OCS Study
MMS 90-0076

A Study of Marsh Management Practice in Coastal Louisiana

Volume II: Technical Description

U.S. Department of the Interior
MMS Minerals Management Service
Gulf of Mexico OCS Region

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Editors

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PREFACE

The role of marsh management in combatting wetland loss has been viewed with increasing importance in recent years. During the 1980s there was a dramatic increase in the use of marsh management techniques to mitigate coastal wetland loss in Louisiana. The popularity of this technique as a mitigative tool is indicated by the number of marsh management projects submitted for consideration in the Governor's Coastal Wetlands Conservation and Restoration Plan, which was approved in March of this year. However, there is growing concern about the potential environmental impacts, particularly cumulative impacts, of this type of wetland management. Because of this concern, the U.S. Army Corps of Engineers is developing a programmatic environmental impact statement on marsh management in coastal Louisiana. At public scoping meetings held in February 1988, the Corps of Engineers determined that public opinion about the effectiveness and environmental impacts of marsh management varies widely.

This study is the first detailed review and analysis of the effectiveness of marsh management in coastal Louisiana. The findings will be incorporated into the Corps of Engineers' programmatic environmental impact statement. While no single study provides all the answers, we hope that these results will clarify many of the issues raised at the scoping meetings. Management policies should be based on objective, scientific data. The information gathered during this study will be useful in refining and revising current management policies and will contribute to the better management of our wetland resources.

Donald R. Cahoon
C. G. Groat
Louisiana Geological Survey
December 1990

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ACKNOWLEDGMENTS

Project Management

We were assisted in this project by a technical steering committee of regulatory agency personnel, private landowners practicing marsh management, and university researchers. We are much indebted to the members of this committee, who gave their time to provide us expert advice on marsh management activities, techniques, research needs, and site selection, and critically reviewed the draft version of this report. The members of the committee were:

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PART I

INTRODUCTION

Chapter 1

INTRODUCTION TO THE STUDY

Donald R. Cahoon and Charles G. Groat
Louisiana Geological Survey

The severity of coastal Louisiana's wetland loss has been well documented (see Turner and Cahoon 1987 for a review). The losses are primarily the result of hydrologic and sedimentologic imbalances in a rapidly subsiding coastal environment stemming from numerous and diverse natural (e.g., subsidence and sea level rise) and human (e.g., canals) causes. Attempts to mitigate the loss of wetlands are focusing on managing water levels and flows and sediment distribution. One popular method for mitigating wetland loss employed on a sub-basin scale is marsh management. This technique is based primarily on controlling water levels in a tract of marsh by means of levees (i.e., spoil banks) and water control structures.

Because of growing concern about the potential environmental impacts (particularly cumulative ones) of this type of water-level management, the U.S. Army Corps of Engineers is developing a programmatic environmental impact statement on marsh management in coastal Louisiana. During public scoping meetings for the environmental impact statement in February 1988, the Corps of Engineers identified many socioeconomic and environmental issues related to the effectiveness of marsh management (U.S. Army Corps of Engineers 1988). The public was split in its position on marsh management; opinions ranged from "the cure may be worse than the disease" to "marsh management is the landowners' best available solution to the wetland loss problem." The public's principal recommendations for marsh management study as expressed in the scoping document (but not in order of importance) are:

1) Emphasize the importance of maintaining fresh and intermediate marsh;

2) Assess the impacts of marsh management on hydrology, sediment transport, nutrient levels, and overall water quality;

3) Assess the impacts of marsh management on freshwater and marine fisheries, particularly ingress and egress;

4) Assess the impacts of marsh management on such wildlife as waterfowl, furbearers, and alligators;

5) Evaluate the impacts of marsh management by marsh type;

6) Assess the cumulative impacts of marsh management; and

7) Evaluate future conditions without marsh management (no action) (U.S. Army Corps of Engineers 1988).

In the fall of 1987, the U.S. Minerals Management Service requested a scope of work from the Louisiana Department of Natural Resources, Louisiana Geological Survey, to conduct a study of marsh management, which included many of the issues raised at the Corps of Engineers' scoping meetings in February 1988. The purpose of this study, which commenced in spring 1988, was to determine which marsh management techniques are best suited to the heterogeneous environmental conditions and human impacts present in coastal Louisiana. This knowledge would improve our understanding of how best to reduce or reverse wetland loss and preserve and improve existing marsh. This study was designed to be comprehensive in that it analyzes many of the legal, policy, regulatory, and environmental issues related to marsh management. Specifically, legal and policy aspects of marsh management, secondary literature sources, environmental conditions of the coast, the extent and type of existing marsh management endeavors, and existing environmental monitoring data were reviewed; and new monitoring data were collected. The results of this study will be available to the Corps of Engineers for use in their environmental impact statement. The study area encompassed the entire Louisiana coastal zone, which lies along the north-central Gulf of Mexico (figure 1).

HISTORY OF MARSH (WATER-LEVEL) MANAGEMENT IN LOUISIANA

Weirs

Water-level management (excluding drainage for agriculture) in the marshes of Louisiana apparently began in the early 1940s with the construction of weirs (low dams) in access ditches used for hunting and trapping (O'Neill 1949). Weirs allowed the marsh to flood during high tides but prevented the ditches from completely draining the marsh at ebb tide. Thus weirs prevented vegetative changes associated with excessive drainage. The use of weirs increased during the 1940s and 1950s; the peak of construction activity occurred from 1955 to 1965 (Nyman 1989), mostly in intermediate and brackish marshes. By 1967, approximately 100,000 hectares (ha) of coastal marsh were being managed by weirs (Herke 1968). Weirs were used extensively to counteract changes in water levels and flows and water salinity caused by an ever-growing network of canals. The purpose of the weirs was to reduce salinity, stabilize water levels, minimize turbidity, and restrict the rate of tidal exchange (Perry and Joanen 1986). Weirs are effective at stabilizing water levels but they affect salinity and turbidity only slightly, if at all (Chabreck and Hoffpauir 1962; Turner et al. 1989). However, production of aquatic vegetation suitable for waterfowl food is often enhanced by weirs (Chabreck 1968).

Marsh Impoundments

In an attempt to improve waterfowl habitat and revegetate deteriorated zones of marsh, Rockefeller Refuge began constructing impoundments in its marshes in 1954 (Chabreck 1960, 1962; Wicker et al. 1983). "A marsh is considered impounded when completely surrounded by elevated land, including levees and natural ridges, that restricts water movement between the marsh and adjacent drainage systems" (Chabreck 1988:82). Water is added or removed from the impounded marsh via water-control structures (e.g., weirs, culverts, pumps) located in drainage channels. The impoundments were designed to prevent saltwater intrusion and

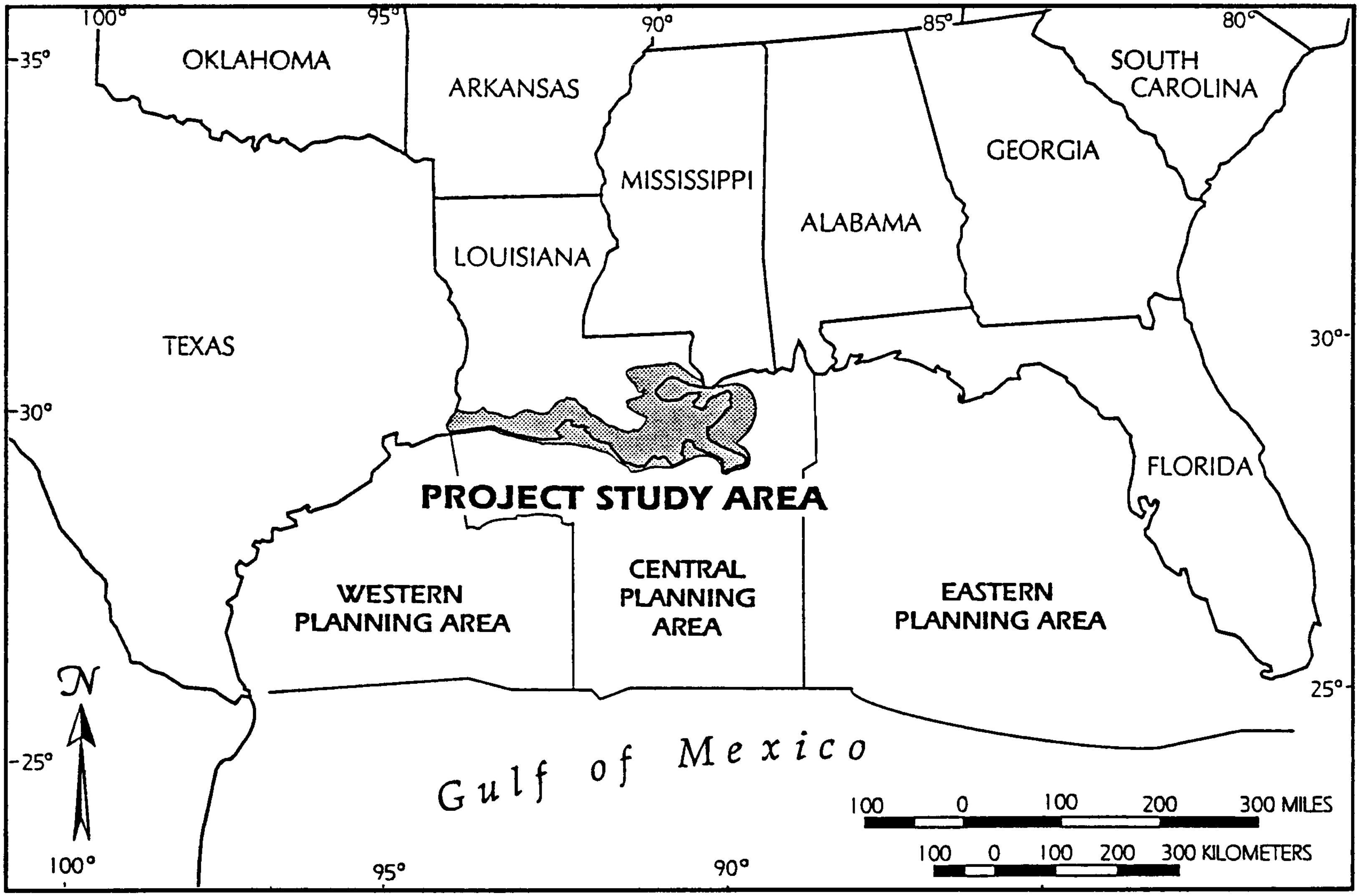

Figure 1. Study area (stippled) in relation to the Gulf of Mexico region.

encourage the growth of plants for duck food. During the 1950s and early 1960s three types of impoundments were constructed at the refuge: permanently flooded brackish water, permanently flooded fresh water, and manipulated fresh water (Chabreck 1962). The impoundments were managed to maintain the species composition of the marsh vegetation and a marsh:water ratio beneficial to waterfowl production (i.e, to maintain open-water ponds, aquatic vegetation, and emergent marsh). Some of the manipulated impoundments have been managed for multiple use (i.e., waterfowl and shrimp).

