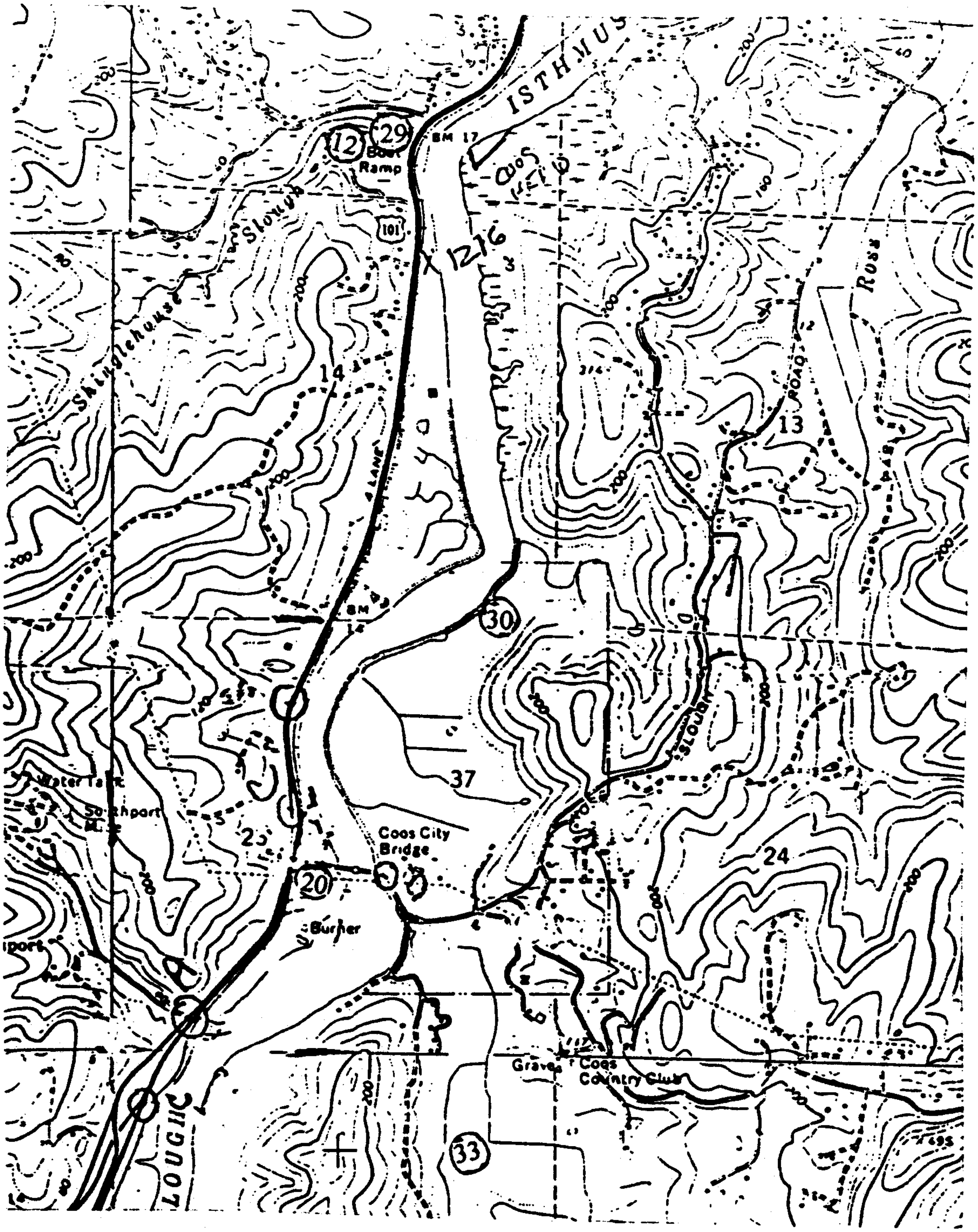
Map 8. Pony Slough, North Bend, Oregon. Circled numbers indicate the locations of the wetland compensatory mitigation projects reviewed in this study. A * provides the location of a reference marsh (USGS 1971b).



Map 9. Larson Slough, Oregon. Circled numbers indicate the locations of the wetland compensatory mitigation projects reviewed in this study (USGS 1971b).



Map 10. Eastside, Oregon. Circled numbers indicate the locations of the wetland compensatory mitigation projects reviewed in this study (USGS 1971a).



Map 11. Isthmus Slough, Oregon. Circled numbers indicate the locations of the wetland compensatory mitigation projects reviewed in this study (USGS 1971a).

location, and size of compensatory mitigation, description of the WCM site prior to mitigation when possible, and proposed action were also recorded (See Appendix B). I made notes about the comments of the DSL wetland specialist who reviewed the WCM site after completion. These comments often contained information on vegetation, hydrology, soils, site shape, location, permit compliance, and the DSL's view of the relative success of a WCM.

Copies of mitigation site maps, original wetland delineation reports, and subsequent site monitoring reports were made when available. Site maps aided in measuring the size of the compensatory mitigation site, determining zoning designations on-site and surrounding the project, and finding the site for later fieldwork. Delineation and monitoring reports allowed me to compare before and after mitigation success.

Zoning Map Information

I visited the Coos County Planning Department, as well as the planning departments for the cities of Coos Bay and North Bend, to obtain information on zoning on and around WCM sites. The county has responsibility for zoning of lands outside the urban growth boundaries of Coos Bay and North Bend. Each city plans for development separately. Their urban growth boundaries border the land along the southern edge of the Coos Estuary. North Bend and Coos Bay define and codify activities within zones differently. See Appendix F to review definitions for each zoning code relevant to this study.

I used the planning department maps to determine on-site zoning designations for WCM projects and the zoning designation of areas within a 0.25 to 0.5 mile radius of the project. I chose a 0.25 to 0.5 mile radius because any action or development within this area should have a direct and immediate impact on the mitigation site. For example, runoff containing oil and gas residues from a parking lot adjacent to a WCM site has the potential to change the productivity and composition of vegetation on that WCM site. Similar effects might be seen from fertilizer or pesticide runoff coming from agricultural fields near WCM sites. Thus, zoning designations aided me in determining potential current and future impacts to WCM sites, and therefore, their success. Appendix B contains zoning information for each WCM site.

Site Visits

I visited each WCM project and reference marsh during the summer/early fall season of 1998. At this time, the majority of plant species had reached their maximum growth and had not yet begun to senesce. I photographed each project and the surrounding area to help me describe sites and determine mitigation success. Careful note was taken of nearby natural areas such as forests and marshes. While these natural areas might be impacted by logging or recreational use, no homes or pasturing occurred on such sites. In some cases, I described the vegetation as a way of attempting to classify the type of natural area. I also recorded a description of the type and use of surrounding farmland. In urban and suburban areas, I described the use of lands surrounding WCM projects -- retail, roads, parking lots, industrial, navigation channel, or construction site.

For each WCM site, I made notes of vegetation species and visually estimated percent coverage. To generate a species list for WCM sites, I walked two transects -- NS and EW -- through each site. At some of the larger sites, I walked two parallel transects in each direction. To catch species in microhabitats that I may have missed during the transect walks, I spent 30 minutes to 2 hours, depending on site size, randomly walking through a project site noting plant species and health. In addition, the transects and random searches aided in estimating site percent coverage, as they provided information on vegetation understory and positive identification of species. I also noted general plant health and looked at plantings and planting success if this was a condition of the mitigation permit.

To estimate vegetative percent coverage at each site, I combined my knowledge of what species were present and common at a site with what I could see as dominant while looking at the entire site at once. If a species covered less than 5% of a site (usually determined by the transect and random walking), its presence was noted, but not given a coverage value. Over two-thirds of the sites were under 1 acre in size and thus could easily be viewed. For some of the larger sites (> 5 acres), like Henderson Marsh site #4 at 100+ acres, the percent coverage estimates may be inaccurate due to the project's size. In general, most WCM sites were dominated by a few species which could be readily distinguished from one another by color, shape, and size.

Despite the transects and random searches, a few plant species may have been missed -- especially if they were growing in open water like a pond or on a submerged tidal flat. For example, site #10's eelgrass beds were not visited because this part of the WCM project was subtidal, located at the end of the North Bend airport runway, and could not be reached from shore. The second part of the mitigation, a high salt marsh, could be visited. Therefore, the plant species list and vegetation analysis for this site only covers the intertidal marsh. Other researchers who have visited the area by boat confirmed the presence of healthy eelgrass beds.

To identify unknown plant species, I used two guides to make positive field identifications -- Guard's <u>Wetland Plants of Oregon and Washington</u> (1995) and Pojar and Mackinnon's <u>Plants of the Pacific Northwest</u> (1994). If neither of these were useful, a sample was placed in a labeled self-sealing bag and later keyed-out with Hitchcock and Cronquist's Flora of the Pacific Northwest (1976). My results were checked against a list of plants known to be found on the Oregon coast and in the Coos Estuary (Jefferson 1975). From the above information, I generated a complete list of all the plant species I found on WCM sites in the Coos Watershed. See Appendices C and D. At each site, I checked for the presence of invasive species, particularly plant species. These species and their approximate percent coverage were noted. Non-native plant species were placed on another list in Appendix E.

Before leaving a site, I took notes of what I felt could be improved at the site and made an on-site judgment of mitigation success based on compliance with WCM project requirements and the health and diversity of wetland vegetation.

Acreage Calculations

By comparing the site location to flight lines of a series of photographs taken 5/18/97, for the Coos Bay BLM, I was able to obtain the necessary aerial photographs of WCM sites in the Coos Watershed. The originals were laser copied for personal use and then returned to the Coos Bay BLM. Laser color copies cost less than having a new set of aerial photos developed and nearly match the clarity of actual photographs. The total WCM site and specific habitat areas within each WCM site were outlined on the laser copied photos for easier use with the computer digitizer.

Difficulties in determining habitat boundaries arose due to the time the picture was taken during the tidal cycle and vegetation. Some of the pictures show the tidally influenced wetlands at or near high tide. Images of salt marsh, mudflat, and tidally influenced freshwater wetlands taken at low tides would have been preferable, as it would have been easier to see exposed tidal flats. Using National Wetland Inventory (NWI) maps I found known intertidal marshes and mudflats (USF&WS 1989a, 1989b, 1989c, 1989d). I then compared the color differences of water on these known intertidal marshes and flats in the air photos to new areas on WCM sites to identify potential intertidal flats and marshes. I also used this method to compare known marsh and mudflat vegetation with vegetation on WCM sites to identify and outline specific habitats. Areas having similar vegetation and coloration indicate similar habitat and species composition (Avery and Berlin 1992).

Vegetation obscured the boundaries of freshwater wetlands in the upper Pony Slough Watershed. Tree foliage prevented an accurate view of the presence of standing water in some areas. Aerial photos taken earlier in the year would have been more helpful. For these WCM sites, I estimated wetland habitat boundaries based on my field survey walks of the sites and drew these boundaries on the laser copies for later measurement.

The scale of the air photos was given as 1 : 12,000. I recalculated scale for the computer digitizing program by measuring the bridge connecting Sumner, Oregon to Hwy. 101 on the air photo. This was compared to a measurement of the same bridge from a U.S. Geological Service (USGS) quad map of the eastern section of Coos Bay (USGS 1971a). The USGS quad map had a scale of 1 : 24,000. Photo scale was calculated using the representative fraction equation *RF = photo distance / ground distance*, where ground distance was taken from the map and photo distance from the digitizer measurement. After the RF factor was entered into the digitizing program, the computer automatically calculated accurate acreages for each measurement. The digitizing program calculated a site's acreage after I traced around the site's boundaries on a digitizer board. Three traces of each area were made using the digitizing wand. The results were averaged to obtain an average acreage value for each WCM site's overall size and, where possible, by habitat type. I used NWI classification notation to label separate habitat types. See Appendix B for a summary of habitat acreage for each WCM project.

Caution should be used in interpreting the acreage results. Some of the sites that were traced covered less than 200 $ft.^2$ on the ground. On an aerial photo with a scale of 1 : 12,000, these areas may show up as a point or a line -- difficult to trace and measure. Some error in acreage calculations comes from the physical tracing of the wetland site. A small deviation in the trace, resulting from a momentary loss of concentration or fine motor control, can add or subtract to the acreage calculated by the digitizing program.

Given acreages for WCM projects and my digitized measurements may also differ due to variances in the maps used to calculate area. Some project managers may have calculated original site size by in-field surveys, while others might have used USGS quads or older county maps. Map scale, and thus acreage, varies with each technique. Also, some areas intended for wetland mitigation may never have been completed or failed after construction. My acreage calculations and vegetation surveys for this study included only those areas of WCM sites that looked like wetlands and could be legally defined as such.

Two WCM sites were measured in the field rather than on an aerial photograph. WCM project #34, constructed on both Millicoma Marsh and Coalbank Slough, was built during the summer of 1997 after the series of aerial photographs I used were taken. As it was impossible to determine the boundaries of these two sites on the laser copied photos, I paced the boundaries of the sites in the field. Multiplying the number of paces by their average size (4 ± 0.26 ft.), I calculated the length of the sites' boundaries. Using simple area formulas and an acreage factor (1 acre = 43,560 $ft.^2$), I determined the final acreages of these WCM sites. See Appendix B.

In-Depth Field Reviews and Comparisons

In addition to the regular field surveys, I conducted a more intensive survey of plant species presence and percent coverage at three WCM sites (#6, #19, #31). I compared data from these site surveys with three similar natural sites and data from each WCM site measured during the course of previous monitoring or delineation. Metcalf Marsh, Hidden Creek Marsh, and a small marsh directly across from Pony Slough site #6 were chosen as the reference marshes for their similar hydrology and proximity to the three WCM sites (See Maps 5, 6, and 8). Unlike the previous field checks, I tried to use more qualitative methods for the in-depth surveys in order to better compare "natural" wetlands with mitigated sites. Measurement methods varied from site to site because I used data collected by other individuals in previous years, and I was not always able to match their exact methods. Despite attempts to put data into comparable formats, comparisons are not error free, as different methods for obtaining data were used for Barview Wayside and Day Creek.

I ran three transects at Metcalf Marsh and the Pony Slough site and two transects at Hidden Creek. The transects roughly divided the sites into equal sections, and ran from the waterline at low tide to the edge of the uplands (i.e. drier treeline). Length of the transect line varied with the distance between the waterline and base of the uplands. Quadrats were laid end to end along the transect line. I estimated species composition and total percent coverage were estimated for each 0.625 m^2 quadrat (0.79m x 0.79m). If the percent coverage value was less than 5% for a particular species, I noted presence, but did not count individual plants. Although the reference marsh data were collected late summer/early fall, plant species were identifiable and it was still possible to make estimates of percent coverage for vegetation. Appendix H contains the field measurements of vegetative percent coverage.

WCM Site #6 -- Pony Slough

Pony Slough site #6 was monitored for two years following completion of the mitigation by Drs. Jan Hodder and Martin Posey (Hodder 1986, Hodder and Posey 1987a, 1987b). Using Hodder's methods, I repeated the same vegetation transects 10 years later in early August 1998. Three transect lines were laid out at the site through the high marsh area, up along the tidal channel, and across the opening of the site to the slough (this transect runs parallel to the high marsh, perpendicular to the tidal channel, and through an elevated area designated a sill by Hodder and Posey 1986, 1987a, and 1987b). Species composition and total percent coverage were estimated for a 0.625 m^2 (0.79m x 0.79m) quadrat. If the percent coverage was less than 1-2%, a count was made of the exact number of plants. These data were then compared with Hodder's July 1986 and 1987 data to test for changes in species composition due to succession. I used only the July data from the monitoring reports because my survey of the site was conducted during early August. Hopefully, this will allow for a more accurate comparison as plants measured during these studies will have had an almost equal length growing season. In addition, I calculated the Shannon-Weiner Diversity values for Site #6 from my vegetation survey data, Hodder and Posey's data (1986, 1987a, 1987b), and from the transects I ran on the small natural marsh located directly across the slough from site #6.

WCM Site #19 -- Barview Wayside

Since 1994, Barview Wayside site # 19 has been monitored as a condition of the WCM permit for the site (Tear and Cornu 1994). Plant composition and percent coverage have been systematically measured each summer since completion of the project. Although Tear used a different method to sample composition and coverage, the overall results were summarized in a manner that could be easily compared to the measurements I took for my study. The Tear and Cornu data (1994) and my site #19 data were compared to test for changes in species composition and coverage over time. Again, I used only the data from Tear and Cornu's summer survey to allow me to compare similar vegetation patterns (my data for the site were also collected during the summer season). Data from both studies were compared with measurements taken at Metcalf Marsh, using the Shannon-Weiner Diversity Index. Metcalf Marsh was used as the reference marsh for this site because of its proximity (both sites are located at the mouth of South Slough) and similar hydrological setting.

WCM Site #31 -- Day Creek

Prior to the opening of a tide gate for the Day Creek wetland compensatory mitigation, a delineation report containing information on species composition and percent cover for various test quadrats was completed (Ternyik, Ternyik, and Guard 1996). Eleven 1 m^2 test quadrats were taken at regular intervals throughout the marsh at Day Creek. The wetland delineator recorded the plant species and percent coverage for each quadrat. Although the survey occurred in April 1996, the delineation report also contained a vegetation list for the entire site -- including plants that might be dormant or not dominant during this time. The delineation values and my field estimates were compared to test for change. Since the mitigation was an enhancement, only small changes were expected. Hidden Creek Marsh in SSNERR was used as a reference marsh. After calculating Shannon-Weiner Diversity Indices for Day Creek delineation and field surveys and Hidden Creek transects, I compared the values to test for differences between natural, impacted, and mitigated wetlands.

Calculating Shannon-Weiner Diversity Indices

The Shannon-Weiner Diversity Index is a means of measuring species richness -- in this study, plant species. Researchers use it to look at biological value, natural richness, and the uniqueness of a particular habitat. To generate a diversity value, I used the equation $H = -\Sigma p_i \log p_i$, where H is the diversity value of a habitat and p_i the percentage importance (percent coverage) of each species within a particular habitat (Shaw 1985). For each in-depth field study site, I calculated a diversity index value for the reference marsh transects, an earlier study of the particular WCM site, and values from my own surveys of the WCM sites in the summer of 1998. These index values were used to compare changes in plant diversity at a WCM site over time and differences between natural and mitigated wetlands sites sharing similar hydrological characteristics. Appendix G contains the Shannon-Weiner Diversity calculations.

While the Shannon-Weiner Diversity Index is a useful tool, there are a few drawbacks to its use. Some researchers have raised questions regarding the Index's precision and validity in the field. Although I used transects to look at plant species on reference marshes and in-depth field review sites, for most WCM sites in this study I generated percent coverage values by visually surveying the vegetation -- a subjective measurement. Also, the Index measures only diversity within specific communities or habitat types. Disturbed habitats can score a higher diversity value. It is better to compare natural salt marshes with natural salt marshes than a natural salt marsh with a WCM salt marsh. After a human disturbance, such as the creation of a new wetland, an area will be inundated with many early successional species which for a time outcompete the later successional species that give a wetland its characteristic monoculture look. Also, human disturbance can allow non-native species to invade a site and outcompete native species for space and nutrients.

For example, Millicoma Marsh site #34's newly restored high salt marsh had a few late successional species, but was mainly covered by non-native *Cotula coronopifolia* (brass buttons) and *Lilaeopsis occidentalis* (western lilaeopsis) -- two early successional plant species. Other weedy type species may thrive on this site for a few years until typical late successional species colonize the area and become established. Such species could include *Distichlis spicata* (salt grass), *Deschampsia caespitosa* (tufted hairgrass), and *Triglochin maritimum* (seaside arrowgrass), if the surrounding salt marsh and plantings are any indication. This transition could take a few years to a few decades to occur. In the meantime, a greater diversity of early successional species will cover the site. Potentially, highly competitive non-native plants could invade and "take-over" the WCM site -- preventing any late successional native plants from colonizing in the future. Both situations could generate a higher Shannon-Weiner Index than would probably be found for the surrounding natural high salt marsh habitat.

Assessing Success

WCM success may be judged both quantitatively and subjectively. Different researchers will use various means involving long-term monitoring, specialized equipment and methods, permit reviews, and site visits to determine wetland mitigation success (Pacific Estuarine Research Laboratory 1990, Shaich and Franklin 1995, Simenstad and Thom 1996). For the purposes of this study, I determined success of WCM in the Coos Watershed through DSL permit reviews, simple field measurements, and subjective on-site surveys. My methods have been described.

Just as different researchers will determine success differently, several definitions of wetland mitigation success exist. Mitsch and Wilson (p 77, 1996) define success as "the establishment of a biologically viable and sustainable wetland ecosystem." Other researchers concur (Mitsch and Gosselink 1993, Pacific Estuarine Research Laboratory 1990, Simenstad and Thom 1996, Zedler 1996), but this view is not always how time-limited, government agency, permit reviewers judge the success of WCM projects in the field. Mitsch and Wilson's (1996) definition forms the basis of my own assessment.

I would add that in addition to functioning as viable wetland habitat, a WCM should replace as well as possible the function of the impacted wetland in the watershed. Wetlands play an important role in watershed function and connectivity. For example, wetlands filter and store water, contribute heavily to primary production, trap sediments, and provide essential habitat for aquatic and terrestrial organisms. If these and other values are lost through fill and removal activities, overall watershed function and connectivity is greatly diminished. I would argue that WCM's that do not adequately replace such values fail, regardless of whether or not they function as viable and sustainable wetland ecosystems. Unfortunately, the replacement of watershed function and connectivity cannot be accurately be measured at this time. I have attempted to subjectively measure a wetland's ability to maintain watershed function and connectivity using a simple scoring system.

To account for wetland and watershed function perspectives in this study, I assessed success using two separate methods. Determining wetland functional success involved visiting each site and reviewing DSL permits. At each site I attempted to answer the following questions: Were DSL permits goals and objectives achieved? Were there any permit compliance violations? Was the WCM site functioning as viable wetland habitat? Was hydrology for the site adequate? For example, if the site was estuarine, were there tide channels present/forming? Did the vegetation look healthy? Were similar plant species found on nearby natural wetlands?

On the basis of my answers to these questions, I placed each WCM site in one of the following categories: failure, success, partial success, or incomplete. Sites judged as partial successes may have functioned poorly or had no stated goals or objectives. Without goals or objectives, there is little to measure success against. All WCM sites labeled as incomplete were less than three years old. I used a cutoff of three years because while vegetation and hydrology have had some time to establish, these habitat parameters may not be sustainable without human assistance. A site could still fail. At some of the incomplete sites, the DSL wetland specialist had already judged the site successful.

My second method of judging success included the first assessment, but added long-term viability and some watershed function and connectivity components. I developed a simple matrix and scoring system in an attempt to better determine success. Table 2 reviews each parameter and how it was scored.

Each WCM site's score for individual categories within the matrix was added together. Within the matrix, possible total score values range from -16 to +16. Based on

TABLE 2. Parameters used to determine WCM site long-term viability and watershed function success.

Permit Compliance

yes - no violations, score = +1
no - one or more violations, score = -1
partial - no mitigation standards stated, therefore cannot determine compliance, score = +0.5
unsure - site has eroded out, cannot determine compliance, score = 0

Within Same Watershed

yes - both the WCM and impact sites were located within the same subbasin, score = +1
no - the WCM and impact sites were located in different subbasins, score = -1
yes & no - WCM was located in two subbasins, one of which contained the impact, score = +1

On-Site

yes - WCM located on same site as impact, score = +1
no - WCM located on different site as impact, score = -1
yes & no - WCM located on and off impact site, score = +1

Proximity to Natural Sites

yes - close to large natural areas such as forests and marshes, score = +1
no - nearby areas are heavily developed/urban, score = -1
~ - nearby areas are lightly developed/rural, score = +0.5

Proximity to Other Sites

yes - WCM is either adjacent to, includes, or is close to (within 0.25 miles) another WCM site. I chose 0.25 mile radius as any action or development within this area should have a direct and immediate impact on the mitigation site. score = +1
no - no other WCM sites are near within 0.25 miles, score = -1

Equal Habitat Exchange

yes - equal exchange, e.g., low salt marsh WCM for low salt marsh impact, score = +1
no - unequal exchange, e.g., freshwater pond WCM for low salt marsh impact, score = -1
partial - some equivalent exchange, i.e. low salt marsh and some high salt marsh WCM for high salt marsh impact, score = +0.5

Acreage Exchange

acre value = actual gained acres - proposed lost acres
In cases where multiple mitigation methods were used, the actual amount of enhanced acreage at a site often could not be determined. Therefore, enhanced acreage was counted as gained rather than lost wetland acreage.

TABLE 2. (Continued).

Site Size > 1 acre

yes - WCM project >= 1 acre in size, score = +1
no - WCM project < 1 acre in size, score = -1

WCM Ratio Met

This accounts for both acreage exchange and the type of WCM -- creation, enhancement, restoration, or some combination of these methods. DSL has two separate methods for calculating estuarine and freshwater mitigation ratios. Estuarine ratio calculations account for the type and quantity of the habitat generated and method used. Freshwater ratios only look at quantity and method -- creation 1:1.5, enhancement 1:3, and restoration 1:1. Freshwater impacts are often mitigated for with estuarine WCM in the Coos Watershed due to the historic loss of so many tidal wetlands. In many cases, I was unclear as to how the ratio calculations were made for each WCM sites because many WCM sites used two or more mitigation methods and tidal wetlands were traded for freshwater wetlands. Therefore, I used the freshwater ratio values to assess whether the WCM ratio had been met.

yes - at or near (within $\pm$0.1) the ratio required, score = +1
no - below the required mitigation ratio, score = -1
partial - more than one WCM method used on site and ratio value falls between required ratio values for each method (dependent on acreage modified by each WCM method), score = +0.5
surpass - ratio far above that required, score = +2

Functioning as Wetland

See the description of the short-term success assessment method. All values in this category are doubled for weighting purposes in the final success calculation.

yes - score = +1
no - score = -1
partial - score = +0.5

Monitoring Plan

yes - plan specifically mentioned and/or site currently monitored, score = +1
no - no plan mentioned, although DSL may check on the site yearly, score = -1
maybe - permit wording indicates monitoring will occur, but no specific plan mentioned and unsure if occurring, score = +0.5

TABLE 2. (Continued).

Invasive Species

The number of invasive plant species found on sites ranged from 0 to 15.
0 - score = +1
1-7 - score = +0.5
8-15 - score = -1

Protective Zoning

yes - WCM site is located and/or surrounded by an area with natural or rural zoning designations, score = +1
no - WCM site is located and/or surrounded by an area with urban residential, industrial, commercial, or similar designations, score = -1
maybe - WCM site is located in an area that may be zoned for natural, rural, or light development, but I am unsure if this will be enough protection in the future, i.e. CBEMP zoning in Henderson Marsh where NUCOR steel wants to build a new plant, score = +0.5

WCM Type

creation - score = +0.5
enhancement - score = -1
restoration - score = +1
combination of methods (e.g. creation and enhancement) - score = +0.5

the total score tally, I assessed each WCM site's potential for long-term viability and contribution to watershed functional success. I judged any total zero or negative score as a failure, a total score of $0 < X < 7$ a partial success, and $X >= 7$ as a success, where X = total WCM site score.

It is important to use caution in interpreting my judgments of WCM success in the Coos Watershed. To a certain extent, my success matrix contained an element of predicting the future -- always dangerous -- based on current conditions and practices within the watershed. Unforeseen disasters, such as the *New Carissa* oil spill, could impact WCM sites in ways that turn successes into failures (ex. oil drifting in on a flood tide smothers and kills vegetation on a site). Future construction on or near WCM sites could also precipitate their failure. While on-site analysis of success included measurement of physical parameters and permit checks, it also included subjective judgments of habitat quality and function.

In addition, Mitsh and Wilson (1996) suggest a minimum of 15-20 years of wetland ecosystem development before a final assessment of success can be made on freshwater marsh mitigations and longer periods for coastal wetland WCM sites. Given this view, only one site (#2) would be available during the summer of 1998 for a mitigation success review. Therefore, as time passes each WCM site in this study should be reevaluated to obtain a firmer conclusion of success in the Coos Watershed.

Other points to consider include definitions of success and time constraints. Definitions of what constitutes successful WCM vary widely. The parameters I used to make my assessments may be different from those used by another researcher, although I tried to include parameters used in previous studies whenever possible. Time constraints limited the use of long-term monitoring of various environmental parameters in my assessment. Monitoring would have aided in generating a stronger baseline from which to judge individual site success.

CHAPTER IV

RESULTS

To better assess the success of WCM in the Coos Watershed, I examined DSL permit and habitat parameters at 35 wetland mitigation sites constructed between 1982 and 1997. Based on the results of the permit review and site examinations, I found a 54% success rate for current wetland function. Nine percent had partial success. For 23% of WCM sites it is too early to judge success, therefore they were considered incomplete. When considering all long-term viability and watershed function standards, only 37% of sites are predicted to have full success. I predict 45% of WCM sites in the Coos Watershed to have partial success. In this chapter, I first report the results of the permit and field check examination. I then describe the results of assessing the wetland and watershed functional success of these sites.