Marsh impoundments are closed systems that provide a mechanism for controlling water depth and salinity (Chabreck et al. 1989). They are most commonly used to manage marshes to improve wildlife habitat (Chabreck 1988; Chabreck et al. 1989). Because wildlife, especially waterfowl, depend on specific plant species for food and shelter, marsh management should maintain water levels and salinity within the ranges that are best for target wetland plant species. In the face of saltwater intrusion, this means maintaining existing fresh, intermediate, and brackish marsh zones and/or creating lower-salinity vegetation zones by converting one marsh type to another (e.g., changing brackish marsh to intermediate marsh).

Chabreck (1988:83) reviewed the literature on the effectiveness of marsh impoundments and noted that, to provide benefits for wildlife, impoundments can "...induce germination and growth of annual plants (Chabreck 1960; Baldwin 1968); attract birds to available food supplies (Sanderson and Bellrose 1969; Chabreck et al. 1974); control mosquitoes, fish, and undesirable plants (Provost 1968; Chabreck 1960; Carney and Chabreck 1978); reduce water turbidity and promote growth of aquatic plants (Chabreck 1960); improve duck-brooding habitat (Allen 1981); enhance production of crayfish (Perry et al. 1970); and improve habitat and food supplies for fur-bearing animals and alligators (Chabreck 1980)." Because of the benefits to wildlife, this form of water-level management has become widely adopted in coastal Louisiana (Bourgeois et al. 1989). Since its first use at Rockefeller Refuge, suitable impoundment techniques for managing water levels have been developed by trial and error. Various flooding regimes have been described for the encouragement of vegetation beneficial to waterfowl in fresh marshes (Frederickson and Taylor 1982; Perry 1987) as well as brackish and saline marshlands (Prevost 1987).

Mitigating Wetland Loss

Wetlands are open systems with direct connections from marsh zone to marsh zone, marsh to estuary, river to marsh and estuary, uplands to marsh and estuary, and marsh and estuary to the Gulf, as well as intercontinental links via migratory waterfowl (Gosselink 1984). These open connections between upland, coast, and ocean are the reason wetlands are among the most productive ecosystems in the world (Odum 1971). The extensive network of canals and their associated spoil banks in coastal Louisiana has increased the direct hydrologic links and rate of water exchange between interior marshes and the estuary (i.e., bays and the Gulf of Mexico), different marsh types (e.g., saline and fresh marshes), and hydrologic basins and sub-basins. These artificial linkages may contribute to imbalances between fresh and salt water, increased tidal amplitude, altered sediment distribution patterns, altered water levels in the marsh, and changes in the normal duration of flooding (see Turner and Cahoon 1987 for a review).

Such hydrologic and sedimentologic alterations in the rapidly subsiding environment of coastal Louisiana contribute, at least in part, to wetland loss.

Structural marsh management is being employed to mitigate wetland loss associated with these hydrologic alterations because it creates a closed system --one in which hydrologic exchanges are severely reduced or periodically eliminated. Controversy has developed over the use of this management technique because of concern that necessary hydrologic connections are being severed and open systems are being replaced by closed ones in increasingly larger portions of the coast. On the other hand, landowners want to combat saltwater intrusion and stop ecologic and economic deterioration by restoring more natural hydrologic conditions on their pieces of the altered open system. This controversy is fueled by limited documentation of and a lack of long-term databases on the effectiveness of structural management (Wicker 1983).

Structural marsh management and particularly marsh impoundments have been proposed to mitigate the impacts of saltwater intrusion and increased tidal amplitude. Because weirs and levees reduce the rate of water exchange between marshes and waterways, it is thought that structural management may retard saltwater intrusion, decrease the physical or erosive impact of amplified tides, and restore more natural hydrologic conditions to marsh altered by canals. Therefore, the closed systems being used to manage wildlife habitat are also intended to mitigate the loss of wetlands. Profit gained from the harvest of wildlife resources provides an added incentive to landowners to employ this type of management because they must bear the costs.

Critics of this approach caution that because weirs and levees reduce water exchange, they may restrict sediment distribution and accumulation, increase plant stress due to waterlogging of the soil, and decrease the overall primary productivity of the marsh. If so, vertical accretion in the marsh will be reduced; in the rapidly subsiding environs of coastal Louisiana this may damage the health of the managed marshes and the marshes influenced by levees and lead to increased wetland loss.

This controversy will only be resolved when the influence of structural management on water salinity, water levels and flows, plant growth and species composition, nutrient cycling, soil development, and sediment distribution and accumulation within a managed marsh and marshes within the surrounding basin has been determined. This study is the first comprehensive analysis of the effects of structural marsh management as it is employed in coastal Louisiana.

STUDY APPROACH

Project Goal

The goal of this study was to prepare a factual array of data and analysis to determine the suitability of marsh management techniques as tools for mitigating wetland loss.

Project Organization

The project was managed by the Louisiana Department of Natural Resources (Louisiana Geological Survey and Coastal Management Division) and Louisiana State

University. Administrative responsibilities included data management and archiving, report and budget coordination, methodology development and experimental design, and establishing a technical steering committee as an advisory group to project investigators and the U.S. Minerals Management Service on the development of data needs and experimental designs.

The technical steering committee was composed of knowledgeable personnel representing all facets of marsh management: each agency involved in regulating marsh management activities (the Louisiana Department of Wildlife and Fisheries, the U.S. Fish and Wildlife Service, National Marine Fisheries Service, the U.S. Environmental Protection Agency, and the Corps of Engineers) (the Louisiana Department of Natural Resources was represented through project administrative staff); the U.S. Soil Conservation Service has extensive knowledge of marsh management techniques and advises landowners on land use practices; two landowners (Vermilion Corporation and Fina LaTerre, Inc.); and wetland researchers from the Louisiana State University and Louisiana Cooperative Fish and Wildlife Research Unit. This diverse group of experts was directly involved in developing the monitoring program by assisting in the selection of field sites, identifying regulatory issues, and defining marsh management activities. The committee also reviewed and provided comments on draft versions of each chapter of the report.

The project goal was achieved by compiling and analyzing existing data, identifying data needs, collecting and analyzing new data, and reviewing and synthesizing all information. The project and this report were organized into six components related to these three tasks: (1) a review of marsh management literature; (2) an analysis of legal and policy issues; (3) a description of structural management techniques; (4) a description of the environmental characteristics of the coast; (5) an evaluation of marsh management effectiveness based on a review of existing field data and newly collected field data; and (6) an ecological evaluation of the effectiveness of marsh management based on its biological effects and suitability for coastal Louisiana.

The review of literature (primarily secondary sources) was aimed at determining the current state of knowledge and identifying those topics for which data needs exist. The legal review presents an analysis of the administrative framework, regulatory procedures, and constraints in which marsh management occurs. The policy review explains the public interest goals of marsh management as reflected in agency policy. The structural management techniques section identifies, describes, and evaluates the effectiveness of engineering and construction techniques currently being used, including recently developed methods. The section on environmental characteristics of the Louisiana coastal zone describes the conditions in which marsh management is occurring, including factors affecting management feasibility and the current intensity of management. The evaluation of marsh management effectiveness is based on a review of existing monitoring data and an analysis of newly acquired aerial imagery and field monitoring data.

Terminology

Marsh management encompasses a wide variety of techniques including structural measures, marsh burning, and the use of chemicals to control unwanted vegetation. However, the primary controversy stems from concern over the use of structures to control water levels. These concerns, as stated at the scoping meetings (U.S. Army Corps of Engineers 1988), include environmental impacts, human access, and mariculture-related activities, among others. But the primary concern of structural management was environmental impacts. Consequently, for the purpose of this study, marsh management is defined as **the use of structures to manipulate local hydrology for the purpose of reducing or reversing wetland loss and/or enhancing productivity of natural renewable resources.**

The marsh management literature contains terms commonly used to describe marsh management activities. Some of these terms are used to describe more than one management technique and some techniques are described by more than one term. To reduce confusion, the terms used in this report are defined below. Figure 2 illustrates each management technique.

Weir Management

This term describes water-level management achieved by the use of weirs (mostly fixed-crest but occasionally variable-crest or gated structures) without accompanying levees. Weir management with fixed-crest weirs reduces channel flows (actual flow depends on the tide and ranges from zero to the reduced, fixed maximum rate), prevents complete de-watering of marsh ponds, but does not eliminate hydrologic exchange with adjacent marshes via surface and subsurface flows. Because the crest height is permanently fixed, management with fixed-crest weirs is considered passive water-level control. Use of variable-crest or gated weirs would provide a limited drawdown capability and would be called active water-level management. Weir management has also been called semi-impoundment in the literature.

Manipulated Impoundment

Water-level management achieved by a combination of levees and water control structures (typically variable-crest, gated structures) is called manipulated impoundment. This management technique reduces channel flows, but the rate of flow can be varied so that water levels can be drawn down or held at a prescribed level. Therefore, in contrast to weir management, this type of management is considered to be active water-level control. Hydrologic exchange with adjacent marshes via marsh surface and marsh subsurface flows is eliminated (except for possible subsurface flows under the levees and surface flows over the levees during storms). The presence of levees makes it possible to capture precipitation as a means of regulating water and soil salinity. This technique includes pumped impoundments, and has also been called semi-impoundment and impoundment in the literature.

Unmanipulated Impoundment

The use of levees without water control structures to manage water levels is called unmanipulated impoundment. This type of management is very rare and has not been implemented in many years. Except for the possible effects of subsurface seepage and storms, this type of management eliminates all hydrologic exchange between the managed and adjacent marsh, and therefore is referred to as passive water-level control. These impoundments capture rainwater and their water levels vary with the water table. This technique has also been called

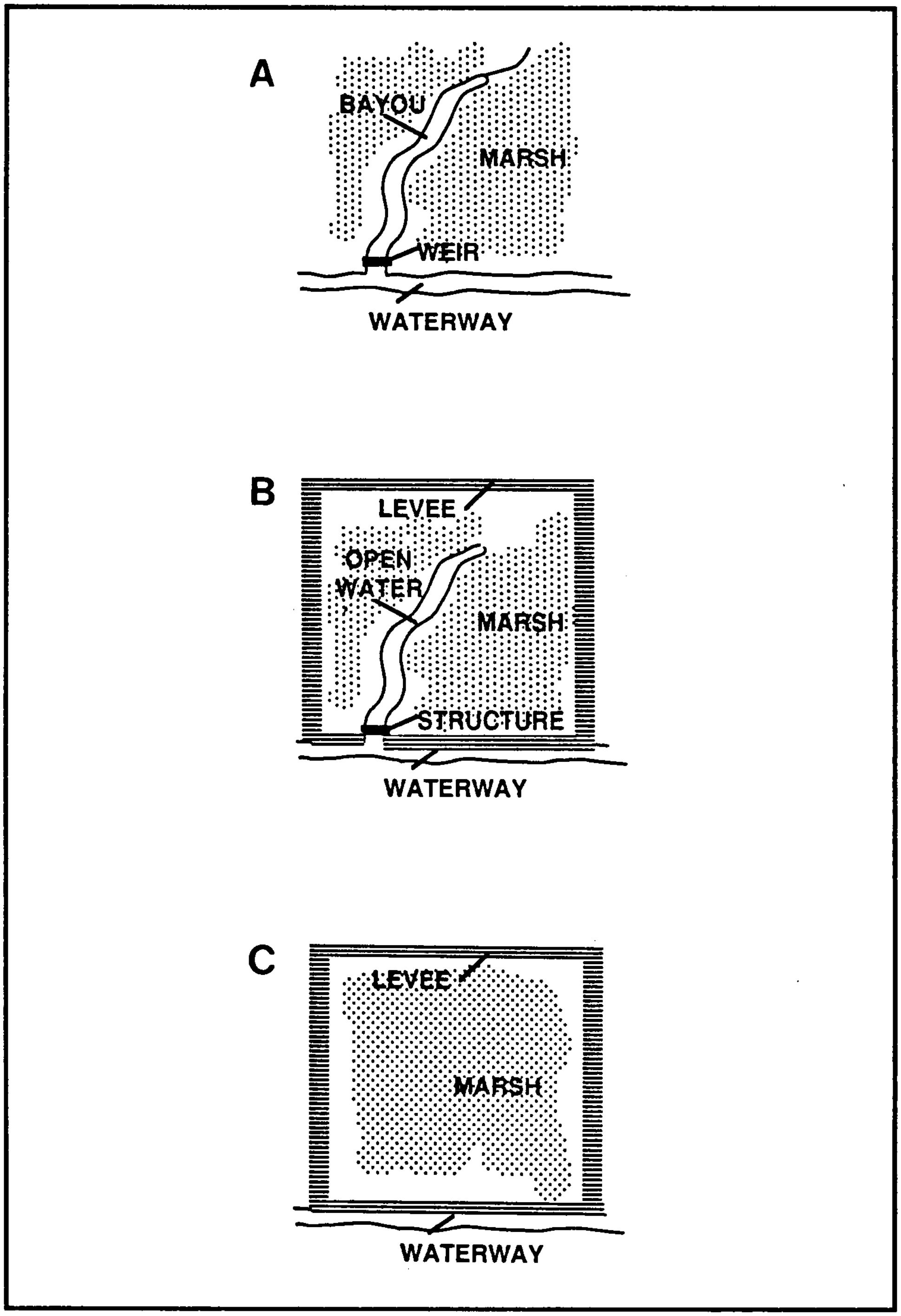

Figure 2. The three basic types of structural marsh management techniques: (A) weir management, (B) manipulated impoundment, (C) unmanipulated impoundment.

permanently flooded impoundment in the literature. This type of impoundment was not evaluated in this study because it is not currently recommended by the regulatory agencies and it has rarely been used.

<u>Unintentional Impoundment</u>

This term describes the partial (two- or three-sided) or complete impoundments that result from the unplanned interaction of levees, spoil banks, roads, natural ridges, etc. Unintentional impoundments can affect water levels and flows, and have also been called semi-impoundments in the literature. Because they are unintentional artifacts of development, rather than management techniques, these impoundments were not evaluated in this study, although some of the results may be applicable to them.

Chapter 2

REVIEW OF SECONDARY DATA SOURCES

Richard D. Hartman
Donald R.Cahoon
Louisiana Geological Survey

INTRODUCTION

Marsh management can take many forms (see the introduction to this study for definitions of structural and chemical management, as well as techniques involving burning and planting). Structural marsh management utilizes fixed or variable-crest weirs, plugs, culverts, flap gates, pumps, and levees as tools to manage local marsh hydrology to achieve some expected benefit. Because structural management involves substantial physical alteration to the environment, is expensive, has met with mixed success, and requires state and federal permits, the requests to develop structural management plans often arouse much more controversy than do other forms of marsh management. For this reason, we have concentrated this review of marsh management literature on structural management techniques.

Many articles and reports concerning structural marsh management have been written by university researchers, private consultants, and personnel of various local, state, and federal agencies. Much of this literature is in the form of unpublished or little-circulated government documents and symposia proceedings. To assist in evaluating structural marsh management, all literature pertinent to the subject was collected and annotated. The resulting bibliography that follows will facilitate access to information on structural marsh management by bringing to light many publications not widely distributed and by cataloging all pertinent information to date.

METHODS

Citations pertinent to structural marsh management were identified by using computerized literature searches, by perusing journals known to contain marsh management articles, by searching "Literature Cited" sections of articles related to marsh management, by contacting personnel in government agencies involved in marsh management, and by interviewing researchers working on the ecology of coastal marshes.

After a potential marsh management citation was identified, a copy of the article was obtained, read, and its relevance to the definition of structural marsh management, as described above, was determined. All literature pertinent to any aspect of structural marsh management was identified and selected for summarization. Many articles were identified that related to aspects of marsh management that were not structural by definition and so were not summarized. The topics of those articles include regulatory guidelines (catch limits, drilling guidelines, etc.), freshwater diversions, marsh burning, bank stabilization, sediment fencing, beach nourishment, vegetative plantings, and marsh creation.

Many of the articles and reports chosen for summary include information on topics other than structural marsh management. In these cases the contents are described, but only data concerning structural marsh management are summarized. When articles contain multiple conclusions relating to structural management, only the primary and most general of these conclusions are included.

CITATION SUMMARY

Approximately 150 citations relating to structural marsh management were selected for summarization (see chapter 17). Computerized literature searches produced relatively few of these citations, because most publications dealing with marsh management were in narrowly circulated journals or "grey" literature and therefore not readily accessible to the various citation services. Most citations were discovered using other methods listed above, all of which produced about the same number of usable citations.

All citations pertinent to structural marsh management in Louisiana are summarized, as well as a few representative articles from elsewhere in the southeastern United States. Approximately 75% of the citations contain results of research done in Louisiana, and about 15% are from work done in South Carolina, followed by Florida (5%), and all other states combined (5%).

Articles selected for summarization are of two general types: those resulting from research done in managed areas and those containing general discussions or recommendations concerning structural marsh management. Approximately 65% of these citations contain research results, while the remainder discuss structural management strategies for a particular area, describe marsh management tools and techniques in general, or discuss marsh management guidelines. Research papers typically report on the effects that some type of marsh management structure (weirs, plugs, impoundments, etc.) has on environmental variables.

Impoundment (combining levees or spoil banks with some type of water control structure to allow complete control over the hydrology of a marsh) is the most frequently reported technique, comprising 45% of the summarized articles. Research on fixed-crest weirs follows at 25%, and another 25% either discuss several structural management techniques or do not differentiate between management strategies.

The effects of structural management on fisheries are reported in 30% of the selected citations, followed by management effects on vegetation (20%), water quality (15%), and waterfowl and wildlife (10% each).

The School of Forestry, Wildlife, and Fisheries at Louisiana State University produced approximately 30% of the summarized citations (mostly research findings), followed by the Soil Conservation Service, Louisiana State University Center for Wetland Resources, Coastal Environments Inc., and South Carolina Sea Grant, with about 10% of the citations each. Personnel of the Louisiana Department of Wildlife and Fisheries were responsible for 7% of the citations.

Data Needs

Several topics important to an evaluation of structural marsh management have not been adequately researched and reported on. These topics are:

1) the effects of various structural management techniques on land loss, sediment deposition, subsidence, plant health, and target species, as determined from a comparison of managed with nearby, unmanaged areas;

2) the cumulative impacts of structural management on hydrologic processes, land loss, and secondary productivity (e.g. fisheries, waterfowl, or furbearers on the basin and sub-basin level);

3) the development of management tools and techniques designed to maximize marine fisheries access while reducing land loss, providing beneficial wildlife habitat, or preventing saltwater intrusion;

4) the environmental effects of operational failure or abandonment of the management plan; and

5) the identification and evaluation of factors affecting the success and cost-effectiveness of structural marsh management.

Data on the above topics are needed to evaluate structural marsh management. A discussion of each topic follows.

The effects of structural management on land loss, a primary reason for management, have been reported in only 6% of the literature. This 6% represents the annual monitoring reports of a few years of management on a few areas. Sediment deposition and subsidence, factors related to land loss, have never been quantified in structurally managed marshes. Plant health and the abundance of various target species (fisheries, waterfowl, wildlife, and/or vegetation) have been described in managed areas, but often the authors have not compared their results to those from similar, unmanaged marshes. Some studies have compared target species abundance in managed versus unmanaged areas, but this has not been done for every form of structural management. Land loss, sedimentation, subsidence, plant health, and the abundance of various target species should be quantified in areas managed with various structural tools and techniques and compared with those from nearby, unmanaged marshes. Only then can the effectiveness of structural management be scientifically determined for those variables and its usefulness as a mitigation tool evaluated.

The cumulative impacts of structural management have not yet been determined for any of its forms. The effect that structural management of large areas in the coastal zone has on surrounding or nearby unmanaged areas by altering the hydrological forces acting on these areas is not known. The cumulative and long-term effects on fisheries, waterfowl, and furbearer productivity are also not understood.

Methods used to maximize fisheries access while controlling land loss and maintaining beneficial waterfowl habitat need to be quantitatively evaluated. Various structural tools and techniques and their coincident effects on fisheries, land loss, and vegetation should be studied and quantified.

The effects of abandonment of structural management have not been investigated. Turner and Neill (1983) reported that 82% of wetland areas leveed and drained for agriculture in the early 1900's are now partially or wholly open water. Many modern marsh management plans implemented in the 1980's to control hydrologic exchange are no longer managed or manageable (see chapter 7 of this study). It is not known if land loss, habitat type, or productivity in marshes that were previously hydrologically managed but presently unmanaged differ from nearby, natural marshes.

An evaluation of factors that affect the success and cost-effectiveness of structural management should be undertaken. Environmental factors causing management plan failure are not understood. Also, what effect environment has on the expense of constructing and maintaining structures is not well quantified. The costs of installing and maintaining various management structures and techniques must be determined and compared among environmental variables and those costs quantified for the naturally occurring range of each factor.

PART II

LEGAL AND POLICY REVIEW

Chapter 3

ADMINISTRATIVE FRAMEWORK

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INTRODUCTION

Over the last 15 years much attention has been focused on Louisiana's coastal erosion problems. One outgrowth of concern for the state's coastal resources has been the idea of using marsh management to help control land loss and to prevent further depletion of fish and wildlife populations. This chapter examines how marsh management practices fit within federal and state regulatory frameworks that affect the coastal areas, identifies potential conflicts in regulatory mandates and policies, and discusses the status of state property law as it affects both public and private ownership of wetlands.