Permit Reviews

Table 3 summarizes the type and purpose of development activities that required WCM in the Coos Watershed. The category number of sites includes the sites impacted by development. Commercial and industrial development projects had the greatest impact at 11 sites each. Public road projects followed with a total of nine impacts. Public facility

Table 3. Type and purpose of development activities requiring wetland mitigation in the Coos Watershed.

General Purpose	Project Activity	Number of Sites	Number of Sites >= 1 acre
Commercial	marina	4	2
Commercial	airport	1	1
Commercial	sports facility	1	1
Commercial	building pad	5	1
Industrial	building pad	2	2
Industrial	dock	2	1
Industrial	dredge spoil disposal	2	2
Industrial	road	1	1
Industrial	log storage	2	1
Industrial	mitigation bank	1	1
Public	boat ramp	4	1
Public	building pad	1	0
Public	sports facility	1	0
Public Road	bridge	7	1
Public Road	road	2	0
TOTAL		**36**	**15**

General Purpose	Number of Sites	Number of Sites >= 1 acre
Commercial	11	5
Industrial	11	9
Public	6	1
Public Road	9	1

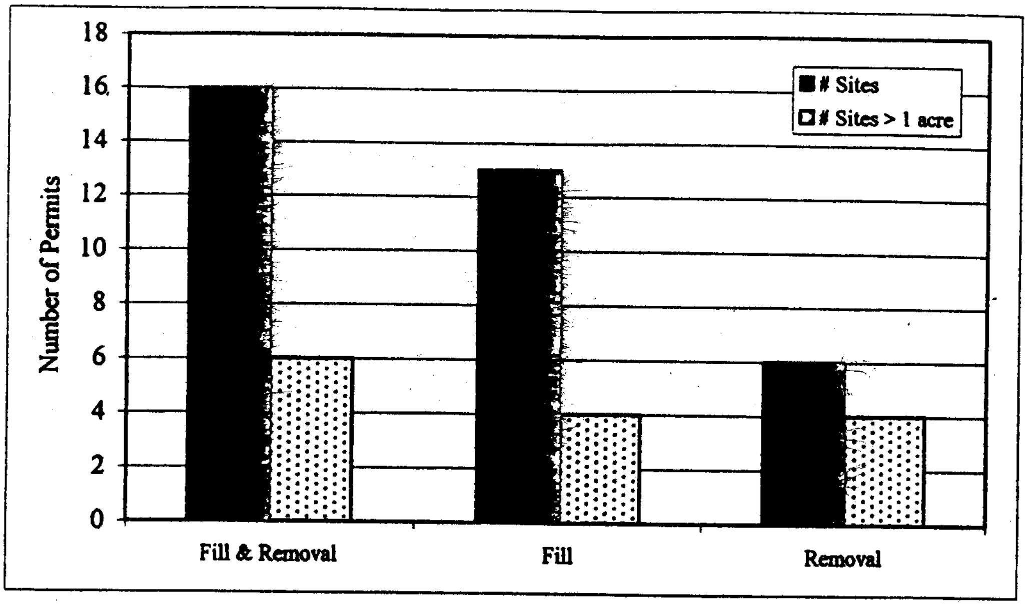


Figure 1. Types of DSL wetland permits granted in the Coos Watershed 1982 to 1997. Black bars show the total number of sites, shaded bars indicate sites larger than 1 acre.

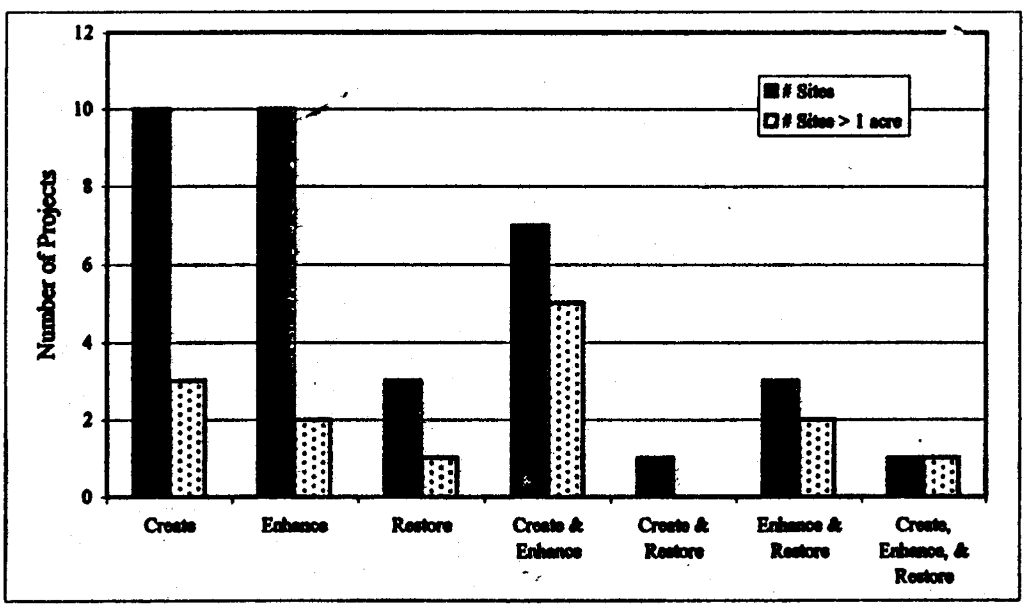


Figure 2. Methods of wetland mitigation used in the Coos Watershed 1982 to 1997. Black bars show the total number of sites, shaded bars indicate sites larger than 1 acre.

construction impacted six wetland sites. Industrial development impacted the largest number of sites (9) larger than 1 acre. Bridge building activities impacted seven wetland areas in the Coos Watershed. Marina construction, building pads, and dredge spoil disposal at two sites each tied for project activities covering sites larger than 1 acre.

Figure 1 depicts the types of permits DSL granted to developers in the Coos Watershed, from 1982 to 1997, under the Oregon Removal-Fill Act of 1971. Most of the permitting includes both fill and removal of sediments in wetlands (16 permits). DSL approved 13 fill-only and six removal-only permits during the 15 year period. Six Fill and Removal permits were for wetland impacts greater than or equal to 1 acre in size. Four permits each for development of 1 acre or more in size were approved for fill only and remove only projects. However, most of the developments impacted small sized wetlands. The cumulative effect of continual filling of small wetland acreages will eventually leads to large wetland losses.

Creation and enhancement (at 10 sites each) were the most commonly used methods of mitigation in the Coos Watershed from 1982-1997 (Figure 2). Restoration was used at only three sites. Developers relied on a combination of creation and enhancement to mitigate wetland loss at seven sites. Other combinations of creation, enhancement, and restoration were used at five other sites. For five sites, 1 acre or larger in size, a combination of creation and enhancement was preferred. In general, restoration of previously disturbed wetlands was not a commonly used mitigation method.

Figure 3 shows all the wetland habitats impacted (IMP) and mitigated (MIT) in the Coos Watershed from 1982 to 1997. While some sites made distinctions between low and high salt marsh habitat, others had no differentiation (ND). Intertidal mudflats (12), subtidal mudflats (9), freshwater marshes (8), and scrub/shrub wetlands (7) sustained the greatest number of impacts. However, if all salt marsh habitat was lumped together, 11

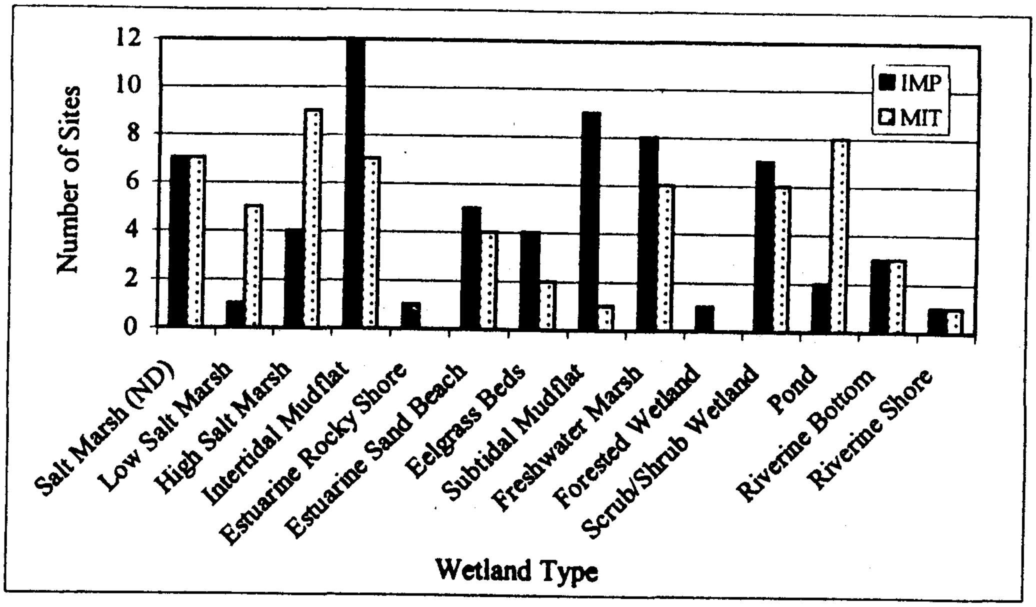


Figure 3. Wetland habitats impacted (IMP) and mitigated (MIT) in the Coos Watershed 1982 to 1997 (with Henderson Marsh).

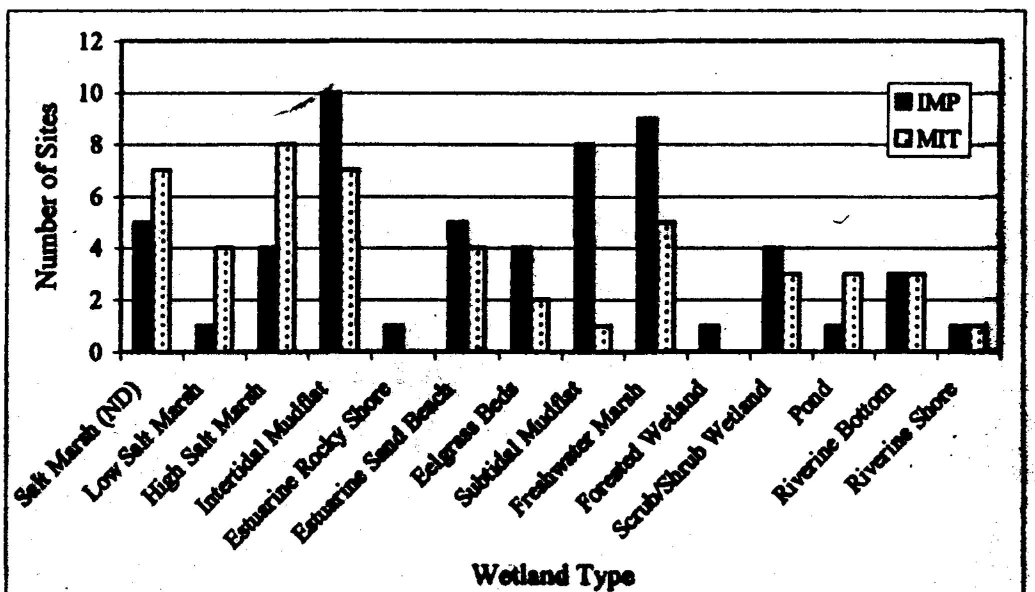


Figure 4. Wetland habitats impacted (IMP) and mitigated (MIT) in the Coos Watershed 1982 to 1997 (without Henderson Marsh).

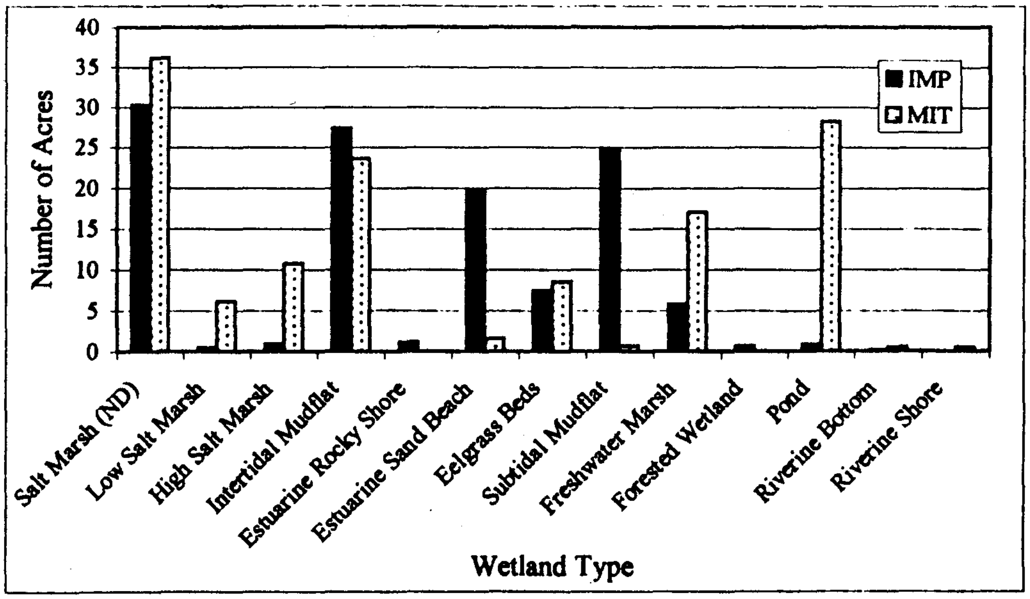


Figure 5. Wetland acreage, by habitat type, impacted (IMP) and mitigated (MIT) in the Coos Watershed 1982 to 1997 (with Henderson Marsh).

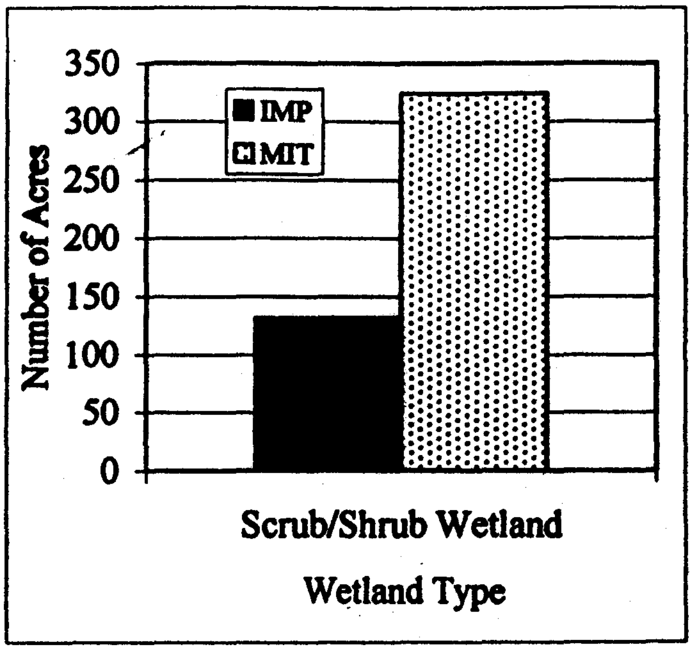


Figure 6. Wetland acreage, by habitat type, impacted (IMP) and mitigated (MIT) in the Coos Watershed 1982 to 1997 (with Henderson Marsh). Figure 6 is a continuation of Figure 5.

sites would be impacted and salt marshes would become the second most heavily impacted wetland type in the watershed. Most WCM projects created, enhanced, and/or restored were tidally influenced -- high salt marsh (9), non-tidal freshwater ponds (8), intertidal mudflat (7), and salt marsh ND (7). Freshwater marshes and scrub/shrub wetlands, at six WCM sites each, also ranked high. If lumped together, 21 WCM projects involved salt marshes. Nearly twice as many salt marshes were WCM projects than were impacted. Four times more freshwater ponds were WCM projects than were impacted. Also, there was an overall loss of intertidal and subtidal mudflat habitat.

Figure 4 shows almost the same information as Figure 3, except all Henderson Marsh WCM sites have been removed from the analysis. Intertidal mudflats (10), subtidal mudflats (8), and freshwater marshes are still the most heavily impacted, but fewer ponds (3) have been used as WCM.

Figures 5, 6, and 7 depict habitat acreage affected by impacts (IMP) and WCM (MIT) in the Coos Watershed. Figures 5 and 6 present proposed acreage impacts and actual mitigation site acreages for all 35 WCM sites. Scrub/shrub wetland was the most heavily impacted at 131.6 acres. Riverine wetlands had the least proposed impact (under 0.2 acres) from development activities. Salt marshes (31.6 acres total), intertidal mudflats (27.4 acres), and subtidal mudflats (24.9 acres) followed scrub/shrub habitat in amount of acres impacted.

Appropriately, most scrub/shrub wetlands had the most WCM acreage (323.3 acres). Salt marshes (53.1 acres total), freshwater ponds (28.1 acres), and intertidal mudflats (23.6 acres) constitute most of the rest of WCM acreage. It is interesting to note the large losses of estuarine sand beach and subtidal mudflat development, as well as the huge gains of freshwater pond and marsh acreage through WCM.

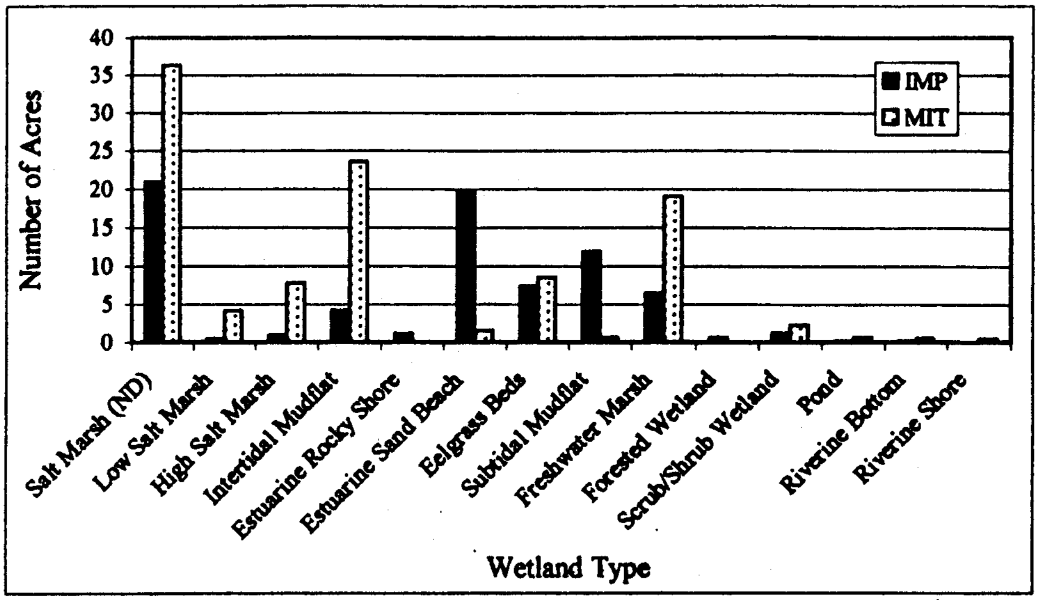


Figure 7. Wetland acreage, by habitat type, impacted (IMP) and mitigated (MIT) in the Coos Watershed 1982 to 1997 (without Henderson Marsh).

Figure 7 shows the same information as Figures 5 and 6 , except that all Henderson Marsh related sites have been removed from the graph. Salt marsh (22.3 acres total) and estuarine sand beach (19.6 acres) habitats have been impacted the most. The greatest amount of WCM occurred on salt marsh (48.2 acres total), intertidal mudflat (23.8 acres), and freshwater marshes (19.0 acres). As seen previously, estuarine sand beach and subtidal mudflat habitats suffered the heaviest losses. Salt marshes, intertidal mudflat, and freshwater marsh habitats had the greatest gains. By removing the Henderson Marsh results from figure 7, it can be shown that most of the WCM and impacts on Henderson Marsh involved scrub/shrub wetlands.

Figure 8 shows the location of WCM sites in relation to proposed wetland losses in the Coos Watershed. Twenty-three WCM projects took place at the same sites where wetlands habitat was lost. Nine wetland impacts were mitigated off site. Three development projects had some WCM both on and off site. For WCM sites 1 acre or greater in size, 14 occurred on the same site as the original wetland development, five were off site, and two mitigations were both on and off site. On-site WCM may allow for some replacement of lost wetland function.

Figure 9 depicts the location of impacted wetlands and WCM sites in the Coos Watershed. Pony Slough Watershed (6) had the greatest amount of impact sites. It was followed by North Spit (4), Coos Bay Waterfront (3), Henderson Marsh (3), Isthmus Slough (3), and South Slough (3). Pony Slough Watershed had the most WCM projects located within its boundaries -- five sites. Barview Wayside, Coalbank Slough, and Henderson Marsh have four WCM sites each. Barview Wayside, Shinglehouse Slough, Coalbank Slough, the Empire waterfront, and Henderson Marsh had more WCM sites than wetlands impacts. These areas were set aside for conservation and natural areas under CBEMP or are not as desirable to developers, therefore they have remained

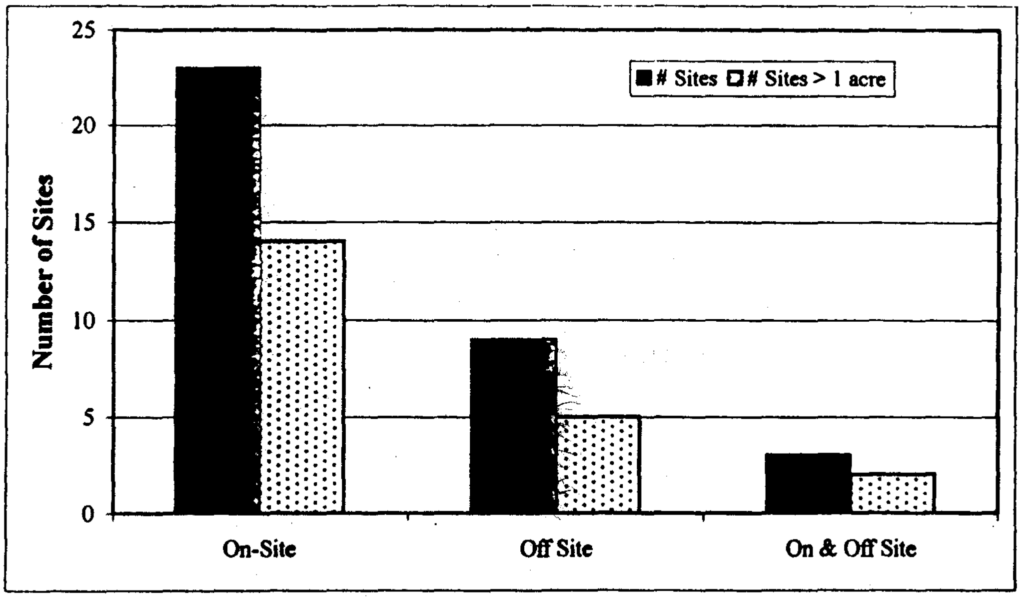


Figure 8. The location of wetland compensatory mitigation projects in relation to proposed impacts in the Coos Watershed. Black bars show the total number of sites, shaded bars indicate sites larger than 1 acre.

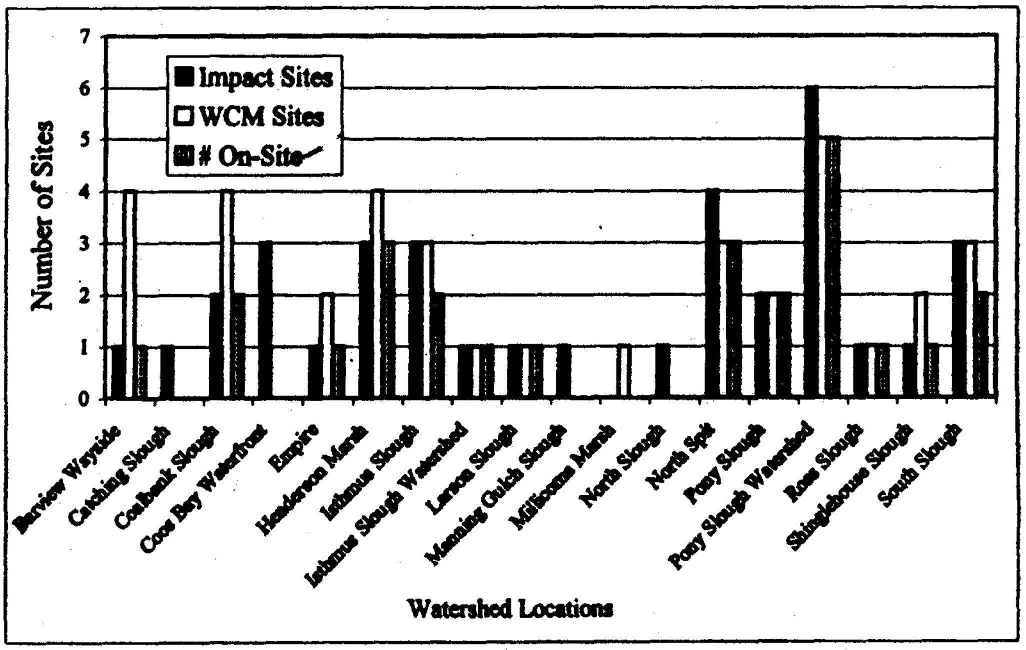


Figure 9. The location of impacted and mitigation sites in the Coos Watershed by watershed subbasin. Black bars indicate impacted sites, white bars represent mitigation sites, and shaded bars show where mitigation occurred on the same site as the impact.

relatively undeveloped. Catching Slough, Coos Bay Waterfront, Manning Gulch Slough, North Slough, North Spit, and the Pony Slough Watershed have fewer WCM sites than wetland impacts. These areas in the Coos Watershed are highly developed and attract further construction.

Figure 9 also shows where on-site WCM occurred throughout the watershed from subbasin to subbasin. Pony Slough Watershed (5) had the greatest amount of on-site wetland mitigation. Henderson Marsh and North Spit also maintained high levels of on-site mitigation (3 sites each). Catching Slough, Coos Bay Waterfront, Manning Gulch Slough, and North Slough sustained wetland impacts, but no WCM occurred on-site in these subbasins.

Zoning

Figure 10 depicts county and city zoning designations. Fifteen WCM projects were constructed in CBEMP areas -- seven were greater than 1 acre in size. Seven WCM sites fell within a commercial zone, four in recreation areas, and three in agricultural areas. Other WCM sites were built on land zoned for airport (2), industrial (2), medical park (1), and rural residential (1). A similar pattern is seen for WCM sites larger than 1 acre.

Figure 11 shows zoning designations for areas within a 0.25 to 0.5 mile radius of all WCM sites in the watershed. Some zoning designations have been lumped together. For example, the category Residential contains all urban residential designations. The Future Planning category is the city of Coos Bay's RFP zoning designation -- anything could be built here in the future but the area currently acts as a buffer between residential and CBEMP zones. Nearby zoning has an effect on WCM sites. Future development in these areas could alter site hydrology and ecology.

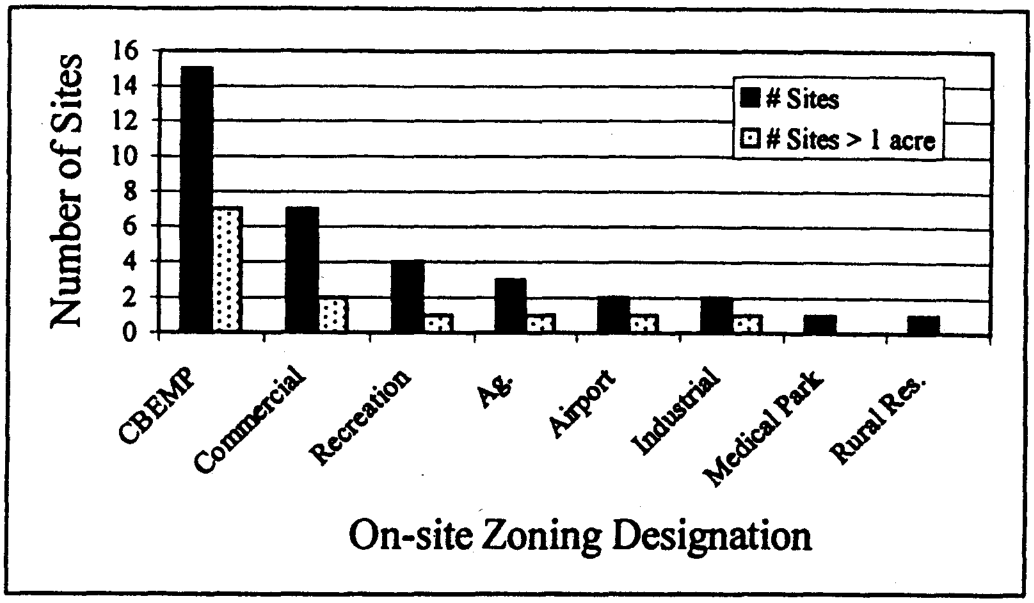


Figure 10. County and city zoning designations for wetland mitigation sites in the Coos Watershed. Ag. is an abbreviation for agriculture; Res. denotes residential. Black bars show the total number of sites, shaded bars indicate sites larger than 1 acre.

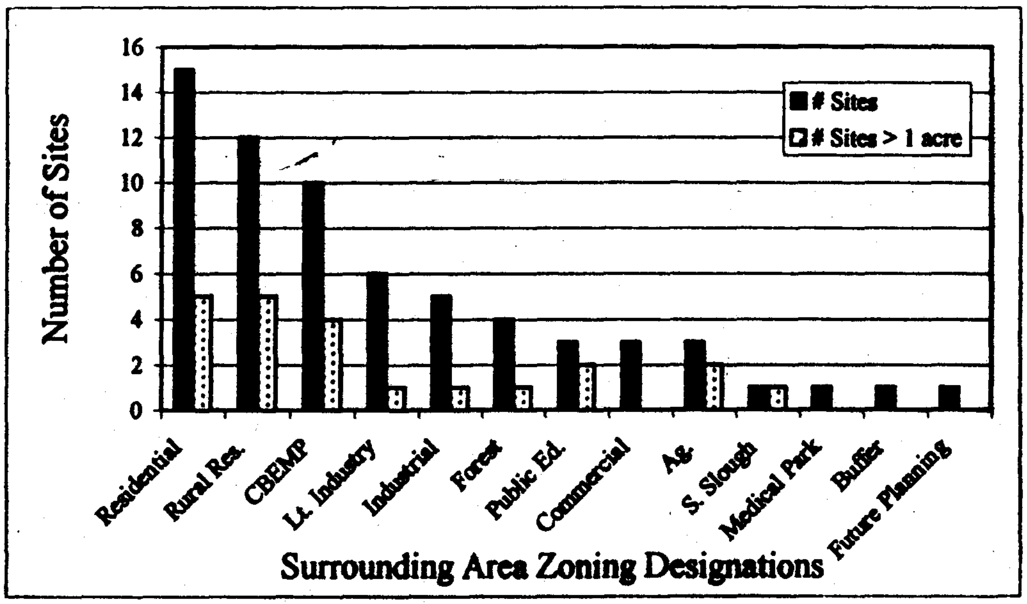


Figure 11. County and city zoning designations within a 0.25-0.5 mile radius of wetland mitigation sites in the Coos Watershed. Ag. is an abbreviation for agriculture; Res. denotes residential; Lt. is light; Ed. abbreviates education. Black bars show the total number of sites, shaded bars indicate sites larger than 1 acre.

Fifteen sites were located near residential areas (See Figure 11). Rural residential zones occurred near 12 WCM sites. Other common nearby zoning categories include CBEMP (10), Light Industry (6), Industrial (5), Forest (4), Public Education (3), Commercial (3), and Agriculture (3). South Slough, Medical Park, Buffer, and Future Planning had a single WCM site near each of these zones. For WCM sites larger than 1 acre in size, Residential and Rural Residential zones were located near five sites in each category. Four large WCM sites occurred near a CBEMP zone. No larger sized WCM sites are located near Commercial, Medical Park, Buffer, or Future Planning zones in this study.

Acreage Calculations

Although acreage impacts have been represented graphically in Figures 5, 6, and 7, tables 4 and 5 have been generated to quickly summarize acreage results. Both depict a habitat summary for wetland acreage impacts and WCM in the Coos Watershed. The riverine shore acreage impacted was for only one project and no projected impact size was given in the original permit. However, during my site visit, I compared the size of the bridge construction impact to that of the WCM site. The impacted wetland was at or slightly below the size of the mitigation. Table 4 summarizes the results for all wetland impacts and WCM projects. Overall, my calculations show a gain of 205.6 acres of wetland in the Coos Watershed -- most of this scrub/shrub wetland. Subtidal mudflat (-24.3 acres) and estuarine sand beach (-18.0 acres) habitats incurred the greatest losses. After removing the Henderson Marsh related projects from the analysis (Table 5), the watershed realized a total gain of only 30.1 acres. These acreage gains were mainly salt

Table 4. Summary of sites and acreages impacted (IMP) and mitigated (MIT) in the Coos Watershed 1982 to 1997 (with Henderson Marsh).

Wetland Type	Number of Wetlands IMP	Number of Wetlands MIT	Area (acres) IMP	Area (acres) MIT	Area Change (acres)
Salt Marsh (no differentiation)	7	7	30.28	36.239	5.959
Low Salt Marsh	1	5	0.42	6.135	5.715
High Salt Marsh	4	9	0.938	10.724	9.786
Total Salt Marsh	*12*	*21*	*31.638*	*53.098*	*21.46*
Intertidal Mudflat	12	7	27.398	23.574	-3.824
Estuarine Rocky Shore	1	0	1.17	0	-1.17
Estuarine Sand Beach	5	4	19.585	1.543	-18.042
Eelgrass Beds	4	2	7.385	8.5	1.115
Subtidal Mudflat	9	1	24.885	0.629	-24.256
Freshwater Marsh	8	6	5.794	16.982	11.188
Forested Wetland	1	0	0.64	0	-0.64
Scrub/Shrub Wetland	7	6	131.63	323.29	191.66
Pond	2	8	0.86	28.147	27.287
Riverine Bottom	3	3	0.174	0.507	0.333
Riverine Shore	1	1		0.49	0.49
TOTALS	**65**	**59**	**251.159**	**456.76**	**205.601**

Table 5. Summary of sites and acreages impacted (IMP) and mitigated (MIT) in the Coos Watershed 1982 to 1997 (without Henderson Marsh).

Wetland Type	Number of Wetlands IMP	Number of Wetlands MIT	Area (acres) IMP	Area (acres) MIT	Area Change (acres)
Salt Marsh (no differentiation)	5	7	20.94	36.239	15.299
Low Salt Marsh	1	4	0.42	4.215	3.795
High Salt Marsh	4	8	0.938	7.752	6.814
Total Salt Marsh	*10*	*19*	*22.298*	*48.206*	*25.908*
Intertidal Mudflat	10	7	4.198	23.574	19.376
Estuarine Rocky Shore	1	0	1.17	0	-1.17
Estuarine Sand Beach	5	4	19.585	1.543	-18.042
Eelgrass Beds	4	2	7.385	8.5	1.115
Subtidal Mudflat	8	1	11.885	0.629	-11.256
Freshwater Marsh	9	5	6.494	18.975	12.481
Forested Wetland	1	0	0.64	0	-0.64
Scrub/Shrub Wetland	4	3	1.23	2.308	1.078
Pond	1	3	0.16	0.617	0.457
Riverine Bottom	3	3	0.174	0.507	0.333
Riverine Shore	1	1		0.49	0.49
TOTALS	**57**	**48**	**75.219**	**105.349**	**30.13**

marsh (25.9 acres total) and intertidal mudflat (19.4 acres). Subtidal mudflat (-11.3 acres) and estuarine sand beach (-18.0 acres) still suffered the largest losses of habitat acreage.

Table 6 summarizes the average mitigation ratios used throughout the Coos Watershed. On average, creation (1.61 : 1) and restoration (1.19 : 1) projects mitigated more wetland acres than were impacted, and enhancement (2.49 : 1) projects undermitigated lost acres. These ratios are compared to required freshwater wetland mitigation ratios, regardless of the wetland habitat type, for simplification purposes. Overall, approximately 2.03 acres were created, enhanced, or restored through mitigation for ever acre lost to development.

Site Visits

Figure 12 depicts WCM permit compliance in the Coos Watershed for the 35 sites in this study. Twenty-five of the WCM sites complied with all permit requirements, and all 14 sites, those larger than 1 acre, complied with their permit's requirements. Only four sites had absolutely no compliance. Five sites exhibited partial compliance. Those five sites had set no mitigation standards, therefore I could not determine the site's compliance. One site had eroded to such an extent that I was unsure if the permit's standards had ever been met, therefore I left this site's compliance open to interpretation. Erosion may indicate the failure of a site, but part of the WCM's purpose was to reopen a marsh to tidal influence. The eroded tidal channel through the site shows the re-establishment of the historical hydrological regime.

Figure 13 shows the proximities of WCM sites in the Coos Watershed to other WCM sites, natural areas like forests and wetlands, rural or lightly developed areas, and urban or heavily developed areas. Light development includes farms, rural residential

Table 6. Summary of acreage mitigation ratios used throughout the Coos Watershed. Ratios are based on freshwater wetland mitigation requirements.

WCM Type	Average Ratio	Required Ratio
Create	1.61 : 1	1.5 : 1
Enhance	2.49 : 1	3 : 1
Restore	1.19 : 1	1 : 1
Create & Enhance	2.16 : 1	
Create & Restore	0.89 : 1	
Enhance & Restore	1.98 : 1	
Create, Enhance, & Restore	4.49 : 1	
Total Average	*2.03 : 1*	

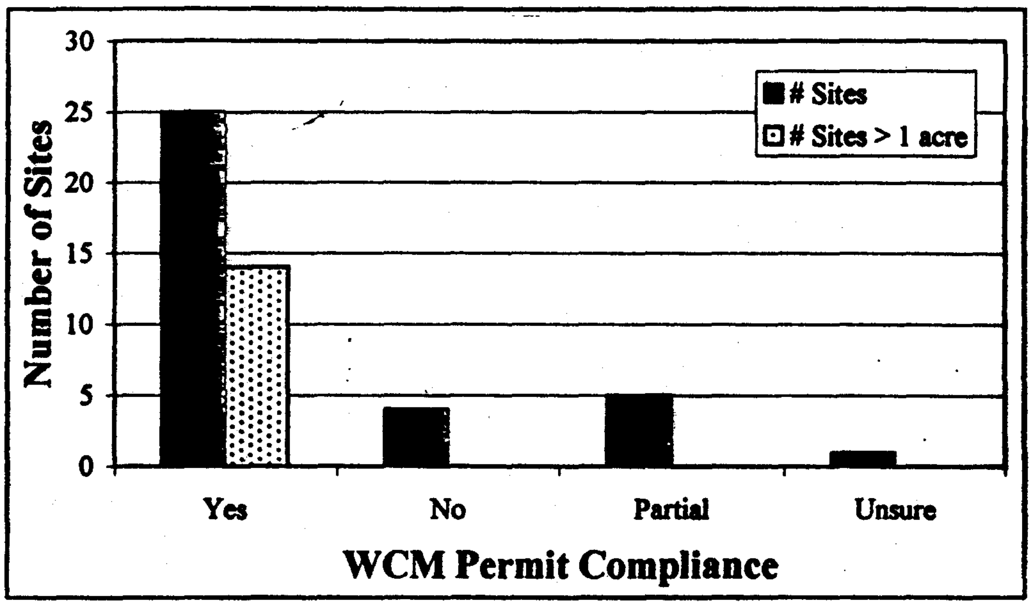


Figure 12. Wetland compensatory mitigation permit compliance in the Coos Watershed. Black bars show the total number of sites, shaded bars indicate sites larger than 1 acre.

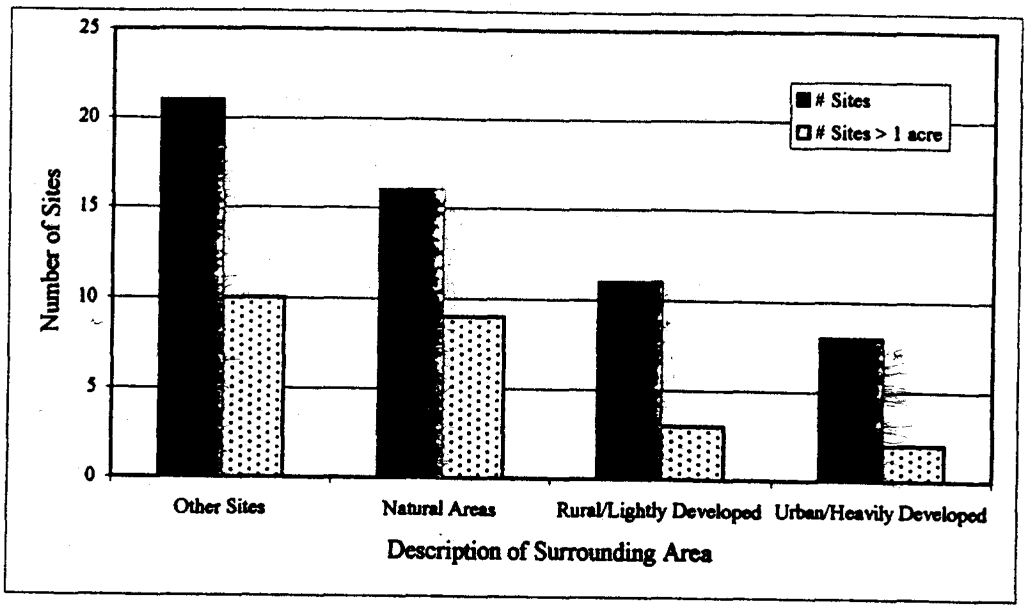


Figure 13. Proximities of wetland mitigation sites in the Coos Watershed to natural areas, lightly developed/rural areas, heavily developed/urban areas, and other sites. Black bars show the total number of sites, shaded bars indicate sites larger than 1 acre.

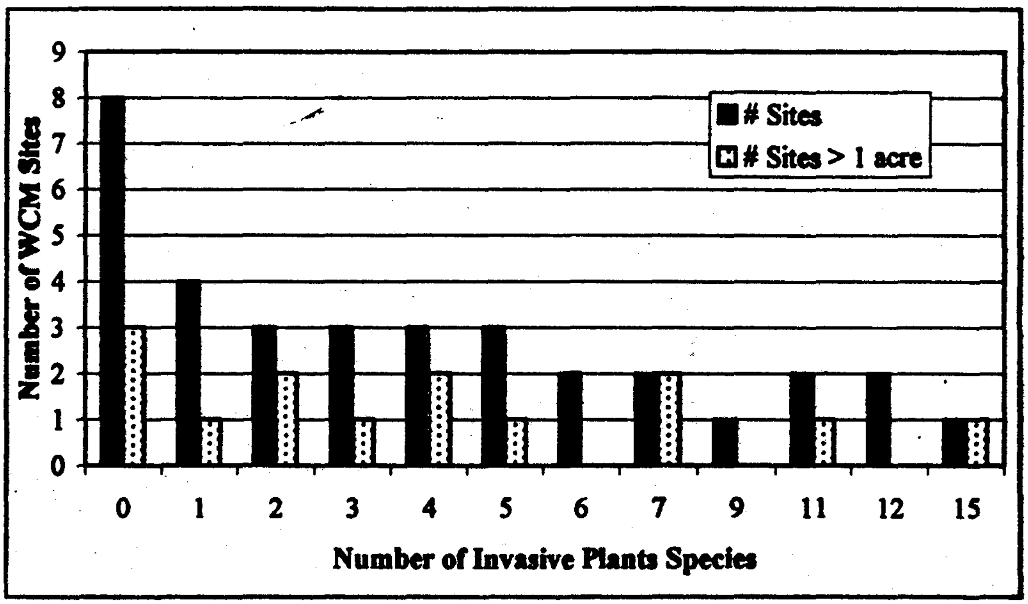


Figure 14. Number of invasive plant species per wetland mitigation site in the Coos Watershed. Black bars show the total number of sites, shaded bars indicate sites larger than 1 acre.

areas, and a few places that were zoned for heavier development but remained relatively undeveloped during the summer of 1998. Twenty-one sites were located adjacent to or within 0.25 miles of another WCM project. Ten of these sites are larger than 1 acre. Sixteen WCM projects occurred near natural areas and 11 are located in rural/lightly developed areas of the watershed. Only eight projects occurred near highly urban/heavily developed areas -- these are all within Coos Bay and North Bend city limits. Of those sites greater than 1 acre in size, nine were located near natural areas, three near rural/lightly developed areas, and two in urban/heavily developed areas in the Coos Watershed.

Introduced Plant Species

Figure 14 depicts the number of invasive plant species per WCM site in the Coos Watershed. I found no invasive plants at eight of the 35 sites. Twenty sites had seven or fewer invasive species. Five WCM supported 9-12 invasive plant species, and at one site I found 15 species. Three of the sites larger than 1 acre had no invasive plants and nine sites had seven species or less. Two large sites contained greater than 11 invasive plant species. The site where I found 15 species was also the largest WCM size.

Figures 15 and 16 (the continuation of Figure 15) show both the percentage of total WCM study sites covered by individual invasive plant species and the average percent coverage per site by individual invasive plant species. Species codes for plants are given in Appendix D. *Cisium vulgare* (CIVU) covered 26% of each of the sites where it was found. *Zostera japonica* (ZOJA) at 22% coverage per sites covered had the second highest coverage on WCM sites, although it was only found on 8% of all sites in the study. *Cystisus scoparius* (CYSC) covered the most number of sites (37%), but only had 2%

predicting the future -- always dangerous -- based on current conditions and practices within the watershed. Unforeseen disasters, such as the *New Carissa* oil spill, could impact WCM sites in ways that turn successes into failures (ex. oil drifting in on a flood tide smothers and kills vegetation on a site). Future construction on or near WCM sites could also precipitate their failure. While on-site analysis of success included measurement of physical parameters and permit checks, it also included subjective judgments of habitat quality and function.

In addition, Mitsh and Wilson (1996) suggest a minimum of 15-20 years of wetland ecosystem development before a final assessment of success can be made on freshwater marsh mitigations and longer periods for coastal wetland WCM sites. Given this view, only one site (#2) would be available during the summer of 1998 for a mitigation success review. Therefore, as time passes each WCM site in this study should be reevaluated to obtain a firmer conclusion of success in the Coos Watershed.

Other points to consider include definitions of success and time constraints. Definitions of what constitutes successful WCM vary widely. The parameters I used to make my assessments may be different from those used by another researcher, although I tried to include parameters used in previous studies whenever possible. Time constraints limited the use of long-term monitoring of various environmental parameters in my assessment. Monitoring would have aided in generating a stronger baseline from which to judge individual site success.

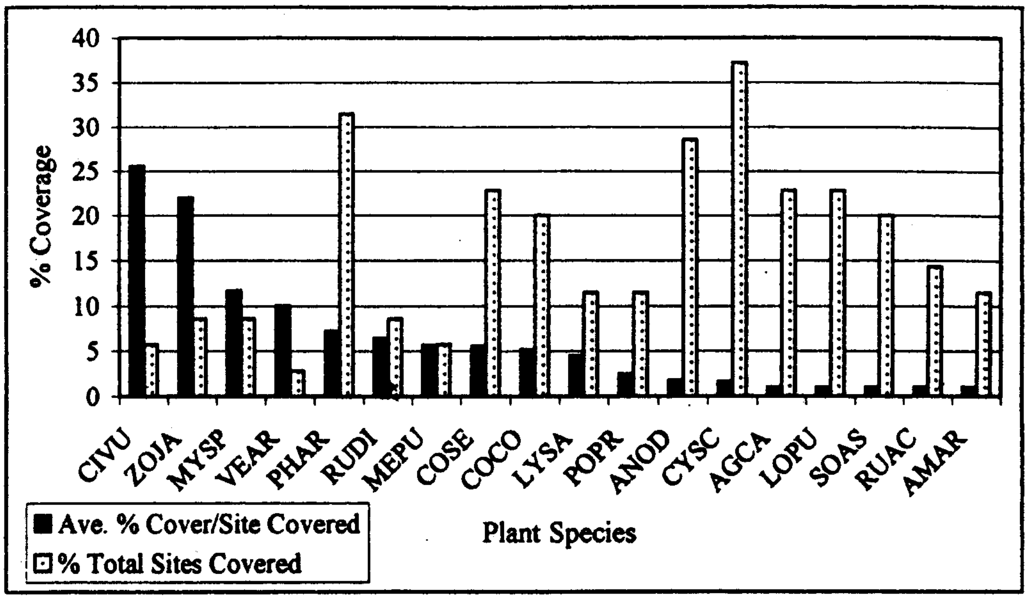


Figure 15. Invasive plant species coverage of wetland mitigation sites in the Coos Watershed. The percentage of total mitigation sites covered by invasive plant species (shaded bars) and the average percent coverage by individual species per site covered (black bars) is depicted. Appendix C contains species codes. See also Figure 16.

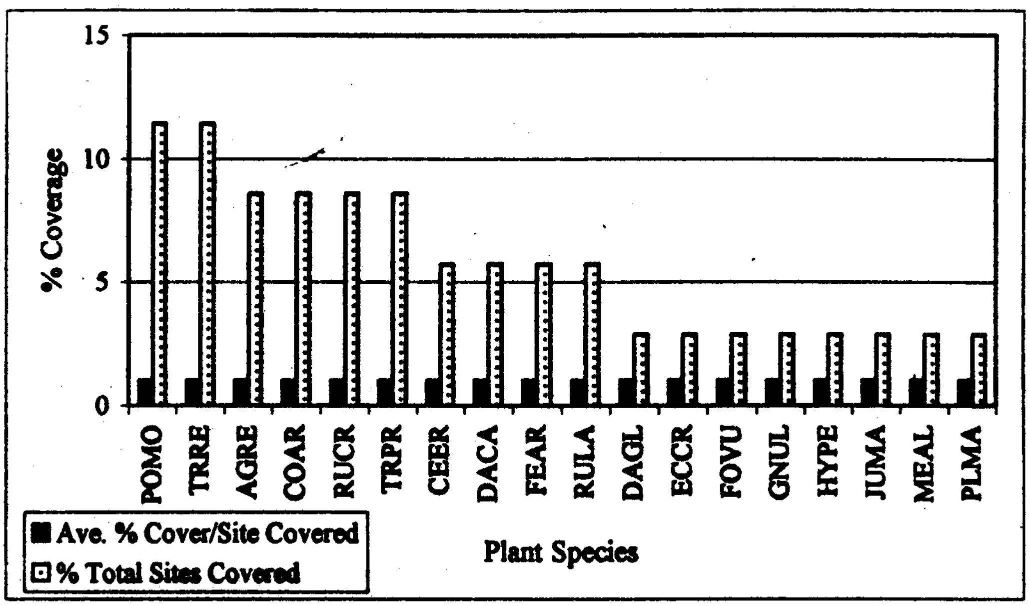


Figure 16. Invasive plant species coverage of wetland mitigation sites in the Coos Watershed (continuation of Figure 15). The percentage of total mitigation sites covered by invasive plant species (shaded bars) and the average percent coverage by individual species per site covered (black bars) is depicted. Appendix C contains species codes.

coverage at those sites. *Pharlaris arundinacea* (PHAR) had the second highest coverage of sites at 32%, but only covered 7% of those sites where it was found. The Coos Watershed has many faunal invaders, but few plant species have gained a roothold in the watershed's wetlands. Colonization and growth for introduced vegetation at WCM sites are limited by the species' tolerance to salinity, temperature, and hydrological changes.

In-Depth Field Reviews

Table 7 summarizes the Shannon-Weiner Diversity Index calculations made on vegetation surveys of three WCM sites and their associated reference marshes. Sites #6 and #19 show an increase in plant diversity since their original creation in 1985 and 1993 respectively. Site #31's enhancement has decreased the marsh's biodiversity by approximately one-third of the original delineation diversity value. As was expected, the biodiversity index values for Metcalf Marsh and the Pony Slough reference marsh were lower than their associated WCM sites at Barview Wayside and Pony Slough. Hidden Creek Marsh, the reference for Day Creek Marsh (site #31), had nearly the same diversity value as the enhanced site. Appendices G and H contain the raw data of these site reviews.

Assessing Success

Figure 17 depicts the results of both the wetland function and long-term viability/watershed function success evaluations. Based on field evaluations, 19 WCM sites demonstrated wetland functional success, three had partial success, and five completely failed. Eight sites were considered incomplete because these WCM projects

Table 7. Summary of Shannon-Weiner Diversity Index calculations for Coos mitigation sites 6, 19, and 31 and their reference marshes.

Study Number	Type of WCM	Diversity Values (H): 1998 WCM Site	1986 Monitoring	1987 Monitoring	1994 Monitoring	1996 Delineation	Reference Marsh
# 6	Creation	0.9828	0.1854	0.1854			0.6463
# 19	Creation	0.9109			0.7908		0.743
# 31	Enhancement	0.8412				1.2038	0.8506

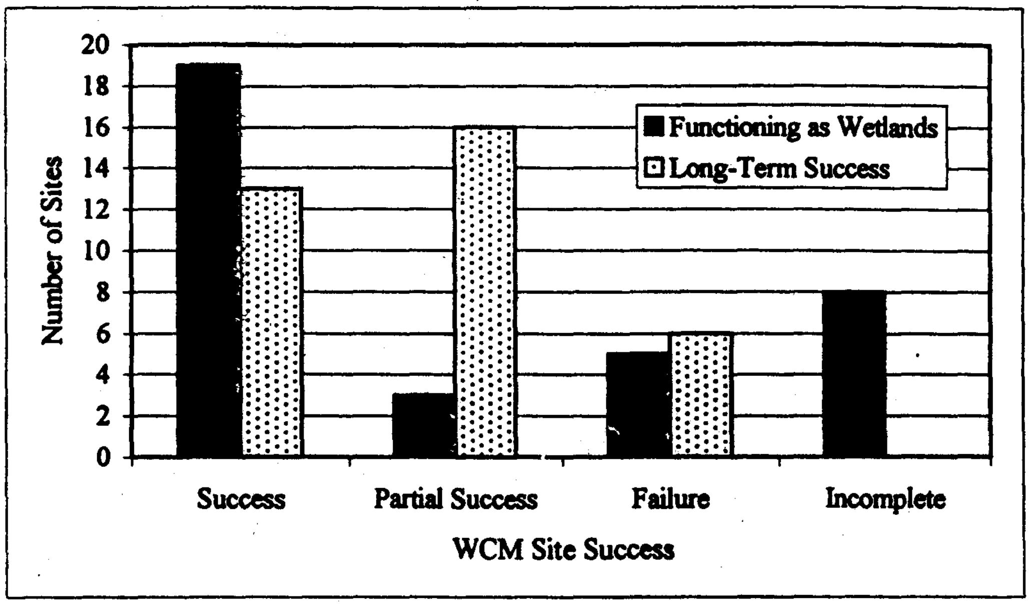


Figure 17. Success of 35 wetland mitigation sites in achieving habitat function and long-term viability/watershed function in the Coos Watershed. Black bars depict current wetland functional success. Shaded bars indicate the potential long-term viability and watershed functional success. Incomplete sites were less than three years old.

Table 8. Long-term viability and watershed function success matrix for 35 sites in the Coos Watershed.

Study Site	Permit Compliance	Within Same Watershed	On-Site	Proximity: Natural Areas	Other Sites
1	yes	no	no	~	yes
2	yes	yes	yes	yes	yes
3	partial	yes	no	yes	no
4	yes	yes	yes	yes	yes
5	yes	yes	yes	~	yes
6	yes	yes	yes	yes	no
7	yes	no	yes	yes	yes
8	yes	yes	yes	yes	yes
9	partial	yes	yes	no	no
10	yes	yes	yes & no	no	no
11	partial	yes	yes	~	yes
12	unsure	yes	yes	yes	yes
13	yes	no	no	~	yes
14	yes	yes	yes	~	yes
15	no	yes	yes	~	yes
16	partial	yes	yes	no	no
17	yes	yes	yes	yes	yes
18	no	no	no	~	yes
19	yes	no	no	~	yes
20	yes	yes	yes	yes	no
21	yes	yes	yes	no	yes
22	partial	no	no	~	no
24	yes	yes	yes	no	yes
25	yes	yes	yes	yes	yes
26	yes	yes	yes	no	yes
27	no	yes	yes & no	no	yes
28	yes	no	no	~	yes
29	yes	no	no	yes	yes
30	yes	no	no	yes	no
31	yes	no	no	yes	no
32	no	yes	yes	no	no
33	yes	yes	yes	yes	no
34	yes	yes & no	yes & no	yes	no
35	yes	yes	yes	yes	no
36	yes	yes	yes	~	no

Table 8. (Continued).

Study Site	Equal Habitat Exchange	Acreage Exchange	Site Size > 1 acre	WCM Ratio Met	Functioning as Wetland	Monitoring Plan
1	no	1.594	yes	yes	yes	no
2	no	-31.693	yes	no	yes	yes
3	partial	-1.764	no	no	yes	yes
4	partial	145.386	yes	partial	yes	yes
5	yes	-0.501	no	no	yes	no
6	partial	0.057	yes	no	yes	yes
7	partial	6.193	yes	no	yes	yes
8	yes	0.906	yes	surpass	yes	no
9	no	0.074	no		yes	no
10	partial	-7.201	no	no	partial	yes
11	partial	-0.079	no	no	no	no
12	partial	0.007	no	surpass	no	no
13	partial	0.31	no	surpass	yes	yes
14	partial	-0.765	no	no	yes	maybe
15	yes	0.002	no		no	no
16	yes	0.05	no	no	no	no
17	yes	0.405	no	yes	partial	no
18	partial	0.541	no	yes	yes	no
19	no	0.02	yes	no	yes	yes
20	no	0.183	no	yes	yes	no
21	yes	0.587	yes	yes	yes	no
22	yes	0.063	no	no	no	no
24	partial	0.677	yes	partial	partial	no
25	yes	38.589	yes	surpass	yes	yes
26	partial	0.411	no	yes	yes	no
27	partial	-0.194	no	no	yes	no
28	yes	1.72	yes	no	yes	no
29	partial	0.131	no	no	yes	no
30	no	23.03	yes	surpass	yes	yes
31	no	3.3	yes	surpass	yes	yes
32	yes	-0.002	no	no	partial	yes
33	partial	13.15	yes	partial	yes	yes
34	partial	-0.051	no	no	yes	yes
35	yes	0.49	no		yes	yes
36	yes	0.3	no	yes	yes	yes

Table 8. (Continued).