Because a myriad of activities are carried out in the name of marsh management, the first step is to define the term. "Marsh management" has been defined for this project as the use of structures to manipulate local hydrology for the purpose of reducing or reversing wetland loss and/or enhancing productivity of natural renewable resources.

Although this definition does not encompass all of the activities traditionally associated with marsh management, it does address most of the current policy considerations and goals. This definition is now or probably will become standard for the regulatory agencies that evaluate proposed marsh management plans; therefore, it will be the focus here, although other management techniques will be examined in less detail.

This discussion is also limited to marsh management plans for privately owned land. Because different laws apply to federal and state wildlife refuges, marsh management in these areas will not be discussed.

Certain terms that will be used repeatedly in this report are defined as follows:

Legislation--enactments of a legislature that become laws.

Law--statutes established by enactments of a legislature or court decisions that have binding legal precedent. In Louisiana, statutory law is supreme over judicial decisions.

Regulations--a rule or order of an administrative agency that has been established and promulgated in accordance with the required state or federal administrative procedures. The rule or order may establish internal operating procedures for the agency or substantive requirements for those affected by the agency's actions. Regulations duly established and promulgated are essentially laws. Regulations differ from laws in that regulations may be changed or amended by the administrative agency (following proper administrative procedure and, in Louisiana, subject to legislative approval), whereas laws may be changed or amended only by the legislature. Additionally, when there is a direct conflict between a law and a regulation, the law takes precedence.

Formal procedures--agency procedures and requirements that are regulations.

Informal procedures--agency procedures and requirements that have not been established and promulgated in accordance with the required state or federal administrative procedures. These are customary operations of the agency.

Guidance--information and advice provided by an administrative agency to a member of the public. The guidance may either explain agency procedure or provide technical information.

AGENCY ROLES AND RESPONSIBILITIES

Permitting and Commenting Agencies

This section will discuss the roles and responsibilities of the various agencies affecting marsh management as mandated by the laws they administer and under which they operate. Other roles and responsibilities of these agencies that do not affect marsh management will not be covered. Most of the agencies discussed herein can be classified as either permitting or commenting agencies. Permitting agencies are those that have been given the authority to regulate activities associated with marsh management by requiring permits for those activities. These agencies may either grant or deny permits on the basis of statutorily mandated requirements and guidelines.

Commenting agencies are those given the authority, either by statute or interagency agreement, to comment favorably or unfavorably on whether or not permits should be granted for proposed activities. Although permitting agencies are usually required to consider the comments of the commenting agencies, they are not required, with a few exceptions, to follow the recommendations in the comments. The interaction between permitting and commenting agencies can be complex and is discussed in more detail in the section entitled "Permit Requirements and Application Procedures."

Federal Agencies

U.S. Army Corps of Engineers

The Corps of Engineers' general mandate is the planning, construction, maintenance, and operation of certain federal civil works, such as flood control, navigation improvement, surveying, and mapping. The Corps of Engineers is the permitting agency for §9 and §10 of the Rivers and Harbors Act of 1899, 33 U.S.C. §401 and 403 (1989), and for §404 of the Federal Water Pollution Control Act of 1972, as amended in 1977 and 1987 (also known as the Clean Water Act), 33 U.S.C. §1344 (1989).

The agency also has responsibilities under the Rivers and Harbors Act of 1899: to review and decide whether or not to approve plans for the building of dams, dikes, wharfs, piers, dolphins, booms, weirs, breakwaters, bulkheads, jetties, or other structures, or to excavate or fill or make other alterations in the navigable waters of the United States. The Corps of Engineers' responsibilities under §404 of the Federal Water Pollution Control Act are to review applications and issue permits for the disposal of dredged or fill material into waters of the United States with guidance from the Environmental Protection Agency.

<u>Environmental Protection Agency</u>

The agency's general mandate is to permit coordinated and effective governmental action to assure the protection of the environment by abating and controlling pollution on a systematic basis through research, monitoring, setting standards, and enforcement activities related to pollution abatement and control. It provides for the treatment of the environment as a single interrelated system and administers, among other laws, the Federal Water Pollution Control Act and the Clean Air Act.

The Environmental Protection Agency's responsibilities under the Federal Water Pollution Control Act are to administer the provisions of the act (permitting agency), including the setting and enforcement of water quality standards and effluent limitations. This agency is also responsible for establishing guidelines to be used by the Corps of Engineers in the permitting decisions for the disposal of dredged or fill material, and has the authority to veto Corps of Engineers dredge-and-fill permitting decisions and oversight authority for federally approved state water quality programs.

<u>U.S. Fish and Wildlife Service</u>

The U.S. Fish and Wildlife Service's general mandate is to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of the American people by providing leadership for the protection and improvement of land and water environments that directly benefit the living natural resources and add quality to human life.

The agency's responsibilities as a commenting agency under the Fish and Wildlife Coordination Act (16 U.S.C. §662 and §663 (1989)), are to review proposed alterations to any water body by an agency of the federal government and to make comments and recommendations on the proposed alteration. The comments, usually directed to §404 Federal Water Pollution Control Act permits and §9 and §10 Rivers and Harbors Act permits, must be given full consideration by the permitting agency and incorporated into any reports to Congress or any other overseeing agency. The comments concern a project's effect on fish and wildlife resources for which the service has responsibility.

The service's responsibilities under the Endangered Species Act of 1973, as amended in 1988, 16 U.S.C. §1531-1543 (1989), are to act as the permitting agency responsible for designating species of animals and plants as threatened or endangered, promulgating regulations to protect them, enforcing such regulations and prohibitions of the act, and permitting exceptions. The responsibilities are shared with the National Marine Fisheries Service, which has jurisdiction over marine fish and wildlife.

National Marine Fisheries Service

The general mandate of the National Marine Fisheries Service is "to achieve a continued optimum utilization of living marine resources for the benefit of the Nation" and to hold "Federal responsibility for the conservation, management, and development of living marine resources and for the protection of certain marine mammals and endangered species under numerous Federal laws." 489 Fed. Reg. 53142 (1983).

Under the Fish and Wildlife Coordination Act, the commenting authority of the National Marine Fisheries Service is identical to that of the Fish and Wildlife Service, but is limited to its own area of jurisdiction. Under the Endangered Species Act, its permitting authority is the same as that of the Fish and Wildlife Service, but is limited to its area of jurisdiction (marine fish, mammals, birds, reptiles, and other wildlife during the aquatic phases of their life cycles).

The service's responsibilities under the Magnuson Fishery Conservation and Management Act of 1976, as amended in 1986, 16 U.S.C. §§1801-1882 (1989), are to serve as a voting member of the regional fishery management councils established under the act (see below) and, through such representation, to promote policies (including habitat protection) fostering the conservation and protection of the marine species for which it is responsible. The National Marine Fisheries Service is also the primary agency responsible for enforcement (permitting) of the regulations established by the councils.

National Oceanic and Atmospheric Administration

As parent organization for the National Marine Fisheries Service, the National Oceanic and Atmospheric Administration oversees the responsibilities of that agency. 35 Federal Reg. 15627 (1970). The general mission of the National Oceanic and Atmospheric Administration is to "explore, map, and chart the global ocean and its living resources and to manage use and conserve those resources; to describe, monitor, and predict conditions in the atmosphere, ocean, sun, and space environment; to issue warnings against impending destructive natural events; to assess the consequences of inadvertent environmental modification over several scales of time and to manage and disseminate long term environmental information."

Specific statutory responsibilities are provided by the Coastal Zone Management Act of 1972, the Marine Mammal Protection Act of 1972, the Endangered Species Act of 1973, and the Magnuson Fishery Conservation and Management Act of 1976.

Regional Fishery Management Councils

The councils were established by the Magnuson Fishery Conservation and Management Act of 1976, as amended in 1986, 16 U.S.C. §1801-1882 (1989), to develop fishery management plans for their respective regions. The plans may include permit requirements; restrictions on fishing zones, species, and numbers to be taken; and specifications of gear and other equipment to be used. The National Marine Fisheries Service enforces the substantive provisions in the plans.

U.S. Soil Conservation Service

The Soil Conservation Service is a subdivision of the U.S. Department of Agriculture, and its mandate is to exercise the powers of the secretary of agriculture under the Soil Conservation and Domestic Allotment Act. The policy of that act is

> to provide permanently for the control and prevention of soil erosion and thereby to preserve natural resources, control floods, prevent impairment of reservoirs, and maintain the navigability of rivers and harbors, protect public health . . . and the Secretary of Agriculture from now on shall coordinate and direct all activities with relation to soil erosion and in order to effectuate this policy is authorized from time to time to conduct surveys, investigations, and research relating to the character of soil erosion and the preventative measures needed to publish the results of any such surveys, investigations or research, to disseminate information concerning such methods, and to conduct demonstrational projects in areas subject to erosion by wind or water. 16 U.S.C. §590(a) (1989).

Among the additional policies and purposes of the act is the "promotion of the economic use and conservation of land." 16 U.S.C. 590(g) (1989).

Under the Soil and Water Resources Conservation Act of 1977, the Soil Conservation Service is recognized as an agency that "possesses information, technical expertise, and a delivery system for providing assistance to land users with respect to conservation and use of soils; plants; woodlands; watershed protection and flood prevention; the conservation development, utilization and disposal of water, animal husbandry, fish and wildlife management; recreation; community development; and related resources uses." Among the duties of the Soil Conservation Service under this act are "developing and updating periodically a program for furthering the conservation, protection, and enhancement of the soil, water, and related resources of the Nation consistent with the roles and program responsibilities of other Federal agencies and State and Local governments." 16 U.S.C. §2001(2) and §2003(c) (2) (1989).

National Environmental Policy Act Requirements

The National Environmental Policy Act requires all federal agencies "to use all practicable means and measures, including financial and technical assistance in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony and fulfill the social, economic, and other requirements of present and future generations of Americans." 42 U.S.C. §4331 (1989). This act requires that every recommendation or report on proposals for legislation and other major federal actions significantly affecting the quality of the human environment include a detailed statement by the responsible official. The statement must describe the environmental impact of the proposed action, any adverse environmental effects that cannot be avoided should the proposal be implemented, alternatives to the proposed action, the relationship between local short-term uses of the human environment and the maintenance and enhancement of long-term productivity, and any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented. 42 U.S.C. §4332 (1989).

<u>Coastal Zone Management Act of 1972 Requirements</u>

Under this act, all "Federal agencies conducting or supporting activities directly affecting the coastal zone" are required to "conduct or support those activities in a manner which is to the maximum extent practicable, consistent with approved state management programs." 16 U.S.C. §1456 (1989). This means that in a state with an approved coastal management program, as in Louisiana, a federal agency cannot issue a permit for an activity that directly affects the coastal zone of the state unless the state coastal management program certifies that the activity is consistent with the state's program. The consistency determination may come with the issuance of a coastal use permit for the activity if one is required, or a statement of consistency if the activity does not require a coastal use permit (e.g., an outer continental shelf activity).