Study Site	# Invasive Plant Sp.	Protective Zoning	WCM Type	Score	TOTAL SUCCESS
1	4	yes	Create	5.5	Partial
2	0	yes	Create	8.5	Success
3	0	yes	C & E	2.5	Partial
4	15	maybe	C & E	12	Success
5	3	yes	Restore	6	Partial
6	2	yes	C & E	9.5	Success
7	5	maybe	C & E	9	Success
8	1	no	Create	10	Success
9	5	no	Create	0.5	Partial
10	4	yes	E & R	2.5	Partial
11	0	no	Create	-1	Failure
12	0	no	Restore	5	Partial
13	2	yes	Create	8	Success
14	12	yes	Enhance	3.5	Partial
15	0	no	Enhance	-1.5	Failure
16	0	no	Create	-3	Failure
17	1	yes	Enhance	7.5	Success
18	6	yes	Enhance	1.5	Partial
19	1	yes	Create	5.5	Partial
20	1	yes	Create	6	Partial
21	7	no	Create	8	Success
22	0	yes	Enhance	-4	Failure
24	7	no	C & E	6	Partial
25	3	maybe	C & E	14.5	Success
26	12	no	Enhance	2.5	Partial
27	11	no	C & E	-2	Failure
28	4	yes	Enhance	4	Partial
29	3	no	Restore	2	Partial
30	2	yes	E & R	7	Success
31	0	yes	Enhance	6	Partial
32	3	no	Enhance	-2.5	Failure
33	11	yes	C, E, & R	9.5	Success
34	6	yes	C & R	5.5	Partial
35	9	yes	E & R	7.5	Success
36	5	yes	Enhance	8	Success

had been constructed within the past three years (Sites #29-#36). Only 13 WCM sites gained a high enough score to be labeled as a success when considering all long-term viability/watershed function standards. Sixteen WCM are predicted to be partial successes, and six failed to adequately meet success criteria.

Table 8 depicts the complete matrix for assessing long-term viability and watershed function success. Site #22, an enhancement of 0.1 intertidal mudflat acres in Empire, had the lowest total score of -4. Site #25, a creation/enhancement of about 45 scrub/shrub and lake acres, earned the highest score of 14.5. By long-term viability and watershed function standards, most WCM projects were only partial success. This seems due mainly to a failure of locating WCM projects on-site and/or within the same subbasin or area of the watershed as the impact, and an unequal exchange of habitat type (i.e. creating low salt marsh for lost scrub/shrub wetland).

Summary of Results

1. DSL permitted a total of 251.2 acres of coastal wetland to be impacted in the Coos Watershed. If Henderson Marsh is removed from the analysis, 75.2 acres were permitted. Public bridge construction and commercial and public boat facilities dominated wetland impacts, although all of the largest sites were related to industrial construction.. Most impact sites were less than 1 acre in size.

2. Approximately 456.8 acres were created through wetland mitigation, for a net gain of 205.6 acres. Most of the acreage gains and losses were scrub/shrub wetland in the Henderson Marsh area. Removing Henderson Marsh from the analysis shows that 105.3 acres were created through WCM, for a net gain of 30.1 acres. Estuarine sand beaches suffered the greatest losses and salt marshes earned the largest gains when Henderson

Marsh WCM was not considered. In terms of numbers of sites, intertidal and subtidal mudflats suffered the greatest losses of habitat, and most WCM created salt marsh habitats. On an individual habitat basis, intertidal and subtidal mudflat and estuarine sand beach lost more acres than were gained through WCM. After removing Henderson Marsh WCM acreages, estuarine sand beach and subtidal mudflat lost more acres than were gained through mitigation.

3. Restoration and creation ratios for the Coos Watershed were above the required averages by 0.19 acres and 0.11 acres respectively. Enhancement ratios fell below the required 3 : 1 ratio by 0.51 acres. On average, 2 acres were generated by compensatory mitigation for every impacted wetland acre.

4. Wetland creation, enhancement, or some combination of the two were the most commonly used mitigation methods in the Coos Watershed. Eight sites involved wetland restoration to compensate for impacts, but only three sites used restoration alone.

5. The majority of WCM projects were constructed on-site and within the same watershed subbasin as the impact. In general, a WCM project was most likely to be sited within a CBEMP zone surrounded by residential, rural residential, and CBEMP areas. Sixty percent of all mitigation projects were on, adjacent, or near other WCM projects, 46% were near natural areas, and 31% were located in rural/light development surroundings. Seventy-one percent of WCM sites larger than 1 acre were sited near other WCM project and 64% were close to natural areas.

6. WCM projects in the Coos Watershed demonstrated a 71% permit compliance rate. Only one of the permits reviewed for this study could not be located as it used banked mitigation credits and no location was given. However, the rest of the WCM sites (35 total) were located and had been completed. In effect, this means that all DSL required wetland mitigations projects were completed.

7. Twenty-three percent of all WCM projects showed no biological invasions of plant species. Most sites had less than 5 species total on site. Healthy populations of the endangered plant species, *Cordylanthus maritimus* (saltmarsh bird's beak), were found covering at least 5% of three WCM sites and 5% of the Pony Slough reference marsh. *Limonium californicum* (sea lavender), an uncommon plant species, was found at two WCM sites and Pony Slough reference marsh.

8. At the three sites where a more in-depth review of vegetation occurred, it was subjectively judged that compensatory mitigation was creating equivalent habitat to that lost to development impacts.

9. Nineteen WCM projects currently function successfully as wetlands. Eight are still too new to judge successful at this time. At the watershed scale, 11 WCM were assessed to be successful in terms of long-term viability and functionally replacing lost wetlands within the watershed. Sixteen sites had partial success at the long-term viability/watershed function scale, and six failed completely.

CHAPTER V

DISCUSSION

In my hypothesis, I proposed that current wetland mitigation practices had led to a loss of wetlands within the Coos Watershed, and that this loss had degraded watershed function and connectivity. While acreage has been gained through WCM, certain types of wetland habitats and wetlands in specific subbasins continue to be lost. Throughout the discussion, I compared my results to other Pacific Northwest WCM studies in an attempt to place the Coos Watershed mitigation experience within a Pacific Northwest regional picture. Two major reviews of WCM permits have occurred in this region. Kentula *et al.* (1992a) looked at Section 404 permitting in Washington and Oregon from 1977 to 1986. Coos Watershed WCM projects are included in this permit-only review. Shaich and Franklin (1995) evaluated WCM projects in the Portland Metro area. These researchers review permits issued from 1981 to 1994 in Portland, Oregon and conduct field checks of the mitigated wetlands.

Permit Reviews

As Oregon's population grows, the need for services and infrastructure increases. A review of Portland Metro WCM permits found construction of commercial and industrial building pads and roads to have the greatest number of wetland impacts in that region (Shaich and Franklin 1995). Kentula *et al.* (1992a) also found roads and building pads the most common impacts in a study of Section 404 permitting in Washington and Oregon. Although Portland is a major port on the Pacific Coast, this city is not a coastal community in the sense of North Bend/Coos Bay -- located on the Pacific Ocean. Transportation through the Coos Watershed entails crossing water bodies on a regular basis, especially in the lower watershed. Although public road building ranked higher than other specific impacts, public bridge construction had the greatest impact on wetlands in the Coos Watershed. Boat transportation activities also figured highly in impacting wetlands, as commercial and public boat facilities -- marinas, docks, and boat ramps -- ranked second (Table 3). In the wake of lost timber jobs and money, the region is focusing on attracting tourists and high-tech/light industry business. It is hoped that improving recreational facilities and transportation routes will help draw tourists and business to the region. Commercial and industrial building pad development came in third for wetland impacts. Approximately 83% of DSL permits approved in the Coos Watershed involved wetland filling (Figure 1).

Creation, enhancement, or some combination of the two were the most commonly used methods of WCM in the Coos Watershed (Figure 2). Only three of 35 sites were restored wetlands, and five sites included restoration in addition to enhancement, creation, or both. Wetland creation remains an unpredictable experience. It is not just a matter of turning on the water. For example, researchers in southern California have shown that if one habitat parameter is not working sufficiently -- soil fertility, pollination, adequate inundation -- the wetland will not function properly (Pacific Estuarine Research Laboratory 1990, Zedler and Powell 1993). Enhancement of existing wetland habitat in exchange for impacted wetlands will always result in a net loss of acreage and function.

Enhanced wetland acres were not figured into my results as lost acres, as they are considered a legitimate form of WCM and, in some cases, it was impossible to separate enhanced acreage from created acreage at a site. However, the number of WCM projects involving enhancement suggests that the Coos Watershed may be experiencing wetland losses.

Shaich and Franklin (1995) found similar results in Portland, where creation and enhancement of wetlands are used equally throughout the region, and restoration is not used as a mitigation method. While Shaich and Franklin (1995) propose no explanations for the lack of restoration in the Portland Metro region, such as the availability of few wetlands to restore, it seems odd that few restoration projects have been attempted in the Coos Watershed. Diked wetlands are a common sight throughout the watershed. Wetland restoration for WCM can involve 1 : 3-4 trades -- a gain of wetland acreage often overlooked by critics of WCM. Restoration of diked wetlands contributes to the recovery of historically lost wetlands. A minimal restoration project could involve removing the dike to promote tidal inundation of the site and allowing natural colonization of vegetation from old seed banks and wind or water carried seeds. This type of restoration project allows natural ecological processes to do most of the work, thus decreasing the potential for error in recreating ecosystems that are not fully understood. Dike removal restoration has been done at SSNERR and at WCM sites 5, 12, 29, and 30 (Rumrill and Cornu 1993, 1995). The fact that much of the diked land in the Coos Watershed is owned by small landowners, wary of government interference, and used as soggy animal pasture probably prevents more extensive restoration (Donnelly 1996).

Intertidal and subtidal mudflat habitats sustained the most impacts in terms of site numbers, but freshwater scrub/shrub wetlands lost the greatest number of acres (Figures 3 and 4). Salt marshes followed in both categories. Kentula *et al.* (1992a) found that freshwater marshes suffered the most impacts in terms of sites and acreage in Oregon, and greatest acreage impact in Washington during their review of Section 404 permitting throughout these states. Intertidal and subtidal mudflats placed second in numbers and acres of wetlands impacted in Oregon (Figures 5, 6, and 7). Like the Coos Watershed, Washington's intertidal and subtidal mudflats were the most impacted sites and second-most impacted acreage (Kentula *et al.* 1992a). The Coos Watershed probably has more mudflat than freshwater marsh acres and sites impacted than the rest of Oregon because residential, commercial, and industrial development within the watershed is centered around the estuary, not in the deflation plain or upper watershed where most freshwater wetlands may be found. The Washington state results may be due to a concentration of wetland impacts and mitigation on estuarine habitats in Grays Harbor and Puget Sound (Kentula *et al.* 1992a).

Most WCM sites in the Coos Watershed involved salt marshes. Freshwater pond creation was the second most common type of WCM. In terms of acreage, though, more scrub/shrub wetlands were created and enhanced than all other wetland acres put together. The majority of scrub/shrub wetland mitigation occurred in Henderson Marsh, where large parcels of this wetland habitat type can be found (NWI 1989). Salt marsh habitat had the second highest amount of WCM acreage mitigated, followed by freshwater ponds. DSL currently encourages WCM on salt marsh due to past losses of this habitat in the watershed (McCabe 1998, personal communication). Kentula *et al.* (1992a) discovered that WCM projects in Washington and Oregon created more freshwater marsh, than salt marsh acreage. The Portland Metro study reports that pond creation constituted most WCM in that region, followed by freshwater marsh, even though few wetland impacts affected freshwater ponds (Shaich and Franklin 1995).

In general, 66% of WCM projects within the Coos Watershed occurred on-site and within the same watershed as the permitted wetland impact (Figures 8 and 9). On-site WCM is usually encouraged if it is possible. This is important, as the Coos sites that failed in long-term viability/watershed function success were also likely to be located off site and outside the watershed subbasin as the original impact. My judgment in this study assumes that removing a wetland from one subbasin and mitigating for the loss in another subbasin within the same watershed causes some loss of watershed hydrological and biological connectivity and function. This judgment is questionable, however, if the WCM project created on-site is small and isolated. Such sites serve little purpose in maintaining watershed integrity.

The Portland Metro study reported a 92% rate of on-site mitigation (Shaich and Franklin 1995). There are several potential reasons for this difference between Portland and the Coos Watershed. Development projects within the Coos Watershed do not always occur in areas where there is room for WCM projects on site. For example, any development on the Coos Bay waterfront requires mitigation, as the waterfront is built on former mudflat and low salt marsh habitat. This area receives high use as a port/marina. Placing WCM wetlands on the city's waterfront would hinder boat traffic, so developers must look elsewhere to conduct WCM projects.

Historic losses of tidal wetlands have given these habitats a unique and desirable status in the Coos Watershed (Cortright *et al.* 1987, McCabe 1998 personal communication). Many diked marshes exist within the watershed where it is relatively easy to create, enhance, and/or restore salt marsh. It may be easier for a developer to mitigate elsewhere in the watershed on tidal wetlands, if land surrounding an impact is already protected habitat, or is owned by landowners unwilling to sell or dedicate property to WCM. Differences in DSL permit reviewer methods could account for this difference as well. Rather than create small, isolated wetlands on-site, a reviewer may consider the mitigation of larger wetland parcels off site more desirable. Other DSL permit reviewers may approve a permit only if WCM is completed on the same site as the wetland impact.

Zoning

Examinations of zoning have not been a standard practice of WCM evaluations to date. I choose to look at zoning as a way of assessing current and future local impacts to compensatory mitigation sites in the Coos Watershed. Urban density in the watershed is increasing . A few tracts of open land still exist within the Coos Bay/North Bend urban growth boundary, but these areas shrink as population growth and accompanying residential, commercial, and industrial development eat into these vacant lots. For example, a spurt of construction in the Upper Pony Slough subbasin has built dentist and doctor offices in freshwater marshes zoned for a medical park. New ballfields at Southwestern Oregon Community College occupy former forested wetlands that children once used as a wooded neighborhood playground.

Twelve WCM projects are located within city limits, mostly in empty, commercially zoned lots surrounded by residences (Figure 10). While WCM sites may be protected from future impacts, surrounding land is fair game to developers. These small, isolated wetland habitats left to languish in urbanized areas are often called postage stamp wetlands with good reason. Parking lot runoff, trash, residential runoff (ex. pesticides applied to keep out dandelions), domestic animals, and city streets isolate and impact the flora, fauna, and hydrology found on WCM sites within the urban growth boundary. Heavy development of surrounding areas serves to isolate and impact these sites further. Is it worthwhile to place WCM projects on-site if they will eventually be surrounded by parking lots, office buildings, and streets? Locating WCM projects adjacent to or within protected open space, such as a park, could prove a better alternative. While this may decrease some watershed function now, it could increase long-term viability and watershed function for the future.

Sixty-six percent of WCM projects were located in natural and rural/lightly developed areas, and 65% of these sites fell within CBEMP zones (Figure 12). These projects were most likely to be surrounded by CBEMP and rural residential zones as well. CBEMP zoning designations include both natural and conservation areas and water dependent industrial/commercial use in the Coos Estuary because of the estuary's deep-draft development designation (Cortright *et al.* 1987). However, when Coos County determined wetland mitigation locations while creating the Coos Bay estuary management plan, they placed most potential WCM sites in CBEMP natural or conservation management areas (Coos Planning Department 1982, Cortright *et al.* 1987). The CBEMP zoned areas containing WCM sites should be well protected from future development.

WCM projects in agricultural and rural residential areas should receive similar protection. Despite a heavy focus on attracting industry to bolster a sagging economy, Coos County is attempting to protect the presence of agriculture by zoning large areas exclusive farmland and low density, rural residential. Although this does not protect WCM sites from agricultural runoff impacts, it does ensure some long-term connectivity between the site and natural areas like forests and other wetlands.

Acreage Calculations

The greatest acreage losses in the Coos Watershed were of subtidal mudflat and estuarine sand beach (Tables 4 and 5). Both the Portland Metro and Oregon/Washington studies found freshwater marsh habitat to have suffered the most losses (Kentula *et al.* 1992a, Shaich and Franklin 1995). Again, I believe this difference stems from local conditions of geography -- the heaviest development in the Coos Watershed surrounds the estuary. Freshwater wetlands near the estuary were filled prior to the federal Clean Water Act and Oregon's Removal-Fill Law. Remaining areas are not extensive. While some of Kentula *et al.*'s (1992a) WCM study sites were in estuarine areas (Coos Bay, Oregon, Puget Sound, and Grays Harbor, Washington), most were located away from tidally influenced wetlands. None of the Portland Metro WCM sites were tidally influenced (Shaich and Franklin 1995).

Since most development impacting wetlands in the Coos Watershed involves bridge and boat facility construction, these acreage losses of subtidal mudflat and estuarine sand beach should not be surprising. Subtidal mudflats are dredged to provide deeper boat channels and marinas. Three of the estuarine sand beaches impacted in this study were filled to build boat ramps, one filled for bridge construction, and another filled for the North Bend Airport. WCM is required for fills the size of airports and boat ramps, but bridge work is viewed by many regulators to impact very small wetland areas. Regulators typically do not require mitigation for bridge work. However, mitigation for bridge construction in the Coos Watershed is seen as a best management practice that generates bonus wetland acreage for the region (McCabe 1998, personal communication).

Sixteen wetland impact sites (46%) in the Coos Watershed were greater than 1 acre in size, but only 14 WCM sites (40%) were larger than 1 acre in size. Like the high use of enhancement, the ratio of large impact to WCM sites would seem to indicate that wetland acreage is being lost. Many WCM projects, however, created more acreage than was necessary to replace the impacted wetland acres. For example, Ocean Terminals impacted 5.5 acres, but restored/enhanced about 28 acres (site #30).

Average mitigation ratios for all sites show that for every acre lost, 2.03 are gained through mitigation (Table 6). This figure contains enhanced wetland acreage and includes 0 ratios. A 0 ratio was given to WCM sites in cases where the impact size was not given. The real ratio is higher, and may be at or above the required mitigation ratio. I added 0 ratios into the total average ratio, so the real average could be higher. Enhancing wetlands causes a lose-lose situation. Wetland habitat is lost to development, and no new acreage is gained through restoration or creation. Habitats currently functioning as healthy wetlands are planted with native vegetation or ponds are dug into scrub/shrub wetlands to attract more ducks (and hunters). In addition, enhancement ratios fell 0.5 acres below the DSL acreage ratio requirement. The inclusion of enhancement ratios in the total acreage may falsely raise the mitigation ratio. Restoration and creation ratios are above those required by DSL, even with 0 ratio values added in. Estuarine mitigation ratio comparisons are inaccurate because I used freshwater mitigation ratio requirements. Freshwater mitigation ratios only account for acreage and mitigation method. For estuarine WCM in Oregon, a special calculation that accounts for habitat type, acreage, and mitigation method is used to calculate ratios (Hamilton 1984). I used the freshwater ratios to simplify comparisons because WCM sites often had more than one type of mitigation and habitat, and no clear description of how each habitat had been mitigated.

The Washington/Oregon and Portland Metro studies report a net loss of wetland acreage in their permit reviews (Kentula *et al.* 1992a, Shaich and Franklin 1995). While mitigation ratios were not calculated, this finding indicates a $X < 1 : 1$ ratio, where X is the number of created wetland acres. Coos Watershed mitigation appears to be doing better than other Pacific Northwest areas reported on in these studies. However, some scientists suggest that a mitigation ratio of 10 : 1, in addition to adaptive management, will ensure improvement of the mitigation process (Zedler and Powell 1993). An increase in required mitigation ratios in the Coos Watershed would, at the least, prevent further losses of wetlands and could help to reverse past losses of watershed function. Given the current political climate of the region, mitigation ratio increases are unlikely to occur.

I would like to reiterate that all of my acreage calculations are subject to error. As reported in Chapter III, the digitizing program calculates acreages for those areas outlined by hand on the digitizing board. A small slip while tracing boundaries can add or subtract a 100 $ft.^2$ or more when outlining on air photos at a scale of 1 : 12,000. Small slips may even out on large sites, but on sites as small as 200 $ft.^2$, a slip can make a huge difference in an acreage calculation. Also, I calculated only acreage for WCM sites, not wetland impacts. Actual wetland impacts may be smaller or larger than those stated in the permit. Differences between proposed and as-built WCM site sizes show that acreage changes between a paper plan and on the ground construction. Why should the impact experience be different? A better comparison would look at both wetland impact and mitigation acreages measured with the digitizer. Finally, I included enhanced acres in the calculations as gained acreage, even though this mitigation practice essentially promotes a net loss of wetland habitat.

Site Visits

Coos Watershed mitigations seem to have a better record of permit compliance than Portland, OR. Seventy-one percent of all WCM, and 100% of all WCM larger than 1 acre, complied with DSL permit requirements in the Coos Watershed (Figure 13). I assessed 14% of sites to have partial rather than no compliance, as no goals or objectives for vegetation, elevation, hydrology, monitoring, or general success standards had been stated. These sites function as wetlands, but without measurable standards, I had difficulty in assessing compliance. Shaich and Franklin (1995) divided and examined permit compliance in seven categories -- including hydrology, construction timing, buffers, and vegetation. Overall, the Portland Metro projects averaged a total 51% compliance rate.

My data may have been more comparable if I had broken compliance into separate categories to review in the field. There may have been more non-compliance at older WCM sites, but because the wetlands have had enough time to establish I was unable to detect non-compliance. It was also more difficult to assess permit compliance on large sites, like those in Henderson Marsh. Dense vegetation and/or site size often prevented me from walking the entire site during a field survey. Still, the majority of WCM projects met all required DSL permit parameters. This ensures some measure of wetland function and long-term viability/watershed function success.

A review of WCM site location in relation to other WCM sites, natural areas, and development in the Coos Watershed revealed that 60% of mitigation projects were located on or adjacent to another site, 46% in natural areas, and 31% in rural/lightly developed regions. While such placement does not guarantee WCM success, it does provide connections to other wetlands and natural habitats within the watershed and allows for greater movement of water and organisms between areas. Urbanization impacts are lessened too. As I mentioned before, other than in passing, previous studies have not accounted for the effects of land use and zoning surrounding WCM sites.

Introduced Plant Species

The Coos Watershed has been heavily impacted by industrial, residential, and agricultural development. Disturbed habitat creates open space for invasion by both native and non-native plants or animals. However, non-native species displace the native flora and fauna and change the structure of local natural communities. Evidence suggests that invaders then alter the disturbance regimes and promote more non-native invasions (Carlton and Geller 1993, Mack and D'Antonio 1998). Eventually, this will have huge impacts on landscape structure, composition, and function. Researchers have documented marine and estuarine invasions of invertebrates and algae in the Coos Estuary by intentional releases, commerce, aquaculture, ballast water, and ship hull transport (Carlton 1995, Carlton and Geller 1993). I found evidence or witnessed invasive organisms -- mink, Great Basin Canada geese, Pacific oysters -- at several WCM sites. Although I did not sample benthic invertebrates, the greatest number of introduced species might be located in the mud, sand, and soil of the Coos Watershed's wetlands. Many of these non-native species were introduced through the methods mentioned above and described in greater detail below.

Mink and Great Basin Canada geese were intentional releases (ODF released the geese) designed to attract hunters. Mink feed on bird eggs, and the geese consume food that might otherwise go to local bird species. Pacific oysters (*Crassostrea gigas*) were brought in through aquaculture. Their introduction has affected native oysters (*Ostrea lurida*) and native eelgrass beds. *C. gigas* takes up space and food that would normally be used by the *O. lurida*. In addition, *Ceratostoma inornatum* (Japanese oyster drill) and *Zostera japonica* (Japanese eelgrass) were attached to the Pacific oysters in their shipping containers (Baker 1995, Couch and Hassler 1989). These species were also released when the oyster spat was put out by oystermen to grow. *Z. japonica* competes for space with the native *Z. marina* and *C. inornatum* feeds selectively on the rare, native oyster *Ostrea lurida* (Baker 1995, Couch and Hassler 1989).

Ships bring in a number of invertebrates and fish to Coos Bay. Some, like sponges and worms, may hitch a ride on a ship's hull from one port to the next. For example, a worm may settle on the hull of a chip transport ship in Japan and travel across the Pacific Ocean to Coos Bay, where it releases fertilized eggs or larvae into the water. The worm could also drop off the hull and take up a new residence on another boat, the pier, or in a nearby mudflat.

Ballast water has transported over 367 species of marine and estuarine organisms into Coos Bay (Carlton and Geller 1993). Empty transport ships take up ballast water for stabilization purposes in Japanese estuaries. The ballast water contains the fertilized eggs, larvae, and seeds of aquatic species, and the oceanic voyage is so short that many of the aquatic organisms survive. This ballast water gets dumped into Coos Bay before wood chips or logs are loaded onto the ships for the return trip to Japan. The released aquatic organisms encounter a habitat similar to what they left behind in Japan. If conditions are good (i.e. food, space, and mating partners are readily available, with low competition for resources) the organism will thrive. While researchers have only begun to document such impacts, many suspect that non-native invasions have restructured the Coos Estuary's ecosystem (Carlton 1993, Carlton and Geller 1993, Graybill 1996).

In this study, however, I focused on vegetation as a way to assess the health and success of creating/restoring/enhancing a wetland habitat with compensatory mitigation and one aspect of determining the WCM success in contributing to watershed functional success. The results of a faunal invasion study could show a different picture. Carlton and Geller (1993) document the average load of new species arriving by ship to the Coos Estuary. Not all may survive, but a number have. Non-native green crabs (*Carcinus maenus*) have recently been reported in the estuary. While vegetation remains a good indicator of primary production, hydrology and soils, a WCM site's fauna aid in describing food webs and ecological processes. A more thorough study would look at non-vegetative species composition, in addition to vegetation.

While a few invasive plant species were obvious in the field, like purple loosestrife (*Lythrum salicaria*) and Scot's broom (*Cystisus scoparius*), I did not classify other plant species as non-native until I looked up their origins in the USACE wetland delineation manual (Reed 1989, 1993). I expected there to be some invasion at all WCM sites, but eight sites contained no invasive vegetation (Figures 15 and 16). Most sites supported one to seven non-native plants in small populations of less than 5% coverage per site covered. The site sustaining the greatest number of invasive plants was also the largest, but most of the WCM projects more than 1 acre in size had low numbers of non-native plant species. Freshwater WCM wetlands in the Upper Pony Slough and Barview Wayside (site # 14) will likely be invaded by *L. salicaria* by the summer of 1999, as surrounding wetlands were clogged with the plant's purple blossoms in the summer of 1998.

Neither Kentula *et al.* (1992a) or Shaich and Franklin (1995) discuss biological invasions of non-native flora or fauna in their WCM permit studies. However, an Ohio study comparing mitigated wetland function to natural wetland habitat found a significant decrease in native plant diversity associated with WCM projects in the early stages of their development (Fennessy and Roehrs 1997). They found no difference in species richness between natural and mitigated wetlands, and concluded that non-native plants were displacing native vegetation. Certainly, non-native plants and animals displace less competitive native species. Human disturbance, like wetland mitigation, opens space up for non-native invasives to establish and thrive. However, abiotic conditions like salinity gradients and hydrology place restrictions on which species will be able to colonize a wetland habitat in the Coos Watershed.

Most WCM in the Coos Watershed created estuarine wetland habitats, thus limiting invasions from upland and salt intolerant vegetation. Currently, only two species, *Zostera japonica* (Japanese eelgrass) and *Cotula coronpofila* (brass buttons), colonize and thrive in the estuarine conditions of Coos Bay. Both are specific to low marsh and mudflat habitats. *Spartina alterniflora* (smooth cordgrass), an Atlantic coast native, could also do well in the Coos Estuary, but it has not yet reached the area. Other invasive plant species, usually found in uplands or freshwater wetlands may colonize upper salt marsh elevations, but such vegetation is limited by tidal inundation and a lack of freshwater influences.