<u>State Agencies</u>

The Coastal Management Division of the Louisiana Department of Natural Resources is the permitting agency responsible for administering the provisions of the State and Local Coastal Resources Management Act of 1978. The Coastal Management Division carries out its mission by regulating certain activities in the statutorily defined coastal zone of Louisiana in a way consistent with the policy of the act. That policy is, in part, "to protect, develop, and where feasible, restore or enhance the resources of the state's coastal zone," La. Rev. Stat. 49:213.2 (1989), and "to encourage full use of coastal resources while recognizing it is in the public interest of the people of Louisiana to establish a proper balance between development and conservation." (La. Rev. Stat. 49:213.8(C)(1)) (1989). The primary method the Coastal Management Division uses to fulfill its mandate is the coastal use permitting process, under which permits are required for certain activities in the coastal zone.

The Louisiana Department of Environmental Quality is the permitting agency that is the "primary agency in the state concerned with environmental protection and regulations" with "jurisdiction over matters affecting the regulation of the environment within the state, including but not limited to the regulation of air quality, noise pollution control, water pollution control, the regulation of solid waste disposal, the protection and preservation of the scenic rivers and streams of the state, the regulation and control of radiation, the management of hazardous waste, and the regulation of those programs which encourage, assist, and result in the reduction of wastes generated within Louisiana." La. Rev. Stat. 30:2011(A)(1) (1989).

In the area of water pollution control, the Department of Environmental Quality exercises its mission by establishing water quality standards and effluent limitations and prohibiting discharges (except by permit from the department), and by decisions concerning certifications of consistency with the Federal Water Pollution Control Act for activities under federal permit or license. The Department of Environmental Quality also has commenting authority on coastal permit decisions under a memorandum of understanding with the Coastal Management Division.

The Division of State Lands, Department of Natural Resources, has numerous functions relating to administration of state-owned property (land). La Rev. Stat. 41:1-14 (1989). Among those functions is the administration of and permitting authority over state-owned water bottoms under La. Rev. Stat. 41:1701-1714 (1989). Under those provisions, the Division of State Lands is responsible for preventing unauthorized encroachments on state water bottoms and issuing leases for authorized encroachments. The Division of State Lands is also responsible for overseeing reclamation of private land lost through erosion and has commenting authority on coastal use permit decisions under a memorandum of understanding with the Coastal Management Division.

The Department of Wildlife and Fisheries is the permitting agency with respect to state wildlife and fisheries laws (including the Natural and Scenic Rivers System) and the commenting agency under the Fish and Wildlife Coordination Act and the Louisiana State and Local Coastal Resources Management Act. Under state law the department is directed to "control and supervise all wildlife of the state, including fish and all other aquatic life, and shall execute the laws enacted for the control and supervision of programs relating to the management, protection, conservation, and replenishment of wildlife, fish, and aquatic life in the state, and the regulation of the shipping of wildlife, fish, furs, and skins." La. Rev. Stat. 36:602 (1989).

Under the Fish and Wildlife Coordination Act, the Department of Wildlife and Fisheries has the same commenting authority as the Fish and Wildlife Service and the National Marine Fisheries Service. Under a memorandum of understanding with the Coastal Management Division of the Department of Natural Resources, the Department of Wildlife and Fisheries has the authority to comment on coastal use permit applications.

Local Agencies

The local (parish) coastal management programs are established, as is the state program, by the Louisiana State and Local Coastal Resources Management Act of 1978. The local coastal management programs have permitting authority in the coastal zone within the respective parish over activities designated by the act as "uses of local concern." Uses of local concern include some marsh management plans, which would therefore be subject to a local coastal use permit. The local coastal management programs also have the authority under the Louisiana State and Local Coastal Resources Management Act and its regulations to comment on state coastal use permit decisions.

LAWS AND ADMINISTERING AGENCIES

Tables 1 and 2 list the state and federal laws affecting marsh management activities and the agencies that administer them or are affected by them.

INFORMAL PLANNING AND GUIDANCE

In this report, "informal planning and guidance" refers to the dissemination of information by an agency to a prospective applicant, often before the permitting process has begun, to help the prospective applicant through the permitting process. There are no requirements in law or regulation for the procedures described here, hence the designation as "informal." The designation of planning and guidance as informal does not mean that it is on a less professional level than the agencies' formal interactions with the public.

Federal Agencies

U.S. Soil Conservation Service

The Soil Conservation Service provides some of the most extensive informal planning and guidance of any of the agencies involved in marsh management. It provides initial technical assistance to prospective applicants, and this assistance continues throughout the development of the marsh management plan, which the Soil Conservation Service actually writes for marsh managers. During the permitting phase and implementation of the marsh management plan, the Soil Conservation Service continues to provide technical assistance for marsh managers. The technical expertise of this agency is an invaluable resource for marsh managers, many of whom have no experience and no idea of where to begin in managing their marsh lands. If it were not for the services provided by this agency, fewer marsh management plans would be proposed. The following is the Soil Conservation Service's statement regarding assistance to coastal land users:

General Statement--Soil Conservation Service Assistance to Coastal Land Users

> The Soil Conservation Service supports the multi-use concept of management in coastal wetland areas and encourages private land users to incorporate this approach into resource management objectives. The overall objective of SCS in the planning process is to work with the land user in a systematic analysis of problems and practical alternatives concerning his resource management decisions. The resulting conservation plan addresses the management objectives of the land user while providing essential protection of the resource base. SCS does have broad resource management objectives as indicated in our environmental policies and guidelines described in Appendix A of Volume II. These policies and guidelines are not unique to the coastal area, but are applicable to all Soil Conservation Service activities as described.

Table 1. Federal laws, regulations, and case law and administering agencies.

Federal Authority	Type	Purpose	Administering Agencies
Federal Water Pollution Control Act 33 U.S.C. §1311 (§301) (1989) and 33 U.S.C. §1342 (§402) (1989)	Statutes	Prohibits unpermitted discharges into waters of the U.S.	Environmental Protection Agency or oversees state administration of federally approved state program
33 U.S.C. §1344(a), (§404(a)) (1989)	Statute	Grants authority to the U.S. Army Corps of of Engineers to regulate and issue permits for discharge of dredged or fill material into the waters of the U.S.	U.S. Army Corps of Engineers with Environmental Protection Agency oversight authority
40 C.F.R. §122.2 (1989)	Regulation	Defines waters of the U.S. for §402 purposes	Environmental Protection Agency
33 C.F.R §328.3 (1989)	Regulation	Defines waters of the U.S. for §404 purposes	U.S. Army Corps of Engineers
33 U.S.C §1344(b)(1) and (c) (1989)	Statute	Grants authority to the Environmental Protection Agency to establish guidelines to be used by the Corps of Engineers when issuing permits for the discharge of dredged or fill material and to veto such permits if the guidelines are not addressed	Environmental Protection Agency
40 C.F.R. §230-230.80 (1989)	Regulation	Establishes guidelines (by authority of 33USC §404(b)(1)) for permitting the discharge of dredged or fill material by the Corps of Engineers	Environmental Protection Agency and applied by U.S. Army Corps of Engineers
33 U.S.C. §401 (1989)	Statute	Requires anyone conducting activities under federal license or permit that may result in any discharge into the waters of a state to obtain certification that the discharge complies with the provisions of the Federal Water Pollution Control Act	State administrative authority responsible for administering Federal Water Pollution Control Act or federally approved state program

Table 1. Federal laws, regulations, and case law and administering agencies (continued).

Federal Authority	Type	Purpose	Administering Agencies
Rivers and Harbors Act of 1899			
33 U.S.C. §§401 and 403 (§§9 and 10) (1989)	Statute	Prohibits the creation of obstructions or dredging or filling in the waters of the U.S. without a permit from the U.S. Army Corps of Engineers	U.S. Army Corps of Engineers
33 C.F.R. §§322.2(a) (1989)	Regulation	Defines navigable waters of the U.S. for 33 USC§§401 and 403 purposes	U.S. Army Corps of Engineers
Coastal Zone Management Act of 1972			
16 U.S.C. §1454 (1989)	Statute	Provides for funding and guidelines under which state coastal management programs are established. See state coastal management law	National Oceanic and Atmospheric Administration
16 U.S.C. §1456 (1989)	Statute	Requires federal activities and activities requiring federal license or permit conducted in the coastal zone of a state to be consistent with that state's federally approved coastal management program	National Oceanic and Atmospheric Administration
15 C.F.R. §§930.1-930.134 (1989)	Regulation	Implements federal consistency provisions of the Coastal Zone Management Act, 33 U.S.C. §1456 (1989)	Federally approved state coastal management programs
Fish and Wildlife Coordination Act			
16 U.S.C. §662 and 663 (1989)	Statute	Grants authority to the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and state wildlife agencies to comment on alteration to water bodies by federal agencies or under federal license or permit	U.S. Fish and Wildlife Service, National Marine Fisheries Service, Louisiana Department of Wildlife and Fisheries

Table 1. Federal laws, regulations, and case law and administering agencies (continued).

Federal Authority	Type	Purpose	Administering Agencies
Endangered Species Act of 1973 16 U.S.C. §§1531-1543 (1989)	Statute	Regulates and prohibits activities that affect endangered or threatened species	U.S. Fish and Wildlife Service, National Marine Fisheries Service, Louisiana Department of Wildlife and Fisheries
50 C.F.R. §171 et seq. (1989)	Regulation	Implements provisions of the Endangered Species Act	U.S. Fish and Wildlife Service, National Marine Fisheries Service
Magnuson Fishery Conservation and Management Act of 1976 16 U.S.C. §§1801-1882 (1989)	Statute	Establishes conservation and management regimes for marine fisheries stocks through the regional fishery management councils, including habitat protection considerations such as wetland protection	National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Regional Fishery Management Councils
National Environmental Policy Act 42 U.S.C. §4321-4370(a) (1989)	Statute	Directs all federal agencies to consider environmental impacts of major federal actions significantly affecting the human environment and to prepare a detailed statement of the findings	The provisions of the act are the responsibility of all federal agencies
Memoranda of agreement between various agencies	Interagency agreements	Facilitates interactions between agencies involved in permitting processes	Signatory agencies including U.S. Army Corps of Engineers, Environmental Protection Agency, U.S. Fish and Wildlife Service, National Marine Fisheries Service
Phillips Petroleum Company v. Mississippi 108 S. Ct. 791 (1988)	Judicial (case law)	Interpreted federal grants of land to states at statehood under the "equal footing doctrine" to include all lands subject to the ebb and flow of the tide	Ruling of the U.S. Supreme Court to be followed by all lower federal courts and state courts as well as appropriate administrative agencies

Table 1. Federal laws, regulations, and case law and administering agencies (continued).