The invasive plants having the greatest coverage at a site most often covered the fewest sites. The WCM sites in this study consisted of both estuarine and freshwater habitats, and within the estuarine sites salinity varied with local hydrological scheme and elevation. Plants like *Z. japonica* (ZOJA) only grow on lower intertidal and subtidal mudflats. At the 8% of WCM sites *Z. japonica* colonized, it covered an average 22% of available space. *Cisium vulgare* (CIVU - bull thistle) an upland plant covered about 25% of the sites it invaded, but water and salinity probably prevented the species from invading more than 6% of all study sites. *C. scoparius* (CYSC - Scot's broom), *Phalaris arundinacea* (PHAR - reed canary grass), and *Anthoxanthum odoratum* (ANOD - sweet vernal grass) each colonized more than 25% of WCM sites in my study, but covered less than 10% of each site they on which they were found. Again, this is likely due to individual species tolerance for water inundation and salinity. *C. scoparius* is primarily an upland species and prefers drier habitats. *A. odoratum*, a pasture grass, is a facultative upland species, while *P. arundinacea* is a facultative wetland plant. *A. odoratum* may occasionally colonize drier, freshwater influenced wetland habitats. *P. arundinacea* can tolerate wetter habitats, but saltwater prevents extensive colonization of estuarine areas.

WCM will continue to provide open space for invasions of non-native vegetation. Currently, most wetland impact permits do not provide measures for invasive removal from WCM sites. Hand-pulling remains costly and bulldozing to remove vegetation could potentially cause more harm than good. Invasions of *L. salicaria*, *C. scoparius*, and *P. arundinacea* can take over a site and crowd out other species. Deliberate plantings of native wetland species help, but plantings can still fail if non-natives are very competitive or if a physical (i.e. hydrology) or biotic (i.e. bacterial symbiosis) requirement remains unmet by the mitigation. An invasive plant removal protocol should be developed in order to prevent the production of weed seed banks for *L. salicaria*, *C. scoparius*, and *P. arundinacea* -- at the least -- on WCM sites. Non-native species will continue to invade the Coos Watershed, but wetland mitigation should not provide colonization space.

In-Depth Field Reviews

In-depth field reviews were intended to provide greater insight into the question of whether WCM projects created wetland habitat equivalent to natural wetlands in the Coos Watershed (Table 7). I also looked at changes in plant species richness as sites aged. Sites #6 (Pony Slough) and #19 (Barview Wayside), both created wetlands, showed greater species richness than their reference marsh counterparts. The Ohio study found non-native plant species replacing native vegetation on WCM sites (Fennessy and Roehrs 1997). At site #6, some of the differences in species richness could be attributed to the presence of non-native vegetation and marine algal species. However, only two of the species found on the reference marsh, which contained a native plant assemblage, were absent from the WCM. Both sites contained the endangered species *C. maritimus* (salt marsh bird's beak) and rare *L. californicum* (sea lavender). Species richness differences between site #19 and Metcalf Marsh, its reference habitat, are due mainly to the freshwater influences at the WCM site. Metcalf Marsh is completely saltmarsh, while upland runoff drains into Barview Wayside. The runoff creates a microhabitat of freshwater emergent marsh on the upland edge of site #19's salt marsh.

Site #31, the Day Creek Marsh enhancement, has nearly the same species richness as its reference wetland, Hidden Creek Marsh, even though I found that the sites shared only nine species. This might suggest that non-native vegetation is replacing native plants, or it could be a chance event. However, the WCM site supported only native plants and the reference marsh contained one invasive species. The Day Creek Marsh mitigation was only a year old at the time of my review. Since the mitigation involved removing a broken tide gate to enhance the flow of estuary water on the marsh, vegetation changes should be slow as the marsh was covered by well-established vegetation when enhancement occurred. In addition, the vegetative composition of Day Creek Marsh contains both freshwater and estuarine species, as the hydrology of the marsh is changing from freshwater domination to estuarine. The reference marsh at Hidden Creek contains only estuarine marsh plant species. Over time, the WCM project may come to have a similar vegetation species composition as the reference marsh.

From these three comparisons it remains difficult to ascertain whether or not WCM is creating wetland habitat equivalent to natural wetlands in the Coos Watershed. Pony Slough (site #6), the oldest WCM, has a slightly more diverse assemblage of plant species than its reference marsh, but the presence of non-natives did not preclude the establishment of *C. maritimus* or *L. californicum*. Barview Wayside's freshwater microhabitat allowed for greater diversity at the expense of creating more salt marsh habitat. However, the site seems to function successfully as a wetland. Day Creek is still too new to judge, but this WCM project was an enhancement of a previously established wetland. One could argue that the marsh was already the equivalent of a natural wetland. Based on these three assessments, I would have to conclude that WCM in the Coos Watershed is creating equivalent habitat. However, this subjective assessment is only for these three sites and should not necessarily be extended to cover all WCM projects in the Coos Watershed.

As predicted by Kentula et al. (1992b), species diversity increased as WCM sites #6 and # 19 aged. Both sites were wetlands created through mitigation. Colonization of vegetation other than that planted on-site was expected. WCM site #31 lost one-fourth of the original vegetation diversity after enhancement. There are a couple of possible explanations. Opening the tidegate increased saltwater intrusion into the marsh. This would cause natural extinctions of plant species which cannot tolerate or adapt to higher salinities. My field survey may not have found and correctly identified all the plant species existing at the Day Creek site. The delineation survey that I used to calculate pre-enhancement diversity was conducted in April. I conducted my survey in August. Some of the species found growing and dominating the marsh in April may have senesced by August. Also, many of the species I used to calculate species richness for the delineation were not specifically mentioned as covering quadrats in the transect survey. The species were taken from a plant list of South Slough vegetation and were suspected to grow on Day Creek Marsh. I used this list to fill in gaps left by the delineation survey.

Success

Measuring the success of wetland mitigation will always be a subjective process, as assessments depend on spatial and temporal scales, local conditions, WCM project goals and objectives, and the expertise of the person making the judgment. Wetland compensatory mitigation is a relatively new environmental science. The earliest developed WCM projects are just now becoming available to researchers and project designers for review of site monitoring plans, construction methods, and comparisons of success. A few studies have been published reviewing WCM projects in places such as Florida, Oregon, Washington, and Ohio (Erwin 1991, Fennessy and Roehrs 1997, Kentula *et al.* 1992a, Shaich and Franklin 1995). This work focuses on why WCM is needed, acreage exchanges, permit compliance, and why WCM sites fail. Most WCM success studies focus on these parameters on a site specific basis. Only a few researchers, like those mentioned above, take the next step of combining their results and judging WCM in their study area as a success, failure, or partial success.

This neglect stems from a lack of comprehensive information on the ecological mechanics of wetlands, a lack of adequate reference sites, time for mitigated wetlands to establish in preparation for success evaluations, and a reluctance to enter the politics of wetland mitigation and habitat conservation. If the scientific community allows that wetland mitigation works, does it condemn the remnants of remaining wetlands to asphalt and concrete graves? If WCM is shown to fail, how rapidly can society adjust to the loss of what has been the most easily acquired and developable land? This is the conflict into which I enter my own thesis work.

While I believe that mitigated wetland habitats do need enough time to establish before judgments of success are passed and that more remains to be learned about wetland ecology, I also believe that some sort of basic assessment of whether or not WCM works is possible and necessary. Asking wetland mitigation project designers to improve a project's chance of success is unfair if there has been no review of past projects in the area to determine which actions work and which fail. Individual agency permit reviewers may have such knowledge, but unless the expertise is readily available and in a format easy to understand, project critiques will not be used for future planning.

In addition, constructed habitat success is not a black and white issue. People want simple answers -- do this, don't do that. Wetland mitigation success will be judged differently at different scales and with different definitions of success. For example, a two acre freshwater marsh may function well as a wetland in a small scale view. However, placed within the context of the watershed it may fail because the small marsh is surrounded by parking lots, has no protection from future development, and fails to adequately replace the two acres of salt marsh lost to boat ramp construction. This imaginary example highlights an extreme situation, but aspects of this scenario are all too common.

Wetland compensatory mitigation in the Coos Watershed has been successful in increasing wetland acreage, but specific types of wetland habitat -- estuarine sand beach and rocky shore, forested wetland, and subtidal mudflat -- are still being lost. Compared to the Florida study, mitigation in the Coos Watershed is working well. Only 4% of the 40 sites fulfilled state permit requirements and functioned successfully as a wetland (Erwin 1991). Twelve percent of sites were partial successes (Erwin 1991). Erwin (1991) found a 14 % failure rate, and 10% of sites were incomplete and could not be assessed at the time. Currently, 54% of WCM sites function successfully as wetlands in the Coos Watershed and 50% of the incomplete sites have already been judged successful by DSL (Figure 17). Partial successes in generating wetland function totaled 9%. On the basis of my research, WCM in the Coos Watershed has had a 14% wetland function failure rate. Room for improvement remains, but overall more than half of the WCM projects are functioning as they were designed to do.

Increasing the spatial and temporal scales to include the long-term wetland viability and maintenance of Coos Watershed integrity, a slightly different picture of landscape function emerges. Completely successful WCM projects drop to 37%, partial successes increase to 46%, and only 17% of all projects are outright failures. The differences in success between in the long-term viability/watershed function and wetland function scales arise from an unequal exchange of habitat type and the location of the WCM in relation to the original wetland impact. Rate of failure changed very little.

Why such a concern over watershed functional integrity and long-term wetland viability though? Each small loss of wetland acreage and function adds up. Eventually, these cumulative impacts start impeding natural habitat and watershed function at both individual wetland and landscape scales (Bedford and Preston 1988, Shaich and Franklin 1995). For example, Shaich and Franklin (1995) found that rarely, if ever, were the long-term effects of constructing in-channel or side-channel ponds considered as part or the mitigation permit approval or design process. These researchers point out that this type of construction is reported to increase stream temperatures, change invertebrate assemblages, and affect sediment transport, *but these impacts were never considered* (my emphasis). Bedford and Preston (1988) argue that the mitigation process should better account for watershed and regional landscape degradation. This means that wetland impact permits should begin to account for what the wetland loss will do to the watershed as a whole, in addition to the loss of a small wetland area.

Recommendations

Historic wetland losses in the Coos Watershed have played an important role in destroying the landscape integrity, habitat diversity, and watershed health of the region.

Further losses jeopardize what function remains. Research, like this study, contributes to expanding local, regional, and national wetland mitigation databases. Analyses of such databases can promote the improvement of mitigation policies and procedures and wetland conservation. It is hoped that the results of this Coos Watershed wetland mitigation analysis will assist local planners, developers, permit reviewers, and researchers improve local WCM project design and implementation, wetland policy, and watershed protection. In light of my findings from permit reviews and field checks, I have a few suggestions for future WCM permitting specific to the Coos Watershed. These may be extended to other watersheds depending upon their current WCM practices.

1. Develop a program of adaptive management of WCM sites. Require developers to actively participate in this adaptive management program, rather than abandon WCM sites after project completion. This program would include regular assessments of the functioning and viability of wetland mitigation sites to determine whether plantings are healthy, the hydrology is correct for the habitat type, and that the site has not become a trash dump. A plan for invasive plant removal should also be included in the adaptive management plan. The adaptive management program would be part of the required site monitoring plan.

2. Focus mitigation efforts on restoration rather than enhancement and creation. There are extensive opportunities for dike removal throughout the Coos Watershed. Dike removal restoration is relatively simple compared to creating a new habitat from scratch, and would return historically lost acreage to its original form.

3. Boost WCM acreage ratios. With large historic losses of wetlands in the Coos Watershed, any increase in wetland acreage should improve watershed function. Wetland acreage increases would also help lessen water quality problems and increase juvenile salmon habitat.

4. Try to locate WCM on-site if possible or within the same watershed subbasin near other sites, if an on-site mitigation would not be feasible.

5. Do a better job of in-kind mitigation -- like for like trades. In the Coos Watershed, past losses of salt marsh, the desirability of regaining lost salt marsh, and the availability of diked marsh for restoration could render this recommendation unfeasible. However, at the minimum, no freshwater ponds should be created in exchange for lost scrub/shrub or salt marsh habitat.

6. Create better buffers between WCM sites and roadsides, parking lots, and residential areas. Runoff and trash pollute wetland sites. Foot traffic disturbs plants and animals trying to establish homes and populations on mitigated wetlands. Roads created to allow access for construction equipment should be replanted -- and access denied until shrubs/trees are established -- after the mitigation work is completed. If trees are to be planted as a buffer, they should be native and suitable for local hydrological conditions. Plantings should mimic nature as best as possible, i.e. no straight rows.

7. Inappropriate mitigation or WCM that decreases the habitat value should not be permitted. A review of the Henderson Marsh mitigation plan shows that many of the mitigation sites in this areas had higher habitat quality values prior to mitigation actions. Removal of some of the scrub/shrub vegetation and creation of freshwater ponds decreased the deflation plain's habitat value. In addition, while the creation of an eelgrass (*Zostera marina*) bed at the end of the North Bend Airport runway replaced some of the subtidal habitat lost to development, it remains uncertain whether or not eelgrass would have colonized the site anyway. The mitigation involved planting *Z. marina* in bare areas between strips of established *Z. marina*.

8. Require goals and objectives for all mitigation projects. Goals and objectives, clearly stated within the permit, would aid in assessing permit compliance, site success, and future management requirements.

9. Require a detailed site monitoring plan as part of the permit. Recently approved permits include monitoring plans, but not all have specific requirements. Monitors should have a detailed checklist to review in the field that includes information on vegetation, hydrology, fauna, and overall site health. Sites should be monitored annually for a minimum of five years. Longer periods may be necessary for sites requiring adaptive management.

10. Reassess WCM site success every five to ten years. This will assist planners, developers, permit reviewers, and researchers to improve the design and function of future wetland compensatory mitigation projects and wetland restorations.

I originally proposed that current wetland compensatory mitigation practices had led to a loss of wetlands within the Coos Watershed, and that this loss had degraded watershed function and connectivity. Although acreage has been gained through WCM in the Coos Watershed, this may not be true of other watersheds in Oregon or the rest of the United States. Past development in the Coos Watershed created a loss of 86% of tidal wetlands and countless more acres of freshwater wetland habitats. These massive losses, combined with current development and resource extraction, heavily stress the ability of the watershed to function properly. Further wetland losses could tip the remaining delicate balance and produce a complete loss of watershed function. Coho salmon listings in the Pacific Northwest have focused attention on declining watershed health. Wetland losses may be one small piece of watershed function, but this piece may be one over which humans have some control through changes in wetland policy to protect these habitats from further impact. Preventing further loss and increasing the number and size of functional wetlands within the Coos Watershed would aid in restoring watershed health and function.

APPENDIX A

DATA SHEET

Permit #:________________ **Permittee:**______________________________
Waterway:____
Permit Expiration Date:__________________ **Active** **Expired**
Type of Development:

Development Project Status: In Progress(date finish?)______ **Compete**(date)______
Proposed Impact Type **Proposed Impact Size** **Air Photo Measured Size**

Description of Site Prior to Development (hydrology, vegetation, functional value):

Mitigation Type:
Mitigation Project Status: In Progress(date finish?)______ **Compete**(date)_______
Proposed Mitigation Type **Proposed Mitigation Size** **Air Photo Measured Size**

Description of Site Prior to Mitigation (hydrology, vegetation, soil, functional value):

Proposed Mitigation Action (dike removal, tide gate removal, pond creation, etc.):

Description of Site After Mitigation
Slope Grade:__________________ **Grading Complete?**
Size/Shape/Location:

Vegetation (species, % coverage, distribution, plantings?, planting success):

Surface Water: Y N **Average Depth:__________% Coverage:_________**
Water Type:__________________ **Tidally Influenced: Y N**
Presence of Tidal Channels: Y N **Approximate % Coverage:_________**
Salinity:
Hydrology Notes:

Saturated Soils: Y N **Organic Materials: Y N**
Soil Texture:____________________ **Soil Salinity:**
Soil Notes:

Surrounding Zoning Designation:

Description of Surrounding Environment:

Presence of Non-native Species (species, % coverage):

Fauna Species Present (birds, mammals, inverts, amphibians, reptiles, fish):

ODSL Comments/Date:

Other Notes/Date:

APPENDIX B

WCM SITE DATA

The following tables summarize WCM site data for DSL permits issued in the Coos Watershed between 1982 and 1997. Definitions for zoning codes are given in Appendix F. Under the "Proximity to Natural Areas?" category, "y" designates natural areas including forests, wetlands, and open water, "n" indicates heavily developed/urban areas, and "~" means lightly developed/rural areas. The habitat codes used to describe lost and gained habitat types come from the National Wetlands Inventory maps (USF&WS 1989a, 1989b, 1989c, 1989d).

Study Number	DSL Number	DSL Permit Type	Permitee
1	3198	Remove	Central Dock Company
2	3613	Fill	Weyerhaueser West Coast, Inc.
3	3835	Remove	Port of Coos Bay
4	3839	Remove-Fill	Weyerhaueser West Coast, Inc.
5	3886	Remove-Fill	George Lindsay
6	3977	Remove	City of North Bend
7	4003	Fill	Port of Coos Bay
8	4067	Remove-Fill	Port of Coos Bay
9	4133	Remove	ODOT
10	4460	Remove-Fill	City of North Bend
11	4505	Remove	Don Giddings
12	4678	Remove-Fill	ODOT
13	5131	Fill	ODOT
14	5567	Fill	Port of Coos Bay
15	5854	Remove-Fill	Port of Coos Bay
16	5858	Remove-Fill	City of Coos Bay
17	6037	Remove-Fill	Coos Bay BLM
18	6063	Remove-Fill	ODOT
19	6070	Remove-Fill	ODOT
20	6398	Remove-Fill	Diamond Wood Products
21	6642	Fill	Walmart
22	6757	Fill	Sause Brothers Ocean Towing
23	7068	Fill	Coos Cty. Urban Renewal Agency
24	7395	Fill	Intermountain Realty Group
25	7550	Remove	Weyerhaueser West Coast, Inc.
26	7610	Fill	Nazarene Church
27	7611	Fill	Dennis Brown, DDS
28	8594	Fill	Knutson Towboat
29	9109	General (RF)	ODOT
30	9772	Remove-Fill	Ocean Terminals Company
31	10225	Fill	SW Oregon Community College
32	10313	Fill	Bay Clinic
33	10346	Remove-Fill	Coos Country Club
34	12004	Fill	City of Coos Bay & OSMB
35	13557	General (RF)	ODOT
36	13817	General (RF)	Coos County Highway Department

Study Number	WCM Location	Development Location
1	Coalbank Slough	Coos Bay Waterfront
2	Henderson Marsh	Henderson Marsh
3	North Spit	North Spit
4	Henderson Marsh	Henderson Marsh
5	Coalbank Slough	Coalbank Slough
6	Pony Slough	Pony Slough
7	Henderson Marsh	North Spit
8	North Spit	North Spit
9	Coalbank Slough	Coalbank Slough
10	Pony Slough	Pony Slough
11	Joe Ney Slough (South Slough)	Joe Ney Slough (South Slough)
12	Shinglehouse Slough	Shinglehouse Slough
13	Barview Wayside	South Slough
14	Barview Wayside	Barview Wayside
15	Joe Ney Slough (South Slough)	Joe Ney Slough (South Slough)
16	Empire	Empire
17	North Spit	North Spit
18	Barview Wayside	North Slough
19	Barview Wayside	Catching Slough
20	Isthmus Slough	Isthmus Slough
21	Upper Pony Slough Watershed	Upper Pony Slough Watershed
22	Empire	Coos Bay Waterfront
23	Henderson Marsh	North Spit
24	Upper Pony Slough Watershed	Upper Pony Slough Watershed
25	Henderson Marsh	Henderson Marsh
26	Upper Pony Slough Watershed	Upper Pony Slough Watershed
27	Upper Pony Slough Watershed	Upper Pony Slough Watershed
28	Coalbank Slough	Isthmus Slough
29	Shinglehouse Slough	Manning Gulch Slough
30	Isthmus Slough	Coos Bay Waterfront
31	Day Creek (South Slough)	Upper Pony Slough Watershed
32	Upper Pony Slough Watershed	Upper Pony Slough Watershed
33	Isthmus Slough Watershed	Isthmus Slough Watershed
34	Isthmus Slough	Isthmus Slough & Millicoma Marsh
35	Larson Slough	Larson Slough
36	Ross Slough	Ross Slough

Study Number	Development Purpose: General	Activity	WCM Permit Compliance?	On-Site?
1	Commercial	marina	yes	no
2	Industrial	building pad	yes	yes
3	Industrial	dock	partial	no
4	Industrial	dredge spoil & building pad	yes	yes
5	Commercial	marina	yes	yes
6	Public	boat ramp	yes	yes
7	Industrial	road	yes	yes
8	Industrial	dock	yes	yes
9	Public Road	bridge	partial	yes
10	Commercial	airport	yes	yes & no
11	Commercial	marina	partial	yes
12	Public Road	bridge	unsure	yes
13	Public Road	bridge	yes	no
14	Industrial	dredge spoil	yes	yes
15	Commercial	marina	no	yes
16	Public	boat ramp	partial	yes
17	Public	boat ramp	yes	yes
18	Public Road	road	no	no
19	Public Road	bridge	yes	no
20	Industrial	log storage	yes	yes
21	Commercial	building pad	yes	yes
22	Commercial	building pad	partial	no
23	Industrial	road & railroad	can't find	
24	Commercial	retail facility	yes	yes
25	Industrial	mitigation bank	yes	yes
26	Public	building pad	yes	yes
27	Commercial	building pad	no	yes & no
28	Industrial	log storage	yes	no
29	Public Road	bridge & road	yes	no
30	Commercial	building pad	yes	no
31	Public	sports facility	yes	no
32	Commercial	building pad	no	yes
33	Commercial	sports facility	yes	yes
34	Public	boat ramp	yes	yes & no
35	Public Road	bridge	yes	yes
36	Public Road	bridge	yes	yes

Study Number	Mitigation Type	Acreage Gain-Loss	WCM Ratio (1:--)
1	Create	1.594	1.5
2	Create	-31.693	0.07
3	Create & Enhance	-1.764	0.32
4	Create & Enhance	145.386	2.05
5	Restore	-0.501	0.65
6	Create & Enhance	0.057	1.05
7	Create & Enhance	6.193	1.44
8	Create	0.906	4.94
9	Create	0.074	
10	Enhance & Restore	-7.201	0.76
11	Create	-0.079	0.03
12	Restore	0.007	1.64
13	Create	0.31	4.1
14	Enhance	-0.765	0.5
15	Enhance	0.002	
16	Create	0.05	1.08
17	Enhance	0.405	3.7
18	Enhance	0.541	3
19	Create	0.02	1.02
20	Create	0.183	1.4
21	Create	0.587	1.99
22	Enhance	0.063	2.05
23	Create		
24	Create & Enhance	0.677	2.35
25	Create & Enhance	38.589	7.33
26	Enhance	0.411	3.45
27	Create & Enhance	-0.194	0.61
28	Enhance	1.72	1.55
29	Restore	0.131	1.27
30	Enhance & Restore	23.03	5.19
31	Enhance	3.3	6.16
32	Enhance	-0.002	0.95
33	Create, Enhance, & Restore	13.15	4.49
34	Create & Restore	-0.051	0.89
35	Enhance & Restore	0.49	
36	Enhance	0.3	3.5

Study Number	Zoning Designation: On-site	Surrounding Area	Proximity to: Other Sites?	Natural Areas?
1	CBEMP (RS 40)	EFU, UR-2, RR-2	y	~
2	CBEMP (NS 00 AREC)	CBEMP	y	y
3	CBEMP (WD 03 EWD)	CBEMP	n	y
4	CBEMP (WD 05 WD)	CBEMP	y	y
5	CBEMP (RS 40)	EFU, RR-2, UR-2	y	~
6	A-Z	ML	n	y
7	CBEMP (WD 05 WD)	CBEMP	y	y
8	IND	CBEMP	y	y
9	C1	CD-5, UR-2	n	n
10	A-Z	ML	n	n
11	C-1	UR-2, RR-2, F	y	~
12	CBEMP (45 NA)	IND, RR-2, C-1	y	y
13	REC	UR-2	y	~
14	REC	UR-2	y	~
15	CC-1	UR-2, RR-2, F	y	~
16	WI	C2, IC, R3, 54 UW	n	n
17	CBEMP (WD 03 EWD)	CBEMP	y	y
18	REC	UR-2	y	~
19	REC	UR-2	y	~
20	EFU	RR-5, IND	n	y
21	C2	R2, R3, R6, QP3	y	n
22	54 UW	IC, R2, R3, RW, WI	n	~
23	CBEMP (WD 05 WD)	CBEMP	y	y
24	C2	R2, R3, R6, QP3	y	n
25	CBEMP (WD 03 EWD)	CBEMP	y	y
26	C-G	R, R7, RM	y	n
27	C-G	C2, IC, ID, MP, R, R1, R7, RM	y	n
28	CBEMP (RS 40)	UR-2, EFU, RR-2	y	~
29	CBEMP (45 NA)	IND, RR-2, C-1	y	y
30	CBEMP (CS 30)	RR-5, IND	n	y
31	CBEMP (RS 63)	RR-5, SS	n	y
32	MP	R2	n	n
33	EFU	F, QRR-5, RR-5	n	y
34	CBEMP (26 UD)	24 NA, 26B CA, IC, QP3, QP5, R2, R3, RFP	n	y
35	EFU	F	n	y
36	RR-5	CBEMP, F, RR-2	n	~

Study Number	Lost Acreage: Habitat Type	Proposed	Gained Acreage: Habitat Type	Proposed	As-built	Difference	Proposed Gain-Loss	As-built Gain-Loss
1	E1US3	3.18					-3.18	-3.18
			E2EM lo	0.74	3.183	2.443	0.74	3.183
			E2EM5N	3.68	1.591	-2.089	3.68	1.591
2	E2USN/E2EMN	34					-34	-34
			POW	2.4	2.307	-0.093	2.4	2.307
3	E2FL6N sand	1.25	E2FL6N	1.8	0.505	-1.295	0.55	-0.745
	E2AB2M	1.36	E2AB2M	2		-2.000	0.64	-1.36
			E2EM		0.341	0.341	0	0.341
4	PSS	110.5	PSS	18.3	273.447	255.147	-92.2	162.947
			PEM	11.1	2.277	-8.823	11.1	2.277
			POW		3.470	3.470	0	3.47
	E2US	6.2					-6.2	-6.2
	E2EM	9	E2EM lo	1.9	1.920	0.020	-7.1	-7.08
			E2EM5N	7.1	2.972	-4.128	7.1	2.972
	E1UB	13					-13	-13
5	E2US3	0.3	E2US3	0.18	0.367	0.187	-0.12	0.067
	E2EMN lo	0.42	E2EMN lo	0.69	0.340	-0.350	0.27	-0.08
	E2EM5N	0.71	E2EM5N	0.61	0.222	-0.388	-0.1	-0.488

Study Number	Lost Acreage: Habitat Type	Proposed	Gained Acreage: Habitat Type	Proposed	As-built	Difference	Proposed Gain-Loss	As-built Gain-Loss
6	E2FL6N	0.16	E2FL6N	0.8	0.383	-0.417	0.64	0.223
	E1UB2	0.88					-0.88	-0.88
			E2EM5N	0.55	0.286	-0.264	0.55	0.286
			E2EM	0.12	0.428	0.308	0.12	0.428
7	PSS	13.8	PSS	36.37	10.757	-25.613	22.57	-3.043
			POW		9.576	9.576	0	9.576
	E2EM	0.34					-0.34	-0.34
8	E2US	0.21	E2US	0.28	0.507	0.227	0.07	0.297
	E1UB	0.02	E1UB	1.44	0.629	-0.811	1.42	0.609
9	E1UBL						0	0
			E2EM lo		0.049	0.049	0	0.049
			E2US3		0.025	0.025	0	0.025
10	E1UBL	4.9					-4.9	-4.9
	E2FL6N	18					-18	-18
	E2EM	0.5	E2EM		0.299	0.299	-0.5	-0.201
	E2AB1	3.7					-3.7	-3.7
	E2AB2M	2.3	E2AB2M	6.5		-6.500	4.2	-2.3
			E2USN	21.9		-21.900	21.9	0
11	E2USN	0.04					-0.04	-0.0385
	E2EM1	0.04					-0.04	-0.04
			E2US1		0.002	0.002		

Study Number	Lost Acreage: Habitat Type	Proposed	Gained Acreage: Habitat Type	Proposed	As-built	Difference	Proposed Gain-Loss	As-built Gain-Loss
12	E2US3	0.008					-0.008	-0.008
	E2EM5N	0.003	E2EM5N	0.011	0.018	0.007	0.008	0.015
13	E1UBL/E2AB2M	0.05					-0.05	-0.05
	E2FL6N/E2EM5N	0.05	E2EM5N	0.06	0.310	0.250	0.01	0.26
			E2FL6N	0.06	0.100	0.040	0.06	0.1
14	PSS	0.26					-0.26	-0.26
	PEM	1.26	PEM	1.25	0.715	-0.535	-0.01	-0.545
			POW	0.3	0.040	-0.260	0.3	0.04
15	E2US3						0	0
			E2US1		0.002	0.002	0	0.0015
16	E2US2	0.6	E2US2	0.29	0.650	0.360	-0.31	0.05
17	E2FL6N sand	0.15	E2FL6N sand	0.39	0.555	0.165	0.24	0.405
18	E2EM5N	0.2	E2EM5N	1.18		-1.180	0.98	-0.2
	PEM	0.07	PEM		0.153	0.153	-0.07	0.083
			PSS		0.658	0.658	0	0.658
19	E2RS2	1.17					-1.17	-1.17
			E2EM	1.18	1.190	0.010	1.18	1.19
20	PEM	0.46					-0.46	-0.46
			E2EM lo	0.5	0.643	0.143	0.5	0.643

Study Number	Lost Acreage: Habitat Type	Proposed	Gained Acreage: Habitat Type	Proposed	As-built	Difference	Proposed Gain-Loss	As-built Gain-Loss
21	PEM	0.09	PEM	0.2	0.464	0.264	0.11	0.374
	PSS	0.5	PSS	0.4	0.713	0.313	-0.1	0.213
22	E2US2	0.06					-0.06	-0.06
			E2US3	0.1	0.123	0.023	0.1	0.123
23	PSS1F	1.72	PSS1F	3.58		-3.580	1.86	-1.72
	PAB3H	0.7	PAB3H	4.27		-4.270	3.57	-0.7
			PEM1F	1.43		-1.430	1.43	0
24	PSS	0.25	PSS	0.25	0.713	0.463	0	0.463
	PEM	0.25					-0.25	-0.25
			PEM/POW	0.3	0.464	0.164	0.3	0.464
25	PSSC	6.1	PSS	52.21	36.782	-15.428	46.11	30.682
			POW		7.907	7.907	0	7.907
26	PEM	0.154					-0.154	-0.154
	R4SB	0.014	R4SB	0.17	0.049	-0.121	0.156	0.035
			PEM	0.17	0.336	0.166	0.17	0.336
			POW	0.25	0.194	-0.056	0.25	0.194
27	PEM	0.5	PEM	0.156	0.155	-0.001	-0.344	-0.345
			POW	0.103	0.151	0.048	0.103	0.151
28	E2EM	3.12	E2EM	5.5	4.840	-0.660	2.38	1.72

Study Number	Lost Acreage: Habitat Type	Proposed	Gained Acreage: Habitat Type	Proposed	As-built	Difference	Proposed Gain-Loss	As-built Gain-Loss
29	PEM	0.1					-0.1	-0.1
	E2EM	0.28	E2EM	0.48	0.611	0.131	0.2	0.331
	E2US3	0.1					-0.1	-0.1
30	E2US/E1UB	5.5					-5.5	-5.5
			E2EM	26	28.530	2.530	26	28.53
31	PFO134	0.64					-0.64	-0.64
			E2EM5N	5.5	3.940	-1.560	5.5	3.94
32	R4SB7	0.04	R4SB7		0.038	0.038	-0.04	-0.002
33	PEM	3.61	PEM	23.77	16.920	-6.850	20.16	13.31
	POW	0.16				0.000	-0.16	-0.16
34	PSS	0.22	PSS	0.33	0.224	-0.106	0.11	0.004
	E2USN/E1UBL	0.26					-0.26	-0.26
			E2EM5N	0.28	0.205	-0.075	0.28	0.205
35	R2US5		R2US5		0.490	0.490	0	0.49
36	R2UBH	0.12	R2UBH	0.115	0.420	0.305	-0.005	0.3
Total:		253.579		249.245	425.185	175.94	-4.334	171.606
Henderson Marsh:		195.36		138.66	351.415	212.755		
Total - Hend. Marsh:		58.219		110.585	73.77	-36.815	52.366	15.551

APPENDIX C

PLANT LIST FOR WCM SITES AND REFERENCE MARSHES

All plants on this list were either found on WCM sites or reference marshes in the Coos Watershed. Plant codes used in the graphs are listed here with both species and common names.

Indicator Status Codes (Guard 1995, Reed 1988, 1993):

FACU - facultative upland species - usually found in uplands (67%-99% probability), but may be found in wetlands (1%-33% probability)

FAC - facultative species - may be found with equal probability in both uplands and wetlands (34%-67%)

FACW - facultative wetland species - usually occurs in wetlands (67%-99% probability), but occasionally grows in non-wetland areas(1%-33% probability)

OBL - obligate wetland species - can almost always be found in a wetland under natural conditions (>99% probability)

NOL - not on a national list of recognized wetland species

'-' - slightly less frequently found

'+' - slightly more frequently found

Species	Common Name	Code	Native?	Indicator Status
Achillea millefolium	yarrow	ACMI	y	FACU
Agropyron repens	quackgrass	AGRE	n	FACU
Agrostis capillaris	colonial bentgrass	AGCA	n	FAC
Agrostis exarata	spike bentgrass	AGEX	y	FACW
Aira caryophyllea	silver hairgrass	AICA	n	NOL
Aira praecox	little hairgrass	AIPR	n	NOL
Alisma plantago-aquatica	American water plantain	ALPL	y	OBL
Alnus rubra	red alder	ALRU	y	FAC
Ammophila arenaria	European beachgrass	AMAR	n	FACU
Anaphalis margaritacea	pearly everlasting	ANMA	y	NOL
Anthoxanthum odoratum	sweet vernalgrass	ANOD	n	FACU
Arctostaphylos columbiana	hairy manzanita	ARCO	y	
Aster subspicatus	Douglas aster	ASSU	y	FACW
Atraplex patula	fat hen	ATPA	y	FACW
Bidens cernua	nodding beggarticks	BICE	y	FACW+
Callitriche verna	spiny water-starwort	CAVE	y	OBL
Carex laeviculmis	smooth-stem sedge	CALA	y	FACW
Carex lyngbyei	Lyngbye's sedge	CALY	y	OBL
Carex obnupta	slough sedge	CAOB	y	OBL
Carex rostrata	beaked sedge	CARO	y	OBL
Carex vesicaria v. major	inflated sedge	CAVEm	y	OBL
Centaurium erythraea	European centaury	CEER	n	FAC-
Chaetomorpha sp.		CHsp		OBL
Chamaecyparis lawsoniana	Pt. Orford Cedar	CHLA	y	FACU+
Chenopodium humile	marsh pigweed	CHHU	y	FAC+
Cicuta douglasii	Douglas waterhemlock	CIDO	y	OBL
Cisium vulgare	bull thistle	CIVU	n	
Convolvulus arvensis	orchard morning-glory	COAR	n	OBL
Conium maculatum	poison hemlock	COMAc	n	FACW-
Cordylanthus maritimus	salt marsh bird's beak	COMA	y	OBL
Cornus stoloifera v. occidentalis	red osier dogwood	COST	y	FACW
Cortaderia selloana	pampas grass	COSE	n	
Cotula coronpofila	brass buttons	COCO	n	FACW+
Cuscuta salina	dodder	CUSA		
Cyperus rivularis	shining flat sedge	CYRI	y	OBL
Cytisus scoparius	scot's broom	CYSC	n	
Dactylis glomerata	orchard grass	DAGL	n	FACU
Daucus carota	Queen Anne's lace	DACA	n	
Deschampsia caespitosa	tufted hairgrass	DECA	y	FACW
Distichlis spicata	saltgrass	DISP	y	FACW

Species	Common Name	Code	Native?	Indicator Status
Echinochloa crusgalli	barnyard grass	ECCR	n	FACW
Eleocharis palustris	creeping spikerush	ELPA	y	OBL
Elymus mollis	American dunegrass	ELMO	y	
Enteromorpha sp.		ENsp		OBL
Epilobium angustifolium	fireweed	EPAN	y	FACU+
Epilobium watsonii	willow herb	EPWA	y	FACW-
Equisetum arvense	horsetail	EQAR	y	FAC
Fescue rubra	red fescue	FERU	y	FAC+
Festuca arundinaceae	tall fescue	FEAR	n	FACU-
Foeniculum vulgare	sweet fennel	FOVU	n	FACU
Fraxinus latifolia	Oregon ash	FRLA	y	FACW
Fritillaria recurva	scarlet fritillary	FRRE	y	
Fucus distichlis	rockweed	FUDI	y	OBL
Gaultheria shallon	salal	GASH	y	FACU
Gnaphalium palustre	western cudweed	GNPA	y	FAC+
Gnaphalium uliginosum	marsh cudweed	GNUL	n	FAC+
Grassilaria sp.		GRsp		OBL
Grindelia integrifolia	gumweed	GRIN	y	FACW
Heracleum lanatum	cow parsnip	HELA	y	FAC
Hordeum brachyantherum	meadow barley	HOBR	y	FACW
Hypericum perforatum	St. Johnswort	HYPE	n	
Jaumea carnosa	fleshy jaumea	JACA	y	OBL
Juncus acuminatus	taper-tipped rush	JUAC	y	OBL
Juncus articulatus	jointed rush	JUAR	y	OBL
Juncus balticus	Baltic rush	JUBA	y	OBL
Juncus bolanderi	Bolander's rush	JUBO	y	OBL
Juncus bufonis	toad rush	JUBU	y	FACW+
Juncus effusus v. gracilis	soft rush	JUEFgr	y	FACW+
Juncus effusus v. pacifica	soft rush	JUEFpa	y	FACW+
Juncus ensifolius	daggerleaf rush	JUEN	y	FACW
Juncus marginatus	grass-leaf rush	JUMA	n	NOL
Lathyrus japonicus	beach pea	LAJA	y	FACU-
Lemna minor	duckweed	LEMI	y	OBL
Lilaeopsis occidentalis	western lilaeopsis	LIOC	y	OBL
Limonium californicum	sea lavender	LICA	y	
Lonicera involucrata	four-line honeysuckle	LOIN	y	FAC
Lotus corniculatus	bird's foot trefoil	LOCO	n	FAC
Lotus purshianus	Spanish clover	LOPU	n	
Lupinus littoralis	seashore lupine	LULI	y	
Lysichiton americanum	skunk cabbage	LYAM	y	OBL

Species	Common Name	Code	Native?	Indicator Status
Lythrum salicaria	purple loosestrife	LYSA	n	OBL
Maianthemum dilatatum	false lily-of-the-valley	MADI	y	FAC
Melilotus alba	white sweetclover	MEAL	n	FACU
Mentha pulegium	penny-royal	MEPU	n	OBL
Myrica californica	Pacific waxmyrtle	MYCA	y	FACW
Myrica gale	sweet gale	MYGA	y	OBL
Myriophyllum spicatum	Eurasian watermilfoil	MYSP	n	OBL
Nuphar lutea v. polysepala	yellow pond lily	NULU	y	OBL
Oenanthe sarmentosa	water parsley	OESA	y	OBL
Parentucellia viscosa	yellow parentucellia	PAVI	n	FAC-
Phalaris arundinacea	reed canary grass	PHAR	n	FACW
Picea sitchensis	sitka spruce	PISI	y	FAC
Pinus contortus	shorepine	PICO	y	FAC-
Plantago major	common ribwort	PLMAj	n	FAC+
Plantago maritima	seaside plantain	PLMA	y	FACW+
Poa pratensis	Kentucky bluegrass	POPR	n	FACU+
Polygonum hydropiperoides	waterpepper	POHY	y	OBL
Polypogon monospeliensis	rabbit's foot grass	POMO	n	FACW+
Polystichum munitum	sword fern	POMU	y	
Porphyra sp.	nori	POsp		OBL
Potamogeton foliosis	leafy pondweed	POFO	y	OBL
Potamogeton natans	floating leaved pondweed	PONA	y	OBL
Potentilla gracilis	northwest cinquefoil	POGR	y	FAC
Potentilla pacifica	Pacific silverweed	POPA	y	OBL
Ranunculus repens	creeping buttercup	RARE	n	FACW
Ranunculus sp.	buttercup	RAsp		FAC
Rorippa nasturtium aquaticum	watercress	RONA	y	OBL
Rubus discolor	Himalayan blackberry	RUDI	n	FACU-
Rubus laciniatus	evergreen blackberry	RULA	n	FACU+
Rubus parviflorus	thimbleberry	RUPA	y	FACU+
Rubus spectabilis	salmonberry	RUSP	y	FAC
Rubus ursinus	trailing blackberry	RUUR	y	FACU
Rumex acetosella	sheep sorrel	RUAC	n	FACU
Rumex crispus	curly dock	RUCR	n	FACW
Rumex occidentalis	western dock	RUOC	y	FACW+
Saggitaria latifolia	wapato	SALA	y	OBL
Salcornia virginica	pickleweed	SAVI	y	OBL
Salix sp.	willow	SAsp	y	FACW
Sambucus racemosa	elderberry	SARA	y	FACU
Scirpus acutus	hardstem bullrush	SCAC	y	OBL

Species	Common Name	Code	Native?	Indicator Status
Scirpus americanus	American threesquare	SCAM	y	OBL
Scirpus cernuus	low clubrush	SCCE	y	OBL
Scirpus maritimus	saltmarsh bullrush	SCMA	y	OBL
Scirpus microcarpus	small-fruited bullrush	SCMI	y	OBL
Scirpus subterminalis	water clubrush	SCSU	y	OBL
Sonchus asper	prickly sowthistle	SOAS	n	FAC-
Sparangium emersum	simple-stem burreed	SPEM	y	OBL
Sparangium eurycarpum	giant burreed	SPEU	y	OBL
Spergularia marina	saltmarsh sandspurry	SPMA	y	OBL
Spirea douglasii	hardhack	SPDO	y	FACW
Stellaria calycantha	northern starwort	STCA	y	FACW+
Thuja plicata	western red cedar	THPL	y	FAD
Trifolium pratense	red clover	TRPR	n	FACU
Trifolium repens	white clover	TRRE	n	FACU+
Trifolium wormskoljii	springbank clover	TRWO	y	FACW+
Triglochin maritimum	seaside arrowgrass	TRMA	y	OBL
Triglochin palustre	marsh arrowgrass	TRPA	y	OBL
Tsuga heterophylla	western hemlock	TSHE	y	FACU-
Typha latifolia	cattail	TYLA	y	OBL
Ulva sp.	sea lettuce	ULsp		OBL
Vaccinium alaskaense	Alaskan blueberry	VAAL	y	FAC
Vaccinium ovatum	evergreen huckleberry	VAOV	y	
Veronica americana	marsh brooklime	VEAM	y	OBL
Veronica arensis	corn speedwell	VEAR	n	FACU
Zostera japonica	Japanese eelgrass	ZOJA	n	OBL
Zostera marina	native eelgrass	ZOMA	y	OBL
	green algal mat	gam	y	OBL

APPENDIX D

PLANT LISTS FOR INDIVIDUAL WCM SITES

WCM site numbers are listed across the top of this table. Plant species, identified by their species code, are listed alphabetically down the left side of each page. An "X" indicates the presence of a species at a WCM site. An estimate of the total percent coverage for the entire site is given, if an individual species covered greater than 5% of a total site. Species totals for each site and totals for the number of sites on which each species was found are listed towards the end of this appendix.

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ACMI	X			X			X											
AGRE				X														
AGCA				X			X		X					X				
AGEX														X				
ALPL																		
ALRU									X					X				5
AMAR				X		X	X						X					
ANMA							X											
ANOD				X			X		X					5				X
ARCO							X											
ASSU		X		X			X											
ATPA				X	5	X			7	X		X	5					
BICE																		
CAVEm																		
CALA																		
CALY	X		X	X	30		X		35			X	X					
CAOB		X		X			X			X								X
CARO							X											
CAVE							X											
CEER				X														
CHsp						5										60		
CHLA																		
CHHU														X				
CIDO				X														
CIVU																		
COAR	X																	
COMA			5			5							5					
COST																		
COSE																		

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
COCO				X										X				
CUSA			X	X		5							X					
CYRI																		
CYSC	X			X	10		X		X									
DACA	X																	
DAGL																		X
DECA				X	10					X		X	5					
DISP	X			10	X	20				X		40	30			X		
ECCR																		
ELPA		X		X			X		X									5
ELMO													20					X
ENsp								5								30	5	
EPAN														X				5
EPWA		X					X							X				
EQAR														X				
FERU														X				
FEAR														X				X
FOVU														X				
FRLA																		
FRRE																		
FUDI						X					X				X		X	
GASH							X											
GNPA																		
GNUL																		
GRsp						X												
GRIN	X			X	12	X			10	X		X	5					
HELA	X																	
HOBR			X	X		X						X						
HYPE																		

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
JACA	X		5	X	X	15			8	X			X					
JUAC							X											
JUAR							X											
JUBO																		
JUBU																		
JUEFgr										X				X				X
JUEFpa				X			X											
JUEN				X			X											
JUMA				X														
LAJA						X												
LEMI							X							X				X
LIOC																		
LICA			5			X												
LOPU				X														
LULI				X														
LYSA														15				X
MEAL																		
MEPU				X														
MYCA							X											5
MYGA																		X
MYSP																		
NULU		X																
OESA														X				10
PAVI				X														
PHAR				X	5				X	X								X
PISI																		5
PICO							X											
PLMAj																		
PLMA			X			X												

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
POPR							X						7					
POHY																		
POMO				X										X				
POMU																		X
POsp						X												
POFO							X											
PONA		X		X	7		X											
POPA	X	X		X						X				X				5
RAsp				X														
RONA																		10
RUDI	X				5				X									
RULA																		
RUPA																		X
RUAC				X										X				X
RUCR														X				
RUOC	X			X	X				X	X				X				X
RUUR	X																	
SALA																		
SAVI	X		10	X	20	25			10	X		60	10					
SAsp		X		X			X							20				35
SARA																		
SCAC	X			X	X									X				
SCAM	X	X	X	X		5							7	10				
SCCE	X				X	X												
SCMA	X			X	5	5				X				5				
SCMI																		
SOAS				X						X				X				
SPEM														X				
SPEU							X							X				

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SPMA	X					5							X					
SPDO																		
STCA																		
THPL																		
TRPR										X				X				
TRRE										X				X				
TRWO				X														
TRMA	X		X	X	5	5			5	X		X		X				
TSHE																		
TYLA														30				
ULsp						X										10	X	
VAAL				X														
VAOV																		
VEAM																		
VEAR																		
ZOJA						X		30									35	
ZOMA						X		X								X	X	
gam	X					X												
# Sp./Site																		
Total:	21	9	10	43	16	26	27	3	14	16	1	8	14	32	1	5	5	23

Code	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Total Sites
ACMI										X			X						5
AGRE															X		X		3
AGCA			X			X		X							X				8
AGEX																X			2
ALPL			X			X													2
ALRU			X			X		5	X		X						X		9
AMAR																			4
ANMA																			1
ANOD			X			X		5				X			X				10
ARCO																			1
ASSU													X					X	5
ATPA	X		X								X		5			X			12
BICE																	X		1
CAVE																			1
CALA																		X	1
CALY							X			X	X	X	25						13
CAOB		6	X			X		X	X			X			X	X		12	14
CARO																			1
CAVEm													X						1
CEER									X										2
CHsp												X							3
CHLA			X			X													2
CHHU																			1
CIDO																			1
CIVU														50	X				2
COAR										X								X	3
COMA																			3
COST																		X	1
COSE								X	10										2

Code	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Total Sites
COCO	X						X				10	X				25	X		8
CUSA	X																		5
CYRI																X			1
CYSC		X	X			X		X	X	X	X			X					13
DACA										X									2
DAGL																			1
DECA	X		X			X					X		30			X		X	12
DISP	25	5		X						X	15	X	10			X			17
ECCR																	X		1
ELPA	5	X	X			X	X				5				X	10	X	5	15
ELMO																			2
ENsp	X			X								X							7
EPAN								X										X	4
EPWA							X												4
EQAR			X			X		X	X										5
FERU			X			X									X				4
FEAR																			2
FOVU																			1
FRLA																		X	1
FRRE			X			X													2
FUDI				X															5
GASH			X			X		X											4
GNPA															X				1
GNUL																	X		1
GRsp																			1
GRIN										X	X	X	5						12
HELA								X		X			X						4
HOBR	X																		5
HYPE									X										1

Code	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Total Sites
JACA	X	X								X									11
JUAC								15	X						X	30			5
JUAR								35							X				3
JUBO			X			X			X										3
JUBU																35	X		2
JUEFgr			X			X		X	15				X		X				9
JUEFpa	X		X			X						X			X	X			8
JUEN			X			X									X				5
JUMA																			1
LAJA	X																		2
LEMI							X								X				5
LIOC																25			1
LICA																			2
LOPU			X			X		X	X						X		X	X	8
LULI																			1
LYSA								X	X										4
MEAL											X								1
MEPU															X	15			3
MYCA							X	X											4
MYGA																			1
MYSP			15			15												5	3
NULU																			1
OESA							X						X		X			X	6
PAVI							X	X	X						X	5			6
PHAR			X			X		X							5		50	12	11
PISI																			1
PICO			X			X		X											4
PLMAj									X										1
PLMA	X																		3

Code	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Total Sites
POPR								X							X				4
POHY															X		X	X	3
POMO									X							X			4
POMU								X											2
POsp																		X	2
POFO								X											2
PONA								5	5										6
POPA	X								X	X		X	5		X	X	X	5	14
RAsp																			1
RONA																			1
RUDI			X			X				X				35					7
RULA								X	X										2
RUPA																			1
RUAC															X		X		5
RUCR								X							X				3
RUOC								X		X		X	X		X			X	13
RUUR			X			X		X		X				5					6
SALA			X			X													2
SAVI	5	5		X						X	20	X							15
SAsp	X	X	X			X	X	X	X						X	X	X	X	16
SARA								X											1
SCAC	X	X	25			X				X					X		X	30	12
SCAM	10									X						5	X		11
SCCE										X	5		X						6
SCMA	25	10								X	5								10
SCMI	X		X			X		X								X			5
SOAS							X	X	X							X			7
SPEM			X			X													3
SPEU							X								X		X		5

Code	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Total Sites
SPMA	X									X	X	X							7
SPDO			X			X													2
STCA													X				X		2
THPL			X			X		X						X					4
TRPR																X			3
TRRE																	X	X	4
TRWO																			1
TRMA	X										25		15			X			13
TSHE														X					1
TYLA	20		X			X		X	35			X	X		X	X	30	30	12
ULsp	X	X																	5
VAAL																			1
VAOV							X	X											2
VEAM			X			X										10			3
VEAR																	10		1
ZOJA																			3
ZOMA				X															5
gam	X		X			X				X		X							7
# Sp./Site																			
Total:	24	10	27	5		33	12	33	20	20	15	15	18	6	29	24	21	21	

APPENDIX E

INVASIVE PLANT LISTS FOR INDIVIDUAL WCM SITES

WCM site numbers are listed across the top of this table. Plant species, identified by their species code, are listed alphabetically down the left side of each page. An "X" indicates the presence of a species at a WCM site. An estimate of the total percent coverage for the entire site is given, if an individual species covered greater than 5% of a total site. Species totals for each site and totals for the number of sites on which each species was found are listed towards the end of this appendix.

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
AGRE				X														
AGCA				X			X		X					X				
AMAR				X		X	X						X					
ANOD				X			X		X					5				X
CEER				X														
CIVU																		
COAR	X																	
COSE																		
COCO				X										X				
CYSC	X			X	10		X		X									
DACA	X																	
DAGL																		X
ECCR																		
FEAR														X				X
FOVU														X				
GNUL																		
HYPE																		
JUMA				X														
LOPU				X														
LYSA														15				X
MEAL																		
MEPU				X														
MYSP																		
PAVI				X														
PHAR				X	5				X	X								X
PLMAj																		
POPR							X						7					
POMO				X										X				
RUDI	X				5				X									

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
RULA																		
RUAC				X										X				X
RUCR														X				
SOAS				X						X				X				
TRPR										X				X				
TRRE										X				X				
VEAR																		
ZOJA						X		30									35	
# Sp./Site																		
Total	4	0	0	15	3	2	5	1	5	4	0	0	2	12	0	0	1	6

Code	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Total Sites
AGRE															X		X		3
AGCA			X			X		X							X				8
AMAR																			4
ANOD			X			X		5				X			X				10
CEER									X										2
CIVU														50	X				2
COAR										X								X	3
COSE								X	10										2
COCO	X						X				10	X				25	X		8
CYSC		X	X			X		X	X	X	X			X					13
DACA										X									2
DAGL																			1
ECCR																	X		1
FEAR																			2
FOVU																			1
GNUL																	X		1
HYPE									X										1
JUMA																			1
LOPU			X			X		X	X						X		X	X	8
LYSA								X	X										4
MEAL											X								1
MEPU															X	15			3
MYSP			15			15												5	3
PAVI							X	X	X						X	5			6
PHAR			X			X		X							5		50	12	11
PLMAj									X										1
POPR								X							X				4
POMO									X							X			4
RUDI			X			X				X				35					7

Code	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Total Sites
RULA								X	X										2
RUAC															X		X		5
RUCR								X							X				3
SOAS							X	X	X							X			7
TRPR																X			3
TRRE																	X	X	4
VEAR																	10		1
ZOJA																			3
# Sp./Site																			
Total	1	1	7	0		7	3	12	11	4	3	2	0	3	11	6	9	5	

APPENDIX F

ZONING DEFINITIONS

Coos County Zoning (1983)

C-1 - Commercial - This district accommodates retail and service businesses within the urban growth boundary and recognizes existing commercial uses outside that boundary.

CD-5 - Controlled Development - Recognized for their scenic and unique qualities, this district within the urban growth boundary has been set aside in an attempt to protect and enhance the "village atmosphere" of the area. A mix of residential, commercial, and recreational uses are permitted. Inconsistent uses are not allowed. One of the purposes of designating areas CD-5 is to aid in tourism development, a major component of the county's economy.

EFU - Exclusive Agriculture - Preserves the integrity and encourages the conservation of agricultural lands within Coos County. This designation limits any development to uses "distinguished as dependent upon or accessory to supporting agricultural or forestry production."

F- Forest - Designates forest lands and protects them for forest uses. Certain limited activity may be allowed, such as a mixed farm and forest use.

IND/ID - Industrial - These areas may be located without regard to the urban growth boundary. The zone is designed to provide enough land to meet current industrial growth needs and encourage future growth and diversification for the region. Consistent with the county's comprehensive plan, this designation can be applied to industrial parcels needed for development before the year 2000.

QRR-5 - Qualified Rural Residential - Provides for homes with acreage outside of the urban growth boundary that have a moderate intensity of land development. Urban services and facilities may not be available. The designation is designed to "encourage the continued existence of rural family life and to provide a transition of densities between urban areas and exclusive agricultural or forestry uses." Some restrictions have been placed on this zoned area.

REC - Recreation - These areas accommodate recreational uses that have high recreational or open space value. It includes state, county, and municipal parks, and private golf courses as designated in the comprehensive plan. Future development in this zone must account for the open space nature of the land and other environmental considerations specifically mentioned in the county's coastal shoreland/dune lands comprehensive plan policies when development is proposed in a coastal resource area.

RR-2 - Rural Residential - Provides for homes with small acreages outside of the urban growth boundary that have a moderate intensity of land development. Urban services and facilities may not be available. The designation is designed to "provide for the continued existence of rural family life and a transition of densities between urban areas and exclusive agricultural or forestry uses."

RR-5 - Rural Residential - Provides for homes with acreage outside of the urban growth boundary that have a moderate intensity of land development. Urban services and facilities may not be available. The designation is designed to "encourage the continued existence of rural family life and to provide a transition of densities between urban areas and exclusive agricultural or forestry uses."

SS - South Slough - This zoning designation is designed to complement the management and scientific objectives of the South Slough National Estuarine Research Reserve. It maintains the sanctuary's integrity, as well as, "preserves the area for long-term scientific and educational use."

UR-2 - Urban Residential - Describes areas within the urban growth boundary that may accommodate single family dwellings, mobile homes, and duplexes. Clustered planned unit developments, such as apartments, are included.

City of North Bend Zoning (~1985)

A-Z - Airport Zone - This area includes all land within the boundaries of the North Bend Municipal Airport. The zone allows for airport uses, airport related uses, and all uses permitted in the M-L district. There may be some conditional general commercial use. No conflicting conditional uses in adjacent areas and no residences within the noise impact area are allowed.

C-G - General Commercial Zone - This district allows the following types of commercial operations: car or boat salesrooms, financial institutions, printers, bus stations, cabinet shops, commercial amusements, frozen food storage, garage, government offices, hotel/motel, laundromat, dry cleaners, fraternal organizations, public assembly rooms, medical offices, mortuaries, parking lots, newspaper offices, restaurants, retail stores, gas stations, theaters, wholesale offices, repair shops (no loud machinery), and any use permitted outright in a light commercial zone. Some use of the area for boardinghouses, churches, governmental structures, hospitals, rest homes, veterinary clinics, sheet metal shops, food and beverage processing, storage, and packaging, day nurseries, building supply outlets, utility substations or pumping stations, manufacturing for on-premise sale, and the improvement of existing dwellings. Adjacent residential areas will be separated from these uses by obscuring fences or hedges. No uses will be allowed if they create excessive noise, glare, or other adverse impacts to adjacent residential areas. Sales lots will be paved. Buildings may not occupy more than 75% of the total lot. Approval is required for any alteration to a unified shopping area. Restrictions exist on signs and yard setbacks.