Federal Authority	Type	Purpose	Administering Agencies
Vaughn v. Vermillion Corporation 444 U.S. 206 (1979)	Judicial (case law)	Held that private canals constructed on private property were private things with no right of public use except possibly in limited situations	Ruling of the U.S. Supreme Court to be followed by all lower federal courts and state courts as well as appropriate administrative agencies

Table 2. State laws, regulations, and case law and administering agencies.

State Authority	Type	Purpose	Administering Agencies
State and Local Coastal Resources Management Act of 1978 La. Rev. Stat. 49:213.21-213.41 (1989)	Statute	To protect, develop, and where feasible, restore or enhance the resources of the state's coastal zone and to encourage full use of coastal resources while recognizing that it is in the public interest of the people of Louisiana to establish a proper balance between development and conservation.	Coastal Management Division, Department of Natural Resources
Rules and regulations (coastal use guideline); Louisiana Coastal Resources Program Final Environmental Impact Statement	Regulations	Implement the provisions of the Louisiana State and Local Coastal Resources Management Act of 1978	Coastal Management Division, Department of Natural Resources
State Water Bottom Management La. Rev. Stat. 41:1701-1714 (1989)	Statute	States that the beds and bottoms and the banks or shores of bays, arms of the sea, the Gulf of Mexico, and navigable lakes are public lands belonging to the state and shall be protected, administered, and conserved to best ensure full public navigation, fishery, recreation, and other interests. Prohibits unregulated encroachments on state-water bottoms. Provides for leasing of state-owned water bottoms	Division of State Lands, Department of Natural Resources

Table 2. State laws, regulations, and case law and administering agencies (continued).

State Authority	Type	Purpose	Administering Agencies
Louisiana Civil Code Property Provisions			
Article §450	Statute	Defines public things	Division of State Lands, Department of Natural Resources
Article §451	Statute	Defines seashore	Division of State Lands, Department of Natural Resources
Article §456	Statute	Defines banks of navigable rivers and streams, provides for ownership and public use	Division of State Lands, Department of Natural Resources
Article §499	Statute	Defines alluvion and dereliction and provides for ownership	Division of State Lands, Department of Natural Resources
Article §500	Statute	Provides that there is no right of alluvion or dereliction on the seashore or the shore of navigable lakes	Division of State Lands, Department of Natural Resources
Article §506	Statute	Provides for ownership of non-navigable rivers and streams	Division of State Lands, Department of Natural Resources
Louisiana Revised Statutes Property Provisions			
La. Rev. Stat. 9:1101 (1989)	Statute	Provides that the waters and beds of all rivers, streams, bayous, lagoons, lakes, and bays not directly owned by August 12, 1910, whether or not navigable belong to the state	Division of State Lands, Department of Natural Resources
La. Rev. Stat. 49:3 (1989)	Statute	Provides that Louisiana owns the water beds and shores to the high-water mark of the Gulf of Mexico and its arms that lie within the boundaries of the state	Division of State Lands, Department of Natural Resources

Table 2. State laws, regulations, and case law and administering agencies (continued).

State Authority	Type	Purpose	Administering Agencies
Article XI§3 of the Louisiana Constitution of 1974	Constitution	Prohibits private ownership of the beds of natural navigable water bodies in Louisiana	Division of State Lands, Department of Natural Resources
Miami Corporation v. State 173 So. 315 (1936)	Judicial (case law)	Held that the state owns the banks of navigable lakes to the high-water mark and that areas adjacent to the banks that erode to become part of the bed or banks are lost to the private owner (if any) and become state property	Division of State Lands, Department of Natural Resources
Gulf Oil Corporation v. State Mineral Board 317 So.2d 576 (La. 1975)	Judicial (case law)	Held that the state may assert ownership to navigable water bodies that it has alienated	Division of State Lands, Department of Natural Resources
Hunter Company v. Ulrich 8 So.2d 531 (La. 1942)	Judicial (case law)	Held that canals constructed on private land pursuant to a right-of-way servitude are private property subject to public use (but see the caveat in Vaughn v. Vermillion Corporation in federal law table)	Division of State Lands, Department of Natural Resources
State Wildlife and Fisheries Laws La. Rev. Stat. 56:107 (1989)	Statute	Prohibits setting fire to marshland except when an owner of the land does so to improve food conditions for wildlife and then only under permit and supervision of the Department of Wildlife and Fisheries	Louisiana Department of Wildlife and Fisheries
La. Rev. Stat. 56:329 (1989)	Statute	Prohibits the obstruction of the free passage of fish in any body of water except for water control structures or dams used to retain water for conservation purposes	Louisiana Department of Wildlife and Fisheries

Table 2. State laws, regulations, and case law and administering agencies (continued).

State Authority	Type	Purpose	Administering Agencies
La. Rev. Stat. 56:579.1 (1989)	Statute	Allows mariculture in a limited number of approved marsh management areas under strict guidelines	Louisiana Department of Wildlife and Fisheries
Louisiana Scenic Rivers Act La. Rev. Stat. 56:1840-1856 (1989)	Statute	To protect the ecological and esthetic qualities of certain free-flowing rivers streams	Louisiana Department of Wildlife and Fisheries

> SCS has a unique working relationship with private landowners and land users relative to resource conservation planning and application. This relationship involves landowners, local soil and water conservation districts (ten in coastal parishes), and the Louisiana Soil and Water Conservation Committee.
>
> SCS is obligated to assist coastal landowners requesting assistance to protect their marshlands from erosion and resulting land loss. The priority for this assistance has been previously established in individual conservation districts and cooperating state agencies. All agencies recognize the need for full cooperation and involvement of private landowners in a successful initiative. (Craft 1988:2)

U.S. Fish and Wildlife Service

The Fish and Wildlife Service provides technical assistance to prospective marsh managers at several stages in the process. First, a prospective marsh manager may contact the Fish and Wildlife Service before developing a marsh management plan to request technical assistance in managing a marsh area to improve wildlife habitat for one or more species. Second, the Fish and Wildlife Service may assist the Soil Conservation Service during the development of a marsh management plan by providing technical advice to the Soil Conservation Service and the applicant. Finally, the Fish and Wildlife Service participates in interagency meetings (described under "Federal Permitting Network," below) usually held before the permit application (but sometimes after public notice of the application has been submitted and issued) to discuss possible conflicts of the plan with various regulatory requirements and solutions to those conflicts. Also, the Fish and Wildlife Service will continue to work individually with an applicant during the permitting process.

National Marine Fisheries Service

The National Marine Fisheries Service provides informal guidance primarily through the interagency meeting described above. Occasionally, applicants will interact individually with the National Marine Fisheries Service after the interagency meeting to receive assistance in meeting the agency's regulatory requirements.

U.S. Army Corps of Engineers

The Corps of Engineers participates in informal planning and guidance both in the interagency meeting and individually with the applicant during the permitting process. As one of the permitting agencies, the Corps of Engineers assists the applicant in meeting regulatory requirements and helps the applicant coordinate with other permitting agencies as well as with commenting agencies.

Environmental Protection Agency

The Environmental Protection Agency provides informal guidance through participation in the interagency meeting process. This participation, however, is infrequent and sporadic.

State Agencies

Coastal Management Division, Department of Natural Resources

The Coastal Management Division of the Department of Natural Resources provides mostly regulatory assistance but also some technical assistance to prospective marsh managers. The division provides this assistance at all phases of the process, including the pre-application and implementation phases. The division provides several documents to prospective marsh managers that describe regulatory requirements and provide technical assistance. One document, the "Louisiana Coastal Resources Program Marsh Management Manual," was prepared in conjunction with the Soil Conservation Service and provides extensive technical and regulatory assistance. Excerpts from this document can be found in appendix A of this report.

In the implementation phase, the Coastal Management Division monitors the progress of marsh management plans, sometimes contracting with the Soil Conservation Service to acquire the necessary data. More informal guidance may result from this monitoring.

Louisiana Department of Wildlife and Fisheries

The Department of Wildlife and Fisheries provides informal planning and guidance on two levels. First, the Refuge and Fur Division provides technical assistance to prospective marsh managers in developing a plan; this assistance may continue after permit application and into the implementation phase if requested.

The second form of informal planning and guidance is by the Habitat Conservation Division, which participates in interagency meetings and provides information to help applicants comply with the agency's regulatory requirements. This assistance may continue past the interagency meeting process.

Local Programs

The local coastal management programs occasionally participate in the interagency meeting process when a marsh management plan is proposed in their parish. This assistance primarily involves helping the applicant comply with any applicable local coastal program requirements.

PROCEDURES AND THE PERMITTING NETWORKS

Permit Requirements and Application Procedures

Under the provisions of the Louisiana State and Local Coastal Resources Management Act of 1978, La. Rev. Stat. Ann. §49:213.1213.22 (1989), landowners or managers wishing to implement a structural marsh management plan in the coastal zone (statutorily defined in La. Rev. Stat. Ann. §49:213.4 (1989)) of Louisiana must obtain a coastal use permit from the Coastal Management Division of the Louisiana Department of Natural Resources or a permit from a local coastal management program. La. Rev. Stat. Ann. §49:213.11 (1989). In most situations they must also obtain a permit from the Corps of Engineers under §10 of the Rivers and Harbors Act of 1899, 33 U.S.C. §403 (1989), or under §404 of the Federal Water Pollution Control Act, 33 U.S.C. 1344 (1989). Both Corps of Engineers permits will usually be required. The Corps of Engineers' jurisdiction is statewide and not limited to the coastal zone as is the coastal use permitting jurisdiction of the Coastal Management Division.

The application process and permitting network are shown in figures 3 through 7. To simplify application procedures, the Coastal Management Division has been designated the lead agency (see the Joint Agreement between the Coastal Management Division and the Corps of Engineers in appendix B) to receive permit applications and hence provide the public with a "one-window" permitting system. The Coastal Management Division is responsible for receiving permit applications and joint public notices for activities in the coastal zone that have a direct and significant impact on coastal waters and that are also subject to the §10 and §404 permitting jurisdiction of the Corps of Engineers (Cahoon and Lemoine 1985). Therefore, an applicant for a marsh management plan within the coastal zone should apply to the Coastal Management Division or a local coastal management program for a coastal use permit. The Coastal Management Division will then immediately notify the Corps of Engineers and send them a copy of the permit application. The Corps of Engineers determines whether or not a §10 or §404 permit is required and, if so, begins processing the application as if the applicant had applied directly to the Corps of Engineers for those permits. The two agencies also determine whether to issue separate public notices or to issue a joint public notice. Both agencies are required to provide a notice and comment period before they may issue their respective permits. La. Rev. Stat. Ann. §49:213.11(c)(2) (1989); 33 U.S.C. §1344(a) (1989). A joint public notice is issued when both agencies receive a complete application. However, the Corps of Engineers and the Coastal Management Division operate under different regulations. If after reviewing their respective regulations, the Coastal Management Division and the Corps of Engineers determine that an application is incomplete for identical reasons, a joint public notice cannot be issued until both agencies receive the required information in a timely fashion. However, the Corps of Engineers must issue its public notice within 15 days after receiving a complete application. Thus, issuance of a joint public notice may not be possible if it would take the applicant too long to provide information required only by the Coastal Management Division (Bosenberg 1988). In those cases the agencies would issue their own public notices and proceed with evaluating the proposed project (Bosenberg 1988). The agencies issue only a joint public notice and not a joint permit.