M-L - Light Industrial District - The following uses are permitted in this zone: automobile repair shops, woodworking shops, cosmetic and drug manufacturing facilities, caretaker dwellings, feed and seed stores, freight depots, cold storage plants, research and testing laboratories (excluding combustion engines), laundries, dry cleaners, lumber and building supply outlets, machinery or equipment sales and service, manufacture using previously prepared material, small goods manufacture, railroad tracks and facilities, utility stations and substations, veterinary clinics, plumbing, heating, electrical, and painting contractor sales, welding, sheet metal, and machinery shops, wholesale distributors, and food and beverage processing, storage, and packaging. Conditional uses include governmental structures, general commercial uses, improvements to existing dwellings, and RV parks. Restrictions exist on allowable nuisances, manufacture materials storage, points of access, signs, yards, and building heights.

R - Residential - This district is zoned to provide for single family housing, duplexes, and multi-family residences such as townhouses.

R7 -Residential 7000 ft^2 - Within this zone, lot sizes must be at least 7,000 ft.2. Only single family housing is allowed and set backs are required.

RM - Residential Multiple - This district provides for multi-family residences, residences containing three or more families (i.e., triplexes, apartments). R6 uses are allowed.

City of Coos Bay Zoning (1987)

C1 - Central Commercial District - Designed to concentrate center/s for general retail and servicing of goods and products and to preserve the significance and character of Coos Bay's major commercial district. A full range of professional, financial, and governmental services may be located within this area. Uses which create noise, impede traffic flow, or store materials outside are not permitted.

C2 - General Commercial District - This district provides a broad range of commercial and other services which may be easily accessed by residential areas. Limited residential and industrial uses are allowed. However, those uses and services not permitted in C1 are not permitted in this district.

GI - General Industrial District - Only industrial uses are allowed within this zone. There are no conditional uses and some permitted commercial, civic, agricultural, and industrial uses are allowed. Caretaker dwellings are permitted. This district tries to encourage intensive industrial use while attempting to reduce air, land, water, and visual pollution associated with such activities.

IC - Industrial/Commercial - Retail and wholesale warehousing and distribution businesses, as well as, some commercial and light industrial uses are allowed. Only those commercial and industrial uses compatible with adjacent residential and commercial uses are permitted. No heavy industrial or other uses which create hazardous levels of noise, vibrations, smoke, dust, or glare permitted.

MP - Medical Park District - This zoning designation was designed to encourage the centralization of Coos Bay's medical facilities and provide an area for administrative business offices, limited complementary commercial, physician/dentist offices, and medically-related multi-family residences that complement such medical establishments. It is hoped that development in the district will allow for a park-like setting around the facilities and prevent the encroachment of medically-related facilities into residential areas.

QP3 - Public Educational Facilities - Within this zone, suitable land may be set aside for public schools and related facilities (outbuildings). Such land may be developed or undeveloped, but development for public education facilities must be compatible with uses in surrounding districts. Some single-family dwellings may be conditionally allowed. All non-related uses prohibited within this zone.

QP5 - Buffer - This zone serves as a buffer between industrial and residential zones.

R1 - Single Family Residence District - This zone permits the construction of single-family, low density, residential development. Some civic uses, home occupations/retail, and group residential care conditionally permitted. Trailer homes, RVs (unless unoccupied and properly stored), duplexes, apartment complexes, and those commercial and civic uses not specified are not permitted. Lot size is set at a minimum of 6000 ft^2, with no more than 35% coverage by buildings.

R2 - Single Family and Duplex Residential District - This zoning designation reserves areas for single and duplex family living at population densities that fall within guidelines established by the city's comprehensive plan and public health and safety standards. Some space is available for semi-public facilities and institutions that complement and require an urban residential setting. Limited civic and commercial uses permitted. Lot size is set at a minimum of 5000 ft^2 for single-family units and 7000 ft^2 for duplexes, with no more than 40% coverage by buildings.

R3 - Multiple Residential District - This zone is designed to encourage high-density, multiple residence structures (apartment buildings). The area acts as a transitional district between commercial/professional zones to lower density, single-family and duplex residential districts. Limited civic and commercial uses and those uses permitted in R1 and R2 zones allowed. No manufactured homes permitted. Lot size is set at minimums related to the number of units within the building, but no more than 44% of the site may be covered.

R6 - This district provides areas for single family homes, duplexes, and certified factory-built homes.

RFP - Reserved for Future Planning - No zoning conditions have been applied to this district. City planners may give land within this area a designation at some future date.

RW - Restricted Waterfront Residential District - This zone provides protection from pollution and erosion to designated waterfront areas. Public vehicle and foot access is provided and maintained where possible. Concentration of multiple family dwellings or other housing units by clustering, etc. is encouraged so that open space may be maintained. Specified residential and commercial and conditional commercial, civic, and residential uses permitted. It is hoped that urban development within this district will enhance and preserve the area.

WI - Waterfront Industrial District - Within this zone, land may be preserved which is "exceptionally suited for water-dependent and water-related uses." Other uses that require water access for optimal operation are permitted as regulated by the Coos Bay Estuary Management Plan (CBEMP). Development in the WI should support the success and stability of the local maritime economy.

Coastal Management Units (CBEMP)

CS - Conservation Shoreland - Areas falling under this designation may have some restricted uses allowed, but in general, the area is protected from development. The small size of these sites prevents their designation and protection under a natural aquatic shoreland zone. Numbers accompanying the CS designation indicate specific locations in the Coos Estuary.

NA/NA - Natural Aquatic/Natural Shoreland - The large tidal marshes and flats at these sites are managed to protect natural resource productivity. Numbers accompanying the NA or NS designation indicate specific locations in the Coos Estuary.

RS - Rural Shoreland - Areas falling under this designation may have some restricted agricultural uses allowed, such as pasture. In general, the area is protected from urban and industrial development. The small size of these sites prevents their designation and protection under a natural aquatic shoreland zone. Numbers accompanying the RS designation indicate specific locations in the Coos Estuary.

WD - Waterfront Development - These wetland areas are managed to allow industrial development (dredging for shipping channels, docks, and other transport facilities). Restrictions apply on non-water uses. Numbers accompanying the WD designation indicate specific locations in the Coos Estuary.

UD - Urban Development - These wetland areas are managed to allow development of marinas, day-use boat ramps, and similar uses. Log storage is allowed on an interim basis. Restrictions on non-water uses may apply. Numbers accompanying the UD designation indicate specific locations in the Coos Estuary.

Examples of CBEMP Zones:

24 NA - Natural Aquatic - The large upper bay tidal marsh and flats at this site are managed to protect natural resource productivity.

26 B CA - Conservation Aquatic - This upper bay site is a dredged material disposal area, which is managed and protected for as a disposal area until it is filled to designed capacity. After the area has been filled, it will be managed for urban development. Road access must be maintained. Any industrial uses must be buffered from adjacent residences to the west. Stream alterations are allowed so long as they do not negatively impact an adjacent marsh (24 NA). Specified long-term activities may include airports, log storage, moorage, recreation facilities, solid waste disposal, stream alteration, mitigation, restoration, fill, etc.

26 UD - Urban Development - This upper bay tideflat will be managed to allow development of a dredged marina and day-use boat ramp. Log storage is allowed on an interim basis. Other uses cannot prevent the future use of this area for at least 22 acres of moorage.

54 UW - Urban Water Dependent - This lower bay site will be managed for shallow-draft water dependent/related uses. Such uses include barging and small fishing boat loading and unloading. The boat ramp and parking lot must be maintained for public recreational use. Some conditional non-water dependent uses allowed.

APPENDIX G

SHANNON-WEINER DIVERSITY INDEX DATA

This appendix contains calculations for WCM site and reference marsh Shannon-Weiner Diversity Index data. A brief summary of H values are provided below.

Site #	WCM	Reference Marsh	Previous WCM Site Data			
			1986	1987	1994	1996
#6	0.9828	0.6463	0.1854	0.1854		
#19	0.9109	0.743			0.7908	
#31	0.8412	0.8506				1.2038

Site #: 6 Pony Slough 1998

Species	Pi	log Pi	Pi log Pi
AMAR	0.003	-2.5228787	-0.0075686
ATPA	0.003	-2.5228787	-0.0075686
CHsp	0.05	-1.30103	-0.0650515
COMA	0.05	-1.30103	-0.0650515
CUSA	0.05	-1.30103	-0.0650515
DISP	0.2	-0.69897	-0.139794
FUDI	0.003	-2.5228787	-0.0075686
GRsp	0.003	-2.5228787	-0.0075686
GRIN	0.003	-2.5228787	-0.0075686
HOBR	0.003	-2.5228787	-0.0075686
JACA	0.15	-0.8239087	-0.1235863
LAJA	0.003	-2.5228787	-0.0075686
LICA	0.003	-2.5228787	-0.0075686
PLMA	0.003	-2.5228787	-0.0075686
POsp	0.003	-2.5228787	-0.0075686
SAVI	0.25	-0.60206	-0.150515
SCAM	0.05	-1.30103	-0.0650515
SCCE	0.003	-2.5228787	-0.0075686
SCMA	0.05	-1.30103	-0.0650515
SPMA	0.05	-1.30103	-0.0650515
TRMA	0.05	-1.30103	-0.0650515
ULsp	0.003	-2.5228787	-0.0075686
ZOJA	0.003	-2.5228787	-0.0075686
ZOMA	0.003	-2.5228787	-0.0075686
gam	0.003	-2.5228787	-0.0075686
TOTAL	0.995		-0.9827854 H = 0.9828

Pony Slough Reference

Species	Pi	log Pi	Pi log Pi
ATPA	0.006	-2.2218487	-0.0133311
COMA	0.05	-1.30103	-0.0650515
DECA	0.01	-2	-0.02
DISP	0.05	-1.30103	-0.0650515
ELMO	0.01	-2	-0.02
JACA	0.2	-0.69897	-0.139794
LICA	0.007	-2.154902	-0.0150843
PLMA	0.05	-1.30103	-0.0650515
SAVI	0.55	-0.2596373	-0.1428005
SPMA	0.01	-2	-0.02
TRMA	0.05	-1.30103	-0.0650515
gam	0.007	-2.154902	-0.0150843
TOTAL	1		-0.6463002 H = 0.6463

Site #: 6 Pony Slough July 1986

Species	Pi	log Pi	Pi log Pi	
ENsp	0.137	-0.8632794	-0.1182693	
SAVI	0.019	-1.7212464	-0.0327037	
SPME	0.002	-2.69897	-0.0053979	
TRMA	0.003	-2.5228787	-0.0075686	
ZOJA	0.011	-1.9586073	-0.0215447	
	0.172		-0.1854842	H = 0.1854

Site #: 6 Pony Slough July 1987

Species	Pi	log Pi	Pi log Pi	
ENsp	0.137	-0.8632794	-0.1182693	
SAVI	0.019	-1.7212464	-0.0327037	
SPME	0.002	-2.69897	-0.0053979	
TRMA	0.003	-2.5228787	-0.0075686	
ZOJA	0.011	-1.9586073	-0.0215447	
	0.172		-0.1854842	H = 0.1854

Site #: 19 1998 Barview Wayside WCM

Species	Pi	log Pi	Pi log Pi
ATPA	0.006	-2.2218487	-0.0133311
COCO	0.006	-2.2218487	-0.0133311
CUSA	0.006	-2.2218487	-0.0133311
DECA	0.006	-2.2218487	-0.0133311
DISP	0.25	-0.60206	-0.150515
ELPA	0.05	-1.30103	-0.0650515
ENsp	0.006	-2.2218487	-0.0133311
HOBR	0.006	-2.2218487	-0.0133311
JACA	0.006	-2.2218487	-0.0133311
JUEFpa	0.006	-2.2218487	-0.0133311
LAJA	0.006	-2.2218487	-0.0133311
PLMA	0.006	-2.2218487	-0.0133311
POPA	0.006	-2.2218487	-0.0133311
SAVI	0.05	-1.30103	-0.0650515
SAsp	0.006	-2.2218487	-0.0133311
SCAC	0.006	-2.2218487	-0.0133311
SCAM	0.1	-1	-0.1
SCMA	0.25	-0.60206	-0.150515
SCMI	0.006	-2.2218487	-0.0133311
SPMA	0.006	-2.2218487	-0.0133311
TRMA	0.006	-2.2218487	-0.0133311
TYLA	0.2	-0.69897	-0.139794
ULsp	0.006	-2.2218487	-0.0133311
gam	0.006	-2.2218487	-0.0133311
TOTAL	1.008		-0.9108867 H = 0.9109

Metcalf Marsh Reference

Species	Pi	log Pi	Pi log Pi
AGCA	0.006	-2.2218487	-0.0133311
ANOD	0.01	-2	-0.02
ATPA	0.006	-2.2218487	-0.0133311
CALY	0.15	-0.8239087	-0.1235863
CAOB	0.006	-2.2218487	-0.0133311
DECA	0.005	-2.30103	-0.0115051
DISP	0.45	-0.3467875	-0.1560544
JACA	0.1	-1	-0.1
JUEFgr	0.05	-1.30103	-0.0650515
JUEFpa	0.006	-2.2218487	-0.0133311
POPA	0.006	-2.2218487	-0.0133311
SAVI	0.15	-0.8239087	-0.1235863
SCMI	0.005	-2.30103	-0.0115051
TRMA	0.05	-1.30103	-0.0650515
TOTAL	1		-0.7429958 H = 0.7430

Site #: 19 1994 Barview Wayside WCM

Species	Pi	log Pi	Pi log Pi
AGAL	0.005	-2.30103	-0.0115051
AGSP	0.005	-2.30103	-0.0115051
ATPA	0.005	-2.30103	-0.0115051
CALY	0.005	-2.30103	-0.0115051
COCO	0.31	-0.5086383	-0.1576779
DECA	0.005	-2.30103	-0.0115051
DISP	0.005	-2.30103	-0.0115051
ELPA	0.3	-0.5228787	-0.1568636
GLOC	0.005	-2.30103	-0.0115051
JUBU	0.005	-2.30103	-0.0115051
PHAR	0.03	-1.5228787	-0.0456864
POMO	0.06	-1.2218487	-0.0733109
PUPU	0.02	-1.69897	-0.0339794
SAVI	0.005	-2.30103	-0.0115051
SCCE	0.005	-2.30103	-0.0115051
SCMA	0.2	-0.69897	-0.139794
SCMI	0.005	-2.30103	-0.0115051
SCVA	0.005	-2.30103	-0.0115051
SPME	0.005	-2.30103	-0.0115051
TYLA	0.02	-1.69897	-0.0339794
	1.005		-0.7908585 H = 0.7908

Site #: 31 Day Creek WCM

Species	Pi	log Pi	Pi log Pi
ACMI	0.005	-2.30103	-0.0115051
ASSU	0.005	-2.30103	-0.0115051
ATPA	0.05	-1.30103	-0.0650515
CALY	0.25	-0.60206	-0.150515
CAVEm	0.005	-2.30103	-0.0115051
DECA	0.3	-0.5228787	-0.1568636
DISP	0.1	-1	-0.1
GRIN	0.05	-1.30103	-0.0650515
HELA	0.005	-2.30103	-0.0115051
JUEFgr	0.005	-2.30103	-0.0115051
OESA	0.005	-2.30103	-0.0115051
POPA	0.05	-1.30103	-0.0650515
RUOC	0.005	-2.30103	-0.0115051
SCCE	0.005	-2.30103	-0.0115051
STCA	0.005	-2.30103	-0.0115051
TRMA	0.15	-0.8239087	-0.1235863
TYLA	0.005	-2.30103	-0.0115051
TOTAL	1		-0.8411709 H = 0.8412

Hidden Creek Marsh Reference

Species	Pi	log Pi	Pi log Pi
ANOD	0.01	-2	-0.02
ATPA	0.01	-2	-0.02
CALY	0.05	-1.30103	-0.0650515
CUSA	0.008	-2.09691	-0.0167753
DECA	0.15	-0.8239087	-0.1235863
DISP	0.25	-0.60206	-0.150515
GRIN	0.01	-2	-0.02
HOBR	0.008	-2.09691	-0.0167753
JACA	0.3	-0.5228787	-0.1568636
JUEF	0.1	-1	-0.1
PLMA	0.008	-2.09691	-0.0167753
SAVI	0.05	-1.30103	-0.0650515
SCCE	0.008	-2.09691	-0.0167753
STCA	0.008	-2.09691	-0.0167753
TRMA	0.03	-1.5228787	-0.0456864
TOTAL	1		-0.8506307 H = 0.8506

Site #: 31 Day Creek Delineation 1996

Species	Pi	log Pi	Pi log Pi
ACMI	0.005	-2.30103	-0.0115051
AGEX	0.005	-2.30103	-0.0115051
AICA	0.005	-2.30103	-0.0115051
AIPR	0.005	-2.30103	-0.0115051
ALRU	0.01	-2	-0.02
ANMA	0.005	-2.30103	-0.0115051
CALY	0.1	-1	-0.1
CAOB	0.005	-2.30103	-0.0115051
CIDO	0.005	-2.30103	-0.0115051
COMA	0.005	-2.30103	-0.0115051
DECA	0.15	-0.8239087	-0.1235863
DISP	0.005	-2.30103	-0.0115051
EQAR	0.005	-2.30103	-0.0115051
HOBR	0.005	-2.30103	-0.0115051
JUBA	0.05	-1.30103	-0.0650515
JUEFpa	0.05	-1.30103	-0.0650515
LOCO	0.05	-1.30103	-0.0650515
LOIN	0.01	-2	-0.02
LYAM	0.01	-2	-0.02
MADI	0.01	-2	-0.02

Species	Pi	log Pi	Pi log Pi	
OESA	0.1	-1	-0.1	
PHAR	0.05	-1.30103	-0.0650515	
POGR	0.01	-2	-0.02	
POPA	0.005	-2.30103	-0.0115051	
RARE	0.05	-1.30103	-0.0650515	
RUSP	0.01	-2	-0.02	
SAVI	0.005	-2.30103	-0.0115051	
SCAM	0.005	-2.30103	-0.0115051	
SCCE	0.005	-2.30103	-0.0115051	
SCMA	0.005	-2.30103	-0.0115051	
SCMI	0.2	-0.69897	-0.139794	
SCSU	0.005	-2.30103	-0.0115051	
SPEM	0.05	-1.30103	-0.0650515	
TRMA	0.005	-2.30103	-0.0115051	
TRPA	0.005	-2.30103	-0.0115051	
TYLA	0.005	-2.30103	-0.0115051	
TOTAL	1.01		-1.2037923	H = 1.2038

APPENDIX H

IN-DEPTH FIELD VEGETATION SURVEYS

This appendix contains the raw data from in-depth field surveys conducted during the summer of 1998 for reference marshes and site #6 at Pony Slough. Unless otherwise indicated, numbers presented in the tables represent estimated percent coverage figures for a 0.625 m^2 quadrat.

Hidden Creek Reference Marsh Transect 1																							
10-Oct-98																							
Species	**Quadrat**																						
Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
ANOD																							
ATPA																	1	1	1				5
CALY																							
CUSA			1	1	5																		
DECA						5	20	10						10	15	15	20	30	10	60	15	15	25
DISP									5	5	60	70	85	90	70	70	45	35	60	15	65	70	55
HOBR																		10	10	5			
JACA	90	100	85	90	100	50	30	85	35	90	40	25	15		10	10	30	20	20	20	20	15	15
PLMA																							
SAVI			15	5	1	45	45	5	60	5					5	5	5	5		1		1	
SCCE	10																						
TRMA				5			5	1				5	1	1				1	1			1	
channel																							

Hidden Creek Reference Marsh Transect 1																							
10-Oct-98																							
Species	**Quadrat**																						
Code	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
ANOD										10										5	5		
ATPA	1	5	3			1									1								
CALY																			5	10	20	35	20
CUSA																							
DECA	40	30	25	20	25	20	25	30	55	55	45	70	65	45	35	30	30	25	30	30	15	30	45
DISP	30	55	52	60	50	65	35	25		5	10	10	15	10	15	35	40	25	45	20	20		
HOBR	10	10																					
JACA	20		20	15	25	15	30	10	45	30	45	15	15	45	50	30	25	10	20	25	20	25	25
PLMA																							
SAVI				5			5					1	5		1		5	5				5	5
SCCE																							
TRMA		1	1			1	5	5		1		5			1	5		1	1			5	5
channel																		35					

Hidden Creek Reference Marsh Transect 1					
10-Oct-98					
Species	**Quadrat**				
Code	47	48	49	50	
ANOD		1	15	15	
ATPA					
CALY	30	35	25	25	
CUSA					
DECA	20	20	20	15	
DISP		5	5		
HOBR					
JACA	35	20	15	25	
PLMA	10	15	20	15	
SAVI					
SCCE					
TRMA	5	5	10	5	
channel					

Hidden Creek Reference Marsh Transect 2																							
10-Oct-98																							
Species	**Quadrat**																						
Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
ANOD																							
ATPA																							
CALY																		25	20	15	30	40	75
DECA							10	25	15	15	5	5	10	5	10		5		5	20	5		
DISP						10	20	40	20	30	20	50	60	1	65	60	60	40	35	45	35	40	20
GRIN																							
HOBR																							
JACA	100	100	100	100	85	70	5	20	35	10	25	25	10	10	15	30	15	25	30	10	25	20	5
JUEF																							
SAVI					5	10	55	15	30	45	40	15	20	20	10	5	10	5	5	10	5		
STCA																							
TRMA					10	10	10				10	5	1	10		5	10	5	5	1		1	

Hidden Creek Reference Marsh Transect 2																
10-Oct-98																
Species	**Quadrat**															
Code	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
ANOD															5	5
ATPA							1									
CALY	40	25	25	30	20	25	25	5		1	1		1		10	5
DECA		15	10	15	15	20	20	10	5	10						
DISP	35	40	30	20	30	10	30	10								
GRIN										1	10	5	10	15	10	25
HOBR															1	5
JACA	20	10	10	20	30	30	15	5	5	1	5	5	5			
JUEF						5	5	60	80	90	80	80	80	65	75	50
SAVI		5	5	10	1	1	5									
STCA											5	5				
TRMA	5	5	10	5	5	10	1	10	10	1	1	5	5	20		10

Pony Slough Reference Marsh Transect 1																		
28-Oct-98																		
Species	**Quadrat**																	
Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
ATPA															1	1		1
COMA											5	5	10	10	20	20		
DECA										1							5	
DISP					5	10	10	5	15	15	15	20	5	10	15	25	25	5
ELMO																	5	10
gam													25					
JACA				20	1	5	5	20	30	55	50	55	55	50	55	10	15	
LICA																5		
PLMA											1	1	1	15	10	5	5	
sand		33	33	20													15	75
SAVI	100	66	66	60	95	85	85	75	55	30	30	20	5	15	1	35	30	10

Pony Slough Reference Marsh Transect 2																							
28-Oct-98																							
Species	**Quadrat**																						
Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
COMA															5	5	20	35	35	25	10	5	
DECA			1																				
DISP		5	5					1	15	10	10	15	5	15	15	20	10				15		
ELMO																							1
JACA											5	25	45	45	40	45	50	50	50	45	15	45	40
LICA																				5	5		5
PLMA																1		5		25	55	50	25
sand	66	30	10																				25
SAVI	33	65	85	100	100	100	100	95	85	85	85	60	50	40	40	30	10	10	15		1	1	5
TRMA								5		5							10		1				

Pony Slough Reference Marsh Transect 3																					
28-Oct-98																					
Species	**Quadrat**																				
Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
ATPA																			1		1
COMA																	5	5	5	5	
DECA	5	10														5			20	10	
ELMO																				25	20
JACA		10	5								15	30	50	30	25	60	60	60	50	30	20
PLMA																	1	10	15	25	
SAVI	85	80	65	95	70	75	100	90	90	85	65	50	50	70	75	35	35	15	10	5	10
SPMA																					5
TRMA			30	5	30	25		10	10	15	20	20				1					
sand																					45

Metcalf Marsh Reference Marsh Transect 1																							
31-Oct-98																							
Species	**Quadrat**																						
Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
AGCA																							
ANOD																							
ATPA											1	1	1	1									
CALY																							
DECA																							
DISP	70	85	60	60	75	70	80	85	70	75	80	90	80	95	70	20	55	95	100	90	85		60
JUEFgr																							
JUEFpa																							
POPA																							
SAVI	30	15	40	40	25	30	20	15	30	25	20	10	20	5	30	20	20	5	1	5	10		40
TRMA				1																5	5		
channel																60	25					100	

Metcalf Marsh Reference Marsh Transect 1																							
31-Oct-98																							
Species	**Quadrat**																						
Code	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**
AGCA					1	1																	
ANOD																							
ATPA																							
CALY																							10
DECA																							
DISP	70	70	85	75	70	65	70	50	55	35	60	75	75	45	55	60	65	65	90	80	65	60	65
JUEFgr																							
JUEFpa																							
POPA																							
SAVI	25	15	10	20	20	15	20	20	15	15	20	10	20	45	25	30	10	15	10	15	30	15	15
TRMA	5	15	5	5	10	20	10	30	15	20	20	15	5	10	20	10	25	20	1	5	5	25	10
channel									25	30													

Metcalf Marsh Reference Marsh Transect 1																							
31-Oct-98																							
Species	**Quadrat**																						
Code	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
AGCA																							
ANOD																					10	20	20
ATPA				1			1													1	5	25	15
CALY	60	45	75	65	40	30	60	75	95	75	55	55	45	25									
DECA					10	5						10	5	20									
DISP	65	45	25	25	30	50	35	15	1	15	25	20	10			1				1	1		5
JUEFgr															70	100	75	90	75	90	60	35	20
JUEFpa												10	30	50	30								
POPA																							1
SAVI	1	1		5	1	1	1																
TRMA	5	10		5	20	15	5	10	5	10	20	5	10	5	1	1	25	10	25	10	25	20	30
channel																							

Metcalf Marsh Reference Marsh Transect 1				
31-Oct-98				
Species	**Quadrat**			
Code	70			
AGCA				
ANOD	70			
ATPA				
CALY				
DECA				
DISP				
JUEFgr	10			
JUEFpa				
POPA	1			
SAVI				
TRMA	20			
channel				

Metcalf Marsh Reference Marsh Transect 2																							
31-Oct-98																							
Species	**Quadrat**																						
Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
ATPA																							
CALY																							
CAOB																							
DECA																							
DISP	25	35	55	55	70	55	50	70	60	60	65	75	90	60	70	95	75	55	75	60	45	70	55
JUEFgr																							
POPA																							
SAVI	75	65	45	40	30	45	50	25	40	40	35	25	10	30	20	5	25	45	25	35	45	20	35
SCMI																							
TRMA				5				5	1		1			10	10	1	1			5	10	10	10
mud																							

Metcalf Marsh Reference Marsh Transect 2																							
31-Oct-98																							
Species	**Quadrat**																						
Code	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
ATPA	1	1				1			1	1	1	5	5	5		5	1	1					
CALY							5		1	1	1	5	1	10	20	40	30	75	95	95	95	80	85
CAOB																							
DECA										1	5												
DISP	45	75	55	50	65	70	70	75	80	75	80	85	80	75	55	40	30	15	5	1			
JUEFgr																		5					
POPA																							
SAVI	40	25	35	30	30	20	20	15	20	5	5	5	5	5			5						
SCMI																							
TRMA	15	1	10	20	5	10	5	10	1	20		5	10	5	25	5	10	5		5	5	25	15
mud																10	25						

Metcalf Marsh Reference Marsh Transect 2							
31-Oct-98							
Species	**Quadrat**						
Code	47	48	49	50	51	52	53
ATPA							
CALY	90	90	90	80	40	90	45
CAOB						1	15
DECA							
DISP				1	40	10	15
JUEFgr				1			
POPA						1	20
SAVI							
SCMI						1	5
TRMA	10	10	10	20	20	1	
mud							

Metcalf Marsh Reference Marsh Transect 3																							
31-Oct-98																							
Species	**Quadrat**																						
Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AGCA																							
ANOD									5	10	5	5	1	5	1								
ATPA				1		1	5	1	1	1		1	1	5	1	1				1			
CALY																					20	15	50
DISP	15	30	65	50	45	40	20	15	20	20	20	20	35	40	65	75	65	85	50	40	35	60	20
JACA	70	55	10	25	35	40	40	50	50	55	55	65	50	35	25	20	25	15	30	15	5	5	5
JUEFgr																							
SAVI	15	15	25	25	20	15	30	25	25	15	20	10	15	15	10	5	5	1	20	30	5	5	5
TRMA						5	5	10									5	1	1	15	10	15	20
mud																							
woodpost																							
channel																					25		

Metcalf Marsh Reference Marsh Transect 3											
31-Oct-98											
Species	**Quadrat**										
Code	24	25	26	27	28	29	30	31	32	33	34
AGCA											5
ANOD											
ATPA											
CALY	65	75	25				5	5	15	15	
DISP	10	5	10	35	30	10	50	45	15		45
JACA	1		10	15	50	80	25	25	25	10	
JUEFgr								10	35	55	25
SAVI	1			5	5	1				1	
TRMA	25	20		15	15	10	10	15	10	20	25
mud			55	30							
woodpost							10				
channel											