Other permit requirements a prospective marsh manager may encounter include a state waterbottom or right-of-way permit from the Division of State Lands of the Department of Natural Resources, La. Rev. Stat. Ann. 41:1703 (1989); a water quality certification from the Department of Environmental Quality, 33 U.S.C. §1341 (1989) (§401 of the Federal Water Pollution Control Act); and a Natural and Scenic Rivers permit from the Louisiana Department of Wildlife and Fisheries, La. Rev. Stat. Ann. 56:1840-1856 (1989). Although the Division of State Lands permits are technically separate requirements, the Coastal Management Division and the Corps of Engineers routinely notify the Division of State Lands of permit applications received by their respective offices. If, after review of the proposed activity, the Division of State Lands determines that a state water-bottoms or right-of-way permit is required, the applicant is notified that he

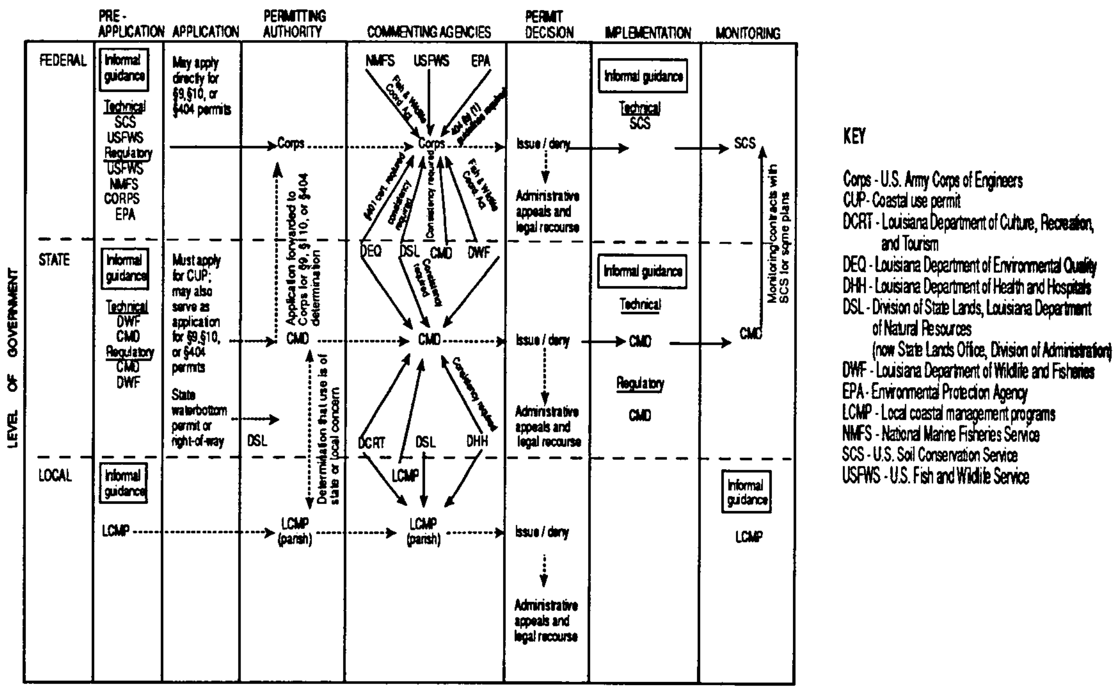

Figure 3. Overview of the governmental role in the permitting process for marsh management plans. (Dotted line shows permit decision process; solid line shows comments and other input.) See figure 5 for detail of state and figure 7 for detail of federal permit processing procedures.

*See figure 6 for an explanation of the processing of state waterbottom or right-of-way permits.

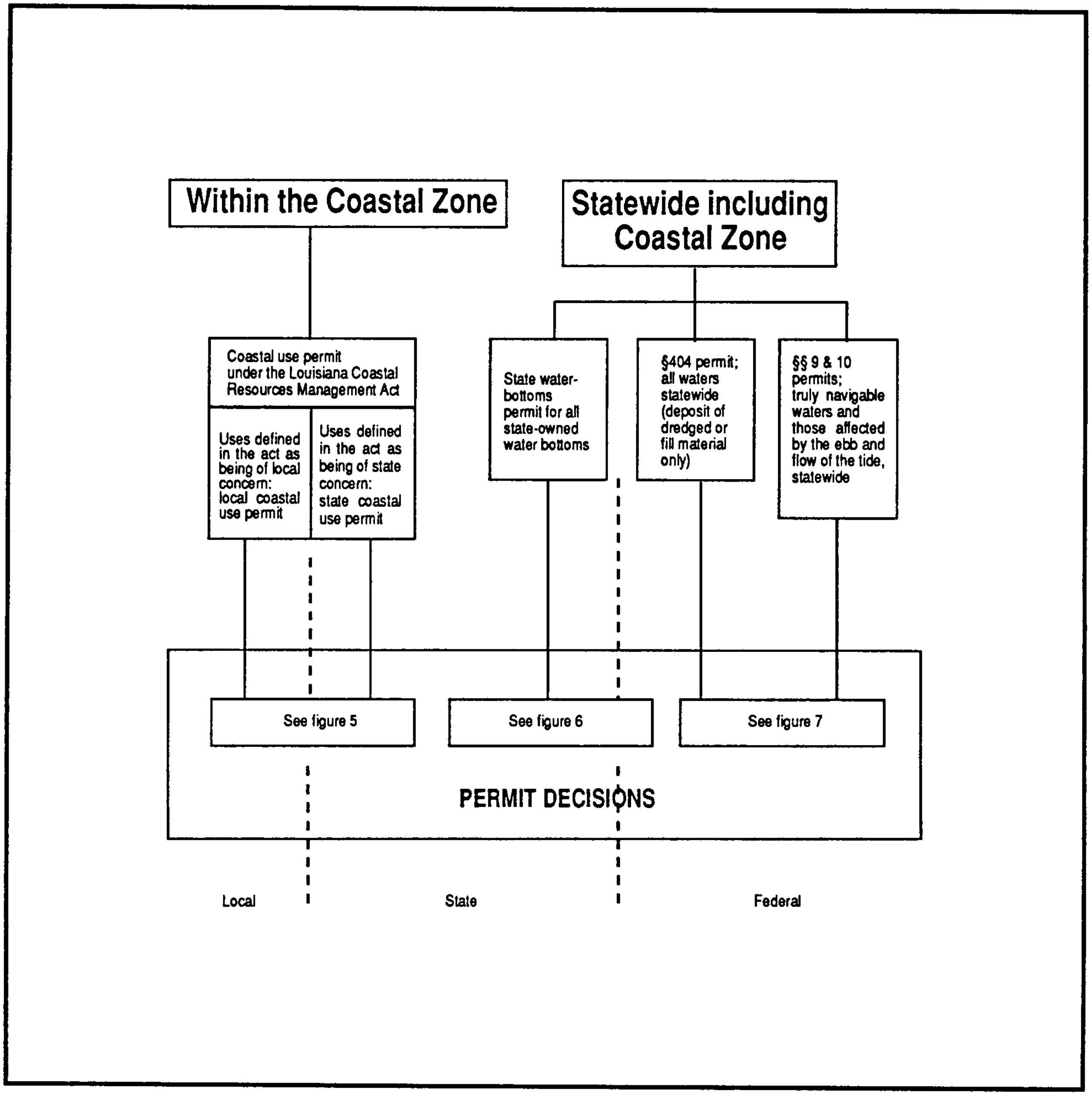

Figure 4. Permitting process for dredging and/or filling operations or creation of obstruction without dredging and/or filling (such as some weirs and other water control structures).

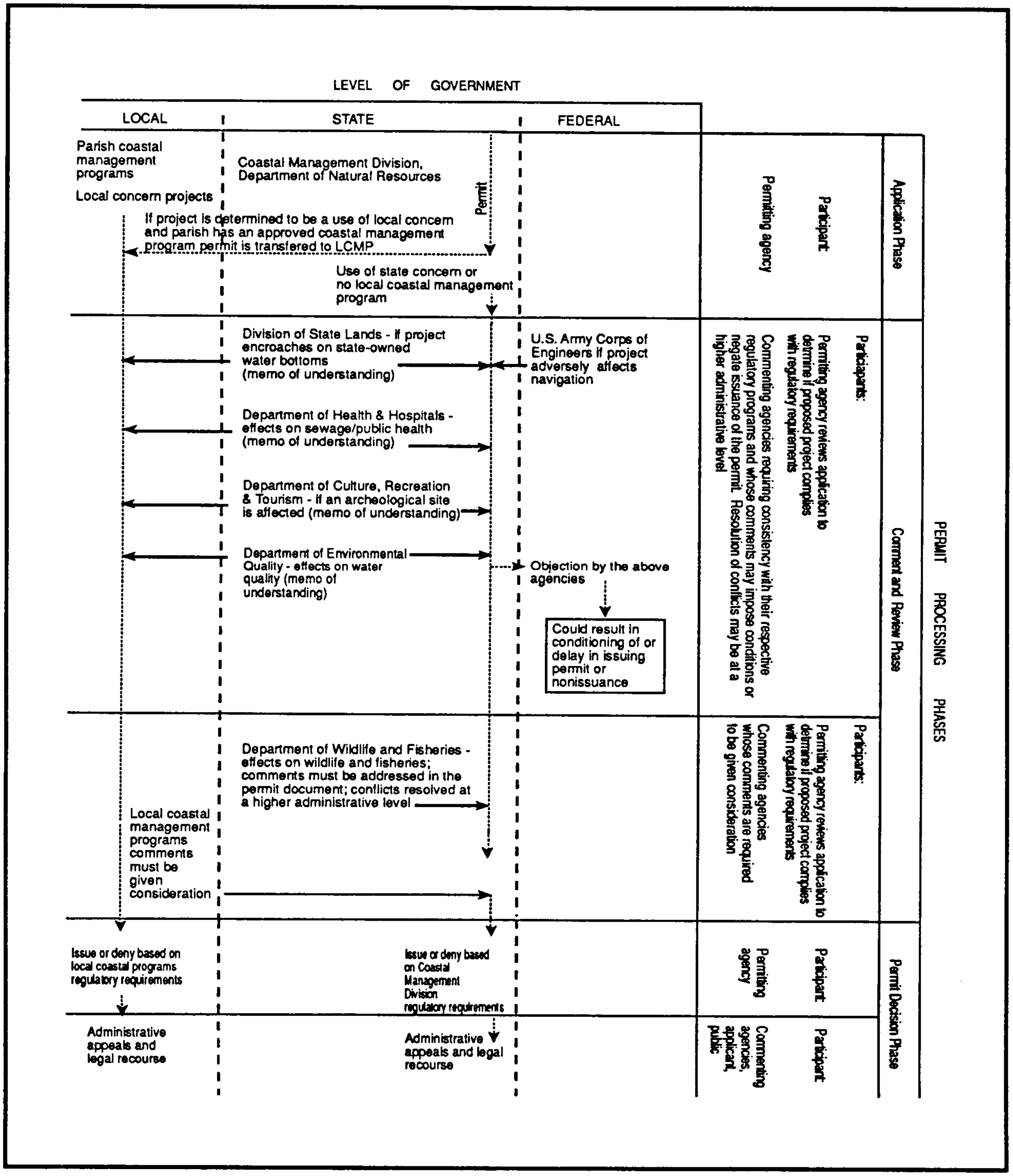

Figure 5. Permit decision process for Louisiana coastal use permits for any activity (including dredging and filling, dams, or weirs) in the coastal zone that directly and significantly affects coastal waters. (Dotted line shows permit decision process; solid line shows comments and other input.)