Pony Slough Site #6 High Marsh Transect
10-Aug-98

Species Code	Quadrat 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SCCE																		
ATPA																		
COMA		2 plant	40	6 plant	15	5												
DISP	50	30	5	20	30	35	20	30										
GRsp															10	5		
GRIN	1 plant																	
JACA					1	15	1 plant										1 plant	
LICA																		
PLMA																		
SAVI	2	30	2	2	25	35	75	30	80	70	20	5	5	20	5	25	30	5
SCAM																		4 plant
SCMA							5	10	15	10	25	50	35	20	5	30	20	
SPMA		1	2	1 plant									1	5		5	5	
TRMA	1 plant		2 plant		10	10		10										
ZOJA																		
gam											5	40	55	45	20	30	50	95

Pony Slough Site #6 High Marsh Transect

10-Aug-98

Species Code	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
SCCE					10				10	10	25	65	1	1	1	5		
ATPA																		
COMA																		
DISP					5	10	60	35	60	25	15		1					1
GRsp				5	5								25	10	5			
GRIN																		
JACA																		
LICA																		
PLMA																		
SAVI	25	90	10	25	30	65	20	30	1	35	30	10	3 plant	40	90	60	80	99
SCAM	5	7 plant	20	20	10													
SCMA			5	5	5	3 plant	2 plant	5 plant	5	5	20	15	10	5				
SPMA	5		5		5 plant	2 plant	3 plant	3 plant	1 plant	5	3 plant	5	1		3	6 plant	1 plant	
TRMA		5	1 plant			1 plant		10	1 plant			1 plant			1 plant	5	10	
ZOJA				40									1					
gam	65	5	60	5	35	25	20	25	25	20	10	5	5		5	30	10	

Pony Slough Site #6 High Marsh Transect

10-Aug-98

Species Code	37	38	39	40	41	42	43	44	45	46	47	48	49
SCCE													
ATPA													5
COMA								5	25	10	20	1 plant	
DISP	90	70	85	85	75	70	65	20	10	5	5	5	5
GRsp													
GRIN													1 plant
JACA							5	10	35	70	40		
LICA											5	10	
PLMA													15
SAVI	5	30	10	15	25	30	30	60	20	10	5	15	10
SCAM													
SCMA													
SPMA													
TRMA		1 plant	5		1 plant			5	5	3 plant	5	5	
ZOJA													
gam	5												

Pony Slough Site #6 Sill (Slough Opening) Transect																		
11-Aug-98																		
Species	**Quadrat**																	
Code	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
AMAR																		
ATPA																		
CHsp											10		3					
COMA																		
CUSA																		
DISP	1 plant	2 plant																5
ENsp									5									
FUDI		1 plant		5			10	15						5				
GRIN																		
JACA	5	3																
LAJA																		
PLMA																		
SAVI	5			5	30	60	55	50	20	5	30	3	20	75	45	30	80	85
HOBR																		
SPMA				5	15	15	5	5	1 plant	5	25	7	7	5	20	30	5	
TRMA							5										15	10
ULsp	5	2	5	1 plant	5		5	1 plant		15		5	10		5	5		
gam	60	55	20	70	50	25	20	30	60	75	35	85	60	15	30	35		

Pony Slough Site #6 Sill (Slough Opening) Transect

11-Aug-98

Species Code	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
AMAR																		
ATPA																		
CHsp																		
COMA												2 plant				5		
CUSA																		2
DISP	5	45	60	45	65	50	75	85	80	75	80	68	70	70	75	65	70	45
ENsp																		
FUDI																		
GRIN																		
JACA													10	5				
LAJA																		
PLMA																10		
SAVI	90	45	35	45	30	45	20	15	20	20	20	25	15	20	25	20	30	55
HOBR																		1 plant
SPMA												5						
TRMA	5	10	5	10	5	5	5		2 plant	5	1 plant	2	5	5	1 plant			
ULsp																		
gam																		

Pony Slough Site #6 Sill (Slough Opening) Transect															
11-Aug-98															
Species															
Code	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**
AMAR															5
ATPA										1 plant	3 plant	1 plant	7	5	4 plant
CHsp															
COMA						3	1 plant	2 plant	1 plant		10	20	3		
CUSA		1 plant	1 plant	3	3	2	1	3	1 plant	5	15	20	10		
DISP	35	30	50	50	55	55	50	45	50	50	65	15	15	5	20
ENsp															
FUDI															
GRIN											5	10		1 plant	10
JACA								10	20			5			
LAJA															4 plant
PLMA							1 plant	5			5	20	1 plant		
SAVI	65	70	50	45	40	40	50	35	25	50	15	30	65	70	30
HOBR	5 plant	1 plant													
SPMA															
TRMA				5	5	2	1 plant	5	5	1 plant					
ULsp															
gam															

Pony Slough Site #6 Tide Channel Transect					running channel to upland										
11-Aug-98															
Species	**Quadrat**														
Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CHsp	1	1	10	10	20	30	30	10	5	5	10	5	35	5	5
DISP															
ENsp	1	1		1						1	5	5	5	10	5
FUDI						1 plant									
GRsp		1	1	1 plant									1		
POsp									1						
SAVI															
SCAM															
SCCE															
SCMA															
SPMA															
TRMA															
ULsp	1	5	5	5	10	20	15	10	5	10	20	15	20	30	15
ZOJA															
ZOMA															
gam															

Pony Slough Site #6 Tide Channel Transect

11-Aug-98

Species Code	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
CHsp	40	35	35	55	25	50	30	10	35	40	20	15	30	50	35
DISP															
ENsp	10	5	5	5	10	20	30	20	10	10	20	15	15	5	5
FUDI			1 plant					1 plant		1 plant			5		
GRsp															
POsp									1 plant				10	1	5
SAVI															1 plant
SCAM															
SCCE															
SCMA															
SPMA															
TRMA															
ULsp	30	35	35	35	35	25	30	30	40	50	55	50	35	35	15
ZOJA															
ZOMA							5	10			5	20	5		30
gam		15	10												

Pony Slough Site #6 Tide Channel Transect															
11-Aug-98															
Species Code	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
CHsp	15	15	45	10	5	20	20	5	5		3				trace
DISP															
ENsp	10		5							2	5				
FUDI							1 plant	1 plant	1 plant						
GRsp															
POsp															
SAVI			1 plant	5	15		2 plant	1 plant	2 plant	2	1 plant	1	5		
SCAM															
SCCE															
SCMA															
SPMA															
TRMA															
ULsp	35	70	30	10	20	40	30	20	10	5	10	15	5	10	5
ZOJA									5			3			
ZOMA	20	1 plant				10									
gam							5	15	15	70		25	15	5	20

Pony Slough Site #6 Tide Channel Transect															
11-Aug-98															
Species															
Code	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
CHsp				2	1		20	5	5						
DISP		1 plant													
ENsp															
FUDI	10	10	10			5	1 plant								
GRsp							2		10						
POsp															
SAVI		3	3		1 plant	1	10	5	5	20	20	5			
SCAM															
SCCE															
SCMA															
SPMA						2 plant	5	10	10	5	5	5		1 plant	
TRMA									2 plant	5					
ULsp	5	1	1 plant	3		5			3		3				
ZOJA		1 plant	1		1 plant	7		35	10	35	5		5		
ZOMA															
gam	30	30	25	15	15	30	15	20	25	30	15	30		3	

Pony Slough Site #6 Tide Channel Transect															
11-Aug-98															
Species Code	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
CHsp															
DISP															
ENsp															
FUDI															
GRsp												2			
POsp															
SAVI					10	5	8	25	10	20	10				
SCAM												5	1 plant	5	10
SCCE															
SCMA															
SPMA														4 plant	1 plant
TRMA															
ULsp															
ZOJA					5	5	2		5						
ZOMA															
gam		5								2			10	20	10

Pony Slough Site #6 Tide Channel Transect

11-Aug-98

Species Code	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
CHsp															
DISP															
ENsp															
FUDI															
GRsp			15	15	65	85	100	20	5						
POsp															
SAVI		1 plant		5			1 plant	1 plant	2	10	5	15	5	10	20
SCAM	5	5		1 plant	2 plant								5	5	5
SCCE		10													
SCMA								1 plant	2 plant		5	3 plant		1 plant	4 plant
SPMA	1 plant	5 plant	10	5				5	3	5	5	5	1 plant	4 plant	5
TRMA		15	25	1 plant				5		25		1 plant			
ULsp															
ZOJA	5	10	trace												
ZOMA															
gam	15	20	5	15				60	90	60	85	80	90	85	70

Pony Slough Site #6 Tide Channel Transect				
11-Aug-98				
Species Code	91	92	93	94
CHsp				
DISP				5
ENsp				
FUDI				
GRsp				
POsp				
SAVI	10	25	65	20
SCAM	15	10	5	5
SCCE	15			
SCMA		20		5
SPMA	5	5	3 plant	2 plant
TRMA		1 plant		
ULsp				
ZOJA				
ZOMA				
gam	55	40	60	65

APPENDIX I

ABBREVIATIONS USED IN THIS TEXT

Federal Agencies:
BLM- Bureau of Land Management
NOAA - National Oceanic and Atmospheric Administration
USACE - United States Army Corps of Engineers
USDA - United States Department of Agriculture
USEPA - United States Environmental Protection Agency
USFS - United States Forest Service
USF&WS - United States Fish & Wildlife Service
USGS - United States Geological Survey

Oregon Agencies:
DEQ - Department of Environmental Quality
DSL - Division of State Lands
LCDC - Land Conservation and Development Commission
ODA - Oregon Department of Agriculture
ODF - Oregon Department of Forestry
ODF&W - Oregon Department of Fish & Wildlife
ODOT - Oregon Department of Transportation
OSMB - Oregon State Marine Board

Others:
CBEMP - Coos Bay Estuarine Management Plan
NWI - National Wetlands Inventory
SSNERR - South Slough National Estuarine Research Reserve
TBT - tributlytin, a toxic chemical used in marine, anti-fouling paint
UN - United Nations
WCM - Wetland Compensatory Mitigation

BIBLIOGRAPHY

Akins, G. and C. Jefferson. 1973. Coastal Wetlands of Oregon. Report. Oregon Coastal Conservation & Development Commission: Florence, OR.

Avery, T.E. and G.L. Berlin. 1992. Fundamentals of Remote Sensing and Airphoto Interpretation: 5th Edition. Prentice Hall: Upper Saddle River, NJ. 472 pp.

Bailey, R., D. Oswalt, D. Fox, A. Merems, R. Brown, S. Riemer, R. Lowe, C. Coon, and R. Crucciola. 1994. Territorial Sea Plan. Oregon Ocean Policy Advisory Council. Oregon Land Conservation and Development Commission: Portland, OR. 250 pp.

Baker, P.. 1995. Review of ecology and fishery of the Olympia oyster, *Ostrea lurida*, with annotated bibliography. *Journal of Shellfish Research* 14(2): 501-518.

Beatley, T., D. Brower, and A. Schwab. 1994. An Introduction to Coastal Zone Management. Island Press: Washington, D.C.. 210 pp.

Beckham, D. 4/16/96. Lecture on the History of Coos Bay. GEOG 510 - Environmental Policy and Landscape Change. University of Oregon.

Beckham, S.D. 1973. Coos Bay: The Pioneer Period 1851-1890. Arago Books: Coos Bay, OR. 70 pp.

Bedford, B.L. and E.M. Preston. 1988. Developing the scientific basis for assessing cumulative effects of wetland loss and degradation on landscape functions: status, perspectives, and prospects. *Environmental Management* 12(5): 751-771.

Bishop, B.. 2/21/99. "Crew begins pumping off oil." The Register Guard: Eugene, OR. pp. 1D and 6D.

Boule, M.E. and K.F. Bierly. 1987. History of estuarine wetland development and alteration: what have we wrought? *The Northwest Environmental Journal* 3(1): 43-61.

Carlton, J.T.. 1993. Biological invasions and biodiversity in the sea: the ecological and human impacts of nonindigenous marine and estuarine organisms. Keynote address. *In* Nonindigenous Estuarine & Marine Organisms Proceedings of the Conference & Workshop. National Oceanic and Atmospheric Administration: Seattle, WA. pp. 5-10.

Carlton, J.T.. 1995. Introduced marine and brackinsh water animals and plants of Coos Bay, Oregon (final draft). Biological Invasions Seminar. July 1995. Oregon Institute of Marine Biology: Charleston, OR. 9 pp.

Carlton, J.T. and J.B. Geller. 1993. Ecological roulette: the global transport of nonindigenous marine organisms. *Science* 261: 78-82.

Castro, P. and M.E. Huber. 1997. Marine Biology: 2nd Edition. Wm. C. Brown Publishers: Dubuque, IA. 450 pp.

Chadwick, D.H.. 1991. Introduction. *In* W.E. Hudson (ed.). Landscape Linkages and Biodiversity. Island Press: Washington, D.C.. pp. xv-xxvi.

City of Coos Bay. 9/18/98. "Vital Statistics." *Coos Bay, Oregon Fact Sheet.* http://www.coosbay.org/aboutcb/facts.html.

City of Coos Bay. Adopted 1987. Coos Bay Zoning Code. Coos Bay City Council: Coos Bay, OR.

City of North Bend. Adopted ~1985. North Bend Zoning Code. North Bend City Council: North Bend, OR.

Constanza, R., R. d'Arge, R. deGroot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. vandenBelt. 1996. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

Coos Bay BLM (Bureau of Land Management). 5/18/97. Color Aerial Photographs of the Coos Watershed. Scale 1 : 12, 000.

Coos County Planning Department. 1982. Coos Bay Estuary Management Plan. Map. Coos-Curry Council of Governments: Coquille, OR.

Coos County Planning Department. Adopted 1983. Coos County Zoning Code. Department of Land Conservation and Development: Coquille, OR.

Cornu, C. 4/25/96. Lecture on South Slough legacies from past land-use policy in Coos County. GEOG 510 - Environmental Policy and Landscape Change. Oregon Institute of Marine Biology.

Cortright, R., J. Weber, and R. Bailey. 1987. The Oregon Estuary Plan Book. Oregon Department of Land Conservation and Development: Salem, OR. 126 pp.

Couch, D. and T.J. Hassler. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest) -- Olympia oyster. U.S. Fish and Wildlife Service Biological Report 82(11.124). U.S. Army Corps of Engineers, TR EL-82-4. 8 pp.

Csuti, B.. 1991. Introduction to conservation corridors: countering habitat fragmentation. *In* W.E. Hudson (ed.). Landscape Linkages and Biodiversity. Island Press: Washington, D.C.. pp. 81-90.

Dahl, T.E. and C.E. Johnson. 1991. Status and Trends of Wetlands in the Conterminous United States, Mid-1970's to Mid-1980's. U.S. Department of the Interior, Fish and Wildlife Service: Washington, D.C.. 28 pp.

Dahl, T., J. Larson, and D. Scheidt. 1993. The United States - the lower "forty-eight." *In* P. Dugan (ed.). Wetlands in Danger: a World Conservation Atlas. Oxford University Press: New York, NY. pp. 70-75.

Department of Planning, Public Policy, and Management (University of Oregon). 4/25/97. "Goal 5: Open Spaces, Scenic and Historic Areas, and Natural Resources; Goal 16: Estuarine Resources; Goal 17: Coastal Shorelands." *Oregon's Land Use Planning Goals*. http://darkwing.uoregon.edu/~pppm/landuse/

Donnelly, A.. 1994. South Slough National Estuarine Research Reserve Management Plan. South Slough National Estuarine Research Reserve: Charleston, OR.

Donnelly, A.. 4/26/96. Lecture on the Coos Watershed. GEOG 510 - Environmental Policy and Landscape Change. University of Oregon.

Douthit, N.. 1981. The Coos Bay Region, 1890-1944, Life on a Coastal Frontier. River West Books: Coos Bay, OR. 163 pp.

Douthit, N.. 1986. A Guide to Oregon South Coast History. River West Books: Coos Bay, OR. 157 pp.

Eastman, D.C.. 1990. Rare and Endangered Plants of Oregon. Beautiful America Publishing Company: Wilsonville, OR. 194 pp.

Erwin, K.L.. 1991. An Evaluation of Wetland Mitigation in the South Florida Water Management District, Volume I. Final report. South Florida Water Management District: West Palm Beach, FL. 124 pp.

Fennessy, S. and J. Roehrs. 1997. A functional assessment of mitigation wetlands in Ohio: comparisons with natural systems. Ohio EPA Final Report to the U.S. Environmental Protection Agency. Ohio EPA: Columbus, OH. 84 pp.

Frenkel, R.E. and J.C. Morlan. 1991. Can we restore our salt marshes? Lessons from the Salmon River, Oregon. *The Northwest Environmental Journal* 7: 119-135.

Gaskill, T.. 4/24/97. "Site Description." *South Slough NERR Home Page*. http://inlet.geol.sc.edu/SOS/home.html.

Giles, M.. 1993. "Ten-minute Trail Guide." Pamphlet. South Slough National Research Reserve: Charleston, OR.

Glomb, S.. 1995. Protecting coastal ecosystems. *Endangered Species Bulletin* 20(5): 4-7.

Good, J.. 1987. Mitigating estuarine development impacts in the Pacific Northwest: from concept to practice. *Northwest Environmental Journal* 3(1): 93-111.

Graybill, M.. 12/2/96. Manager. South Slough National Estuarine Research Reserve. Charleston, OR. E-mail Interview. mgraybill@harborside.com. (541)888-5558.

Guard, B.J.. 1995. Wetland Plants of Oregon and Washington. Lone Pine Publishing: Redmond, WA. 239 pp.

Haagen, J.T.. 1989. Soil Survey of Coos County, Oregon. National Cooperative Soil Survey. USDA, Soil Conservation Service in cooperation with the Oregon Agricultual Experiment Station: Washington, D.C.. 269 pp.

Hamilton, S.. 1984. *Estuarine Mitigation: the Oregon Process*. Policy Statement. Oregon Division of State Lands: Salem, OR.

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest: An Illustrated Manual. University of Washington Press: Seattle, WA. 730 pp.

Hodder, J.. 5/5/98. Lecture on the Introduction of European Beachgrass into the Oregon Dunes. ENVS 410 - Coastal Environmental Issues. University of Oregon.

Hodder, J.. 1986. Activities at the Pony Slough mitigation site, April - July 1986. A report to the Oregon Division of State Lands and the Department of Land Conservation and Development. Charleston, OR. 8 pp.

Hodder, J. and M. Posey. 1987a. Monitoring activities at the Pony Slough mitigation site, April 1986 - January 1987. A report to the Oregon Division of State Lands and the Department of Land Conservation and Development. Charleston, OR. 17 pp.

Hodder, J. and M. Posey. 1987a. Monitoring activities at the Pony Slough mitigation site, April 1987 - September 1987. A report to the Oregon Division of State Lands. Charleston, OR. 15 pp.

Hoffnagle, J.. 1976. Site comparison. *In* Hoffnagle, J., R. Ashley, B. Cherrick, M. Grant, R. Hall, C. Magwire, M. Martin, J. Schrag, L. Stunz, K. Vanderzanden, and B. VanNess (eds.). *A Comparative Study of Salt Marshes in the Coos Bay Estuary*. National Science Foundation Student Originated Project. Oregon Institute of Marine Biology: Charleston, OR.

Jefferson, C.A.. 1974. Plant communities and succession in Oregon coastal salt marshes. Doctoral Dissertation. Oregon State University. 192 pp.

Kentula, M., J. Sifneos, J. Good, M. Rylko, and K. Kunz. 1992a. Trends and patterns in Section 404 permitting requiring compensatory mitigation in Oregon and Washington, USA. *Environmental Management* 16(1): 109-119.

Kentula, M.E., R.P. Brooks, S.E. Gwin, C.C. Holland, A.D. Sherman, and J.C. Sifneos. 1992b. An Approach to Improving Decision Making in Wetland Restoration and Creation. U.S. Environmental Protection Agency: Washington, D.C.. 151 pp.

Kukoy, S.J. and L.W. Canter. 1995. Mitigation banking as a tool for improving wetland preservation via Section 404 of the Clean Water Act. *The Environmental Professional* 17(4): 301-308.

Leibowitz, N.. 1995. Oregon's Wetland Consrevation Strategy. Oregon Division of State Lands: Salem, OR. 100 pp.

Leopold, A.. 1966. A Sand County Almanac. Ballantine Books: New York, NY. 295 pp.

Mack, M.C. and C.M. D'Antonio. 1998. Impacts of biological invasions on disturbance regimes. *Theoretical Research in Ecology and Evolotion* 13(5): 195-198.

Marsh, G.P.. 1864. Man and Nature. Reprinted 1965, D. Lowenthal (ed.). Belknap Press: Cambridge, MA. 472 pp.

McCabe, M.V.. 1998. Natural Resource Coordinator Field Operations. Oregon Division of State Lands. Salem, OR. Interviews. mike.mccabe@dsl.state.or.us. (541)378-3805.

Miller, J.A. and C.A. Simenstad. 1997. A comparative assessment of a natural and created estuarine slough as rearing habitat for juvenile chinook and coho salmon. *Estuaries* 20(4): 792-806.

Mitsch, W.J. and J.G. Gosselink. 1993. *Wetlands*. Van Nostrand Reinhold: New York, NY. 722 pp.

Mitsch, W.J. and R.F. Wilson. 1996. Improving the success of wetland creationand restoration with know-how, time, and self-design. *Ecological Applications* 6(1): 77-83.

Morlan, J.C.. 1990. Oregon Wetlands: Wetland Inventory User's Guide. Oregon Division of State Lands: Salem, OR. 11 pp.

National Research Council (U.S.). Committee on the Restoration of Aquatic Ecosystems -- Science, Technology, and Public Policy. 1991. *Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy*. National Academy Press: Washington, D.C.. 552 pp.

NOAA (National Oceanic and Atmospheric Administration). 4/30/96. "Population Estimates for Estuarine Drainage Areas and Coastal Drainage Areas." *Population and Development in Coastal Areas*. http://seaserver.nos.noaa.gov/projects/population/population_estimate.html.

Ochoco National Forest. 1997. "Watersheds: Their Importance and Functions." Pamphlet. U.S. Forest Service Pacific Northwest Region: Washington, D.C..

Pacific Estuarine Research Laboratory. 1990. A Manual for Assessing Restored and Natural Coastal Wetlands with Examples from Southern California. California Sea Grant Report No. T-CSGCP-021. La Jolla, CA. 105 pp.

Platt, R.H.. 1996. Land Use and Society: Geography, Law, and Public Policy. Island Press: Washington, D.C.. 505 pp.

Pojar, J. and A. MacKinnon (eds.). 1994. Plants of the Pacific Northwest Coast: Washington, Oregon, British Columbia, and Alaska. Lone Pine Publishing: Vancouver, BC. 527 pp.

Reed, P.B.. 1988. National list of plant species that occur in wetlands: Northwest (Region 9). 85 pp. *In*: Federal Interagency Committee for Wetland Delineation (eds.). 1989. Federal Manual for Identifying and Delineating Jurisdictional Wetlands. U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish & Wildlife Service, U.S.D.A. Soil Conservation Service, Washington, D.C.. Cooperative technical publication. 76 pp. plus appendices.

Reed, P.B.. 1993. Supplement to the national list of plant species that occur in wetlands: Northwest (Region 9). 24 pp. *In*: Federal Interagency Committee for Wetland Delineation (eds.). 1989. Federal Manual for Identifying and Delineating Jurisdictional Wetlands. U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, U.S. Fish & Wildlife Service, U.S.D.A. Soil Conservation Service, Washington, D.C.. Cooperative technical publication. 76 pp. plus appendices.

Roye, C.. 1979. Natural Resources of the Coos Bay Estuary - Estuary Inventory Report. Oregon Department of Fish and Wildlife, Research and Development Section: Salem, OR. 87 pg.

Rumrill, S.S. and C.E. Cornu. 1993. Restoration of estuarine tidelands in South Slough National Research Reserve. *Park Science* 13(4): 1, 4-6.

Rumrill, S.S. and C.E. Cornu. 1995. South Slough coastal watershed restoration: a case study in integrated ecosystem restoration. *Restoration & Management Notes* 13(1): 53-57.

Ryan, J.C.. 1994. State of the Northwest. Northwest Environmental Watch: Seattle, WA. 80 pp.

Salvesen, D.. 1994. Wetlands: Mitigating and Regulating Development Impacts. The Urban Land Institute: Washington, D.C.. 150 pp.

Satterlund, D.R. and P.W. Adams. 1992. Wildland Watershed Management: 2nd Edition. John Wiley & Sons, Inc.: New York, NY. 436 pp.

Shaich, J.A. and K.T. Franklin. 1995. Wetland compensatory mitigation in Oregon: a program evaluation with a focus on Portland Metro area projects. A report to the U.S. Environmental Protection Agency and Oregon Division of State Lands. Oregon Division of State Lands: Salem, OR. 51 pp.

Shaw, J.H.. 1985. Introduction to Wildlife Management. McGraw-Hill, Inc.: New York, NY. 316 pp.

Siry, J.. 1984. Marshes of the Ocean Shore. Texas A & M University Press: College Station, TX. 216 pp.

Simenstad, C.A. and R.M. Thom. 1996. Functional equivalency trajectories of the restored Gog-Le-Hi-Te estuarine wetland. *Ecological Applications* 6(1): 38-56.

Siuslaw National Forest. 1994. "Geology of the Oregon Dunes." Pamphlet. U.S. Forest Service Pacific Northwest Region: Washington, D.C..

Soule, M.E.. 1991. Theory and strategy. *In* W.E. Hudson (ed.). Landscape Linkages and Biodiversity. Island Press: Washington, D.C.. pp. 91-104.

Stedman, S. and J. Hanson. 1997. Wetlands, fisheries, and economics in the Pacific coastal states. National Oceanic and Atmospheric Administration (NOAA). *Habitat Connections* 1(1): 1-4.

Tear, L. and C. Cornu. 1994. Summary of year 1 monitoring -- summer 1994: Barview Wayside mitigation site, Charleston, Oregon. A report to the Oregon Department of Transportation and Oregon Division of State Lands. 19 pp.

Ternyik, W.E., M.J. Ternyik, and B.J. Guard. 1996. Wetland delineation report: Linda Shapiro property located on Day Creek, Coos County. Wetland Consultants: Florence, OR.

Turner, K. and T. Jones (eds.). 1990. Wetlands Market and Intervention Failures: Four Case Studies. Earthscan Publications Limited: London, England. 202 pp.

Weinmann, F., M. Boule, K. Brunner, J. Malek, and V. Yoshino. 1984. Wetland Plants of the Pacific Northwest. US Army Corps of Engineers: Seattle, WA. 85 pp.

Williams, M.. 1990. Protection and retrospection. *In* M. Williams (ed.). Wetlands: A Threatened Landscape. Blackwell Publishers: Oxford, England. pp. 323-353.

Williams, T.. 1996. What good is a wetland? *Audobon* 6: 42-53, 98-100.

UN Conference (United Nations). 1992. United Nations Conference on Environment and Development. United States National Report. 423 pp.

USEPA (U.S. Environmental Protection Agency). 4/9/99. "Coos Watershed Indicators -- 17100304." *Watershed Heath (IWI).* http://www.epa.gov/surf2/hucs/17100304/score.html.

USF& WS (U.S. Fish and Wildlife Service). 1989a. Charleston, OR Quad. National Wetlands Inventory. Region I: Portland, OR.

USF& WS (U.S. Fish and Wildlife Service). 1989b. Coos Bay, OR Quad. National Wetlands Inventory. Region I: Portland, OR.

USF& WS (U.S. Fish and Wildlife Service). 1989c. Empire, OR Quad. National Wetlands Inventory. Region I: Portland, OR.

USF& WS (U.S. Fish and Wildlife Service). 1989d. North Bend, OR Quad. National Wetlands Inventory. Region I: Portland, OR.

USF&WS (U.S. Fish and Wildlife Service). 1994. "Salmon of the Pacifc Coast." Pamphlet. U.S. Fish and Wildlife Service, Pacific Region: Portland, OR.

USGS (U.S. Geological Service). 1970a. Charleston, OR Quad. 15 minutes. N4315-W12415/7.5.

USGS (U.S. Geological Service). 1970b. Empire, OR Quad. 15 minutes. N4322.5-W12415/7.5.

USGS (U.S. Geological Service). 1971a. Coos Bay, OR Quad. 15 minutes. N4315-W12407.5/7.5.

USGS (U.S. Geological Service). 1971b. North Bend, OR Quad. 15 minutes. N4322.5-W12407.5/7.5.

Zedler, J.B. 1996. Ecological issues in wetland mitigation: an introduction to the forum. *Ecological Applications* 6(1): 33-37.

Zedler, J.B. and A.N. Powell. 1993. Managing coastal wetlands: complexities, compromises, and concerns. *Oceanus* 36(2): 19-29.