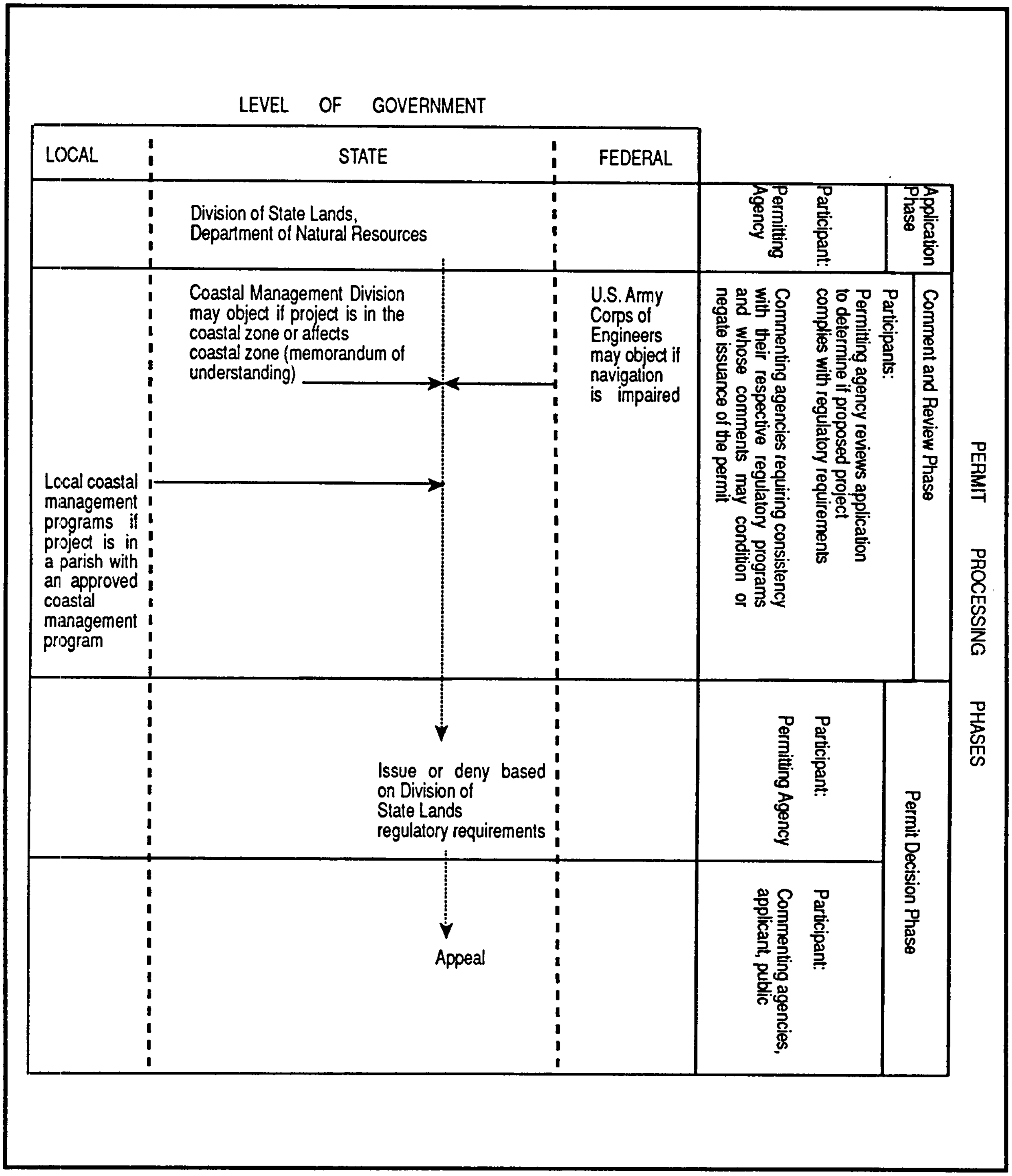

Figure 6. Permit decision process for state waterbottom permits (either for filling or other encroachments, such as weirs). (Dotted line shows permit decision process; solid line shows comments and other input.)

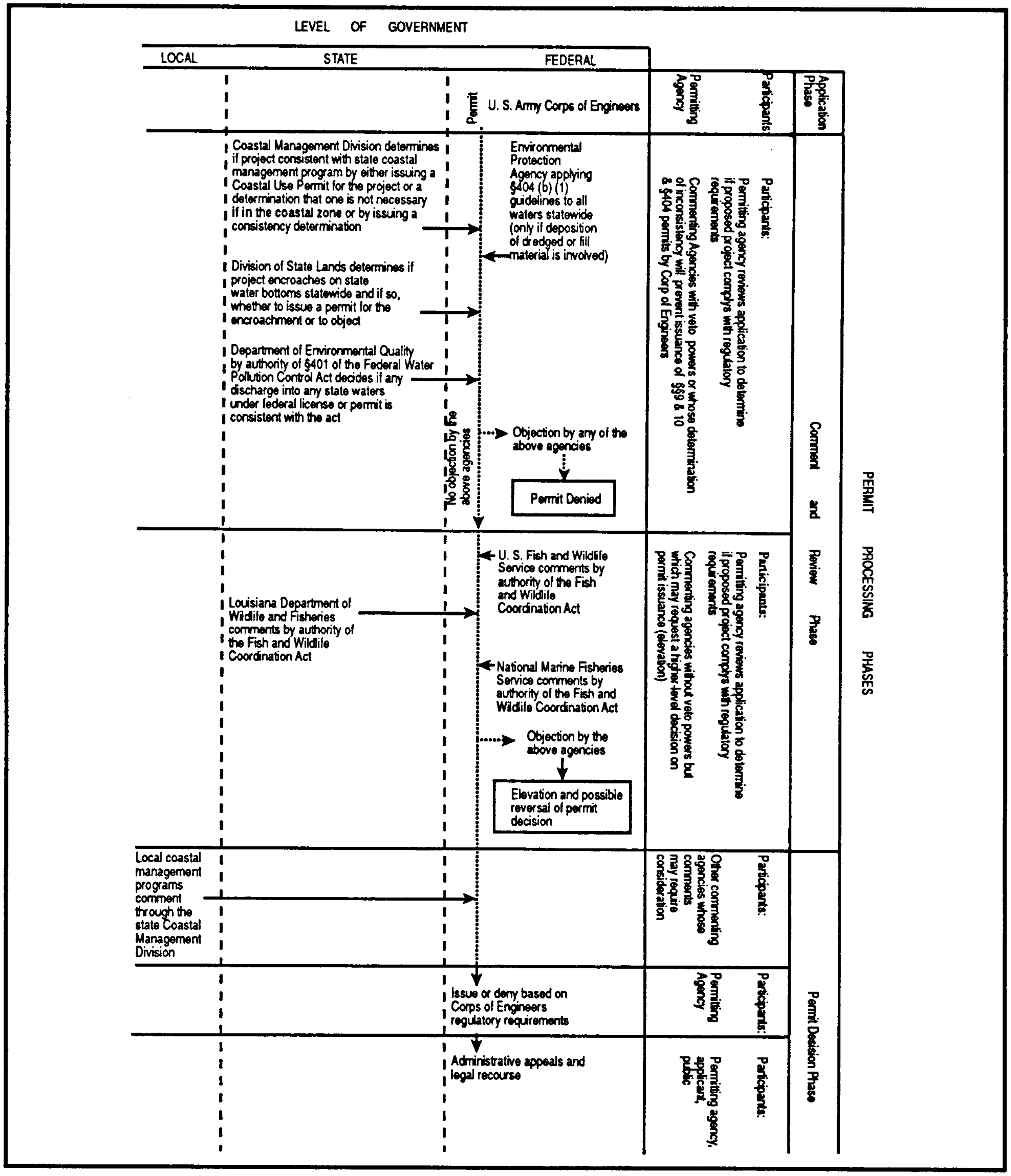

Figure 7. Permit decision process for permits under §§9 and 10 of the Rivers and Harbors Act of 1899 and §404 of the Federal Water Pollution Control Act. (Dotted line shows permit decision process; solid line shows comments and other input.)

or she will have to obtain a permit from the Division of State Lands (see figures 3, 4, 5). The Corps of Engineers will not issue its permits until any required by the Division of State Lands are issued.

For the Department of Environmental Quality §401 water quality certifications, a similar process takes place between the Corps of Engineers and the Department of Environmental Quality. The Corps of Engineers will not issue its permits unless the applicant has obtained the water quality certification.

The Natural and Scenic Rivers permit from the Department of Wildlife and Fisheries is also a separate requirement, but under a memorandum of understanding with the Coastal Management Division can affect the coastal use permitting process (see below). A flow chart describing the permit process and network of agencies is presented in figure 3.

State Permitting Network

At the state level the permitting network for coastal zone activities, including marsh management, consists of the permitting agency, the Coastal Management Division or the local (parish) coastal management program, and the state commenting agencies (see figures 3, 4, 5). Under this system, decisions on the issuance of a coastal use permit are based not only on the guidelines and regulatory policies of the lead agency but also are affected by the regulatory requirements and policies of the commenting agencies. The Coastal Management Division has memoranda of understanding with seven other state agencies: the Office of Conservation and the Division of State Lands of the Department of Natural Resources; the Department of Environmental Quality; the Department of Health and Human Resources, the Department of Culture, Recreation and Tourism; the Department of Agriculture; and the Department of Wildlife and Fisheries (see appendix B). These memoranda provide for notification from the Coastal Management Division of activities that may fall under the jurisdiction of the various agencies and give the agencies authority to comment on the proposed activity. Additionally, the memoranda provide that for all the agencies listed above, except the Department of Agriculture and the Department of Wildlife and Fisheries, the Coastal Management Division will condition the approval of a coastal use permit on compliance with the rules and regulations of these commenting agencies and upon the applicant's obtaining all permits required by these agencies, if any. Under this system, for example, if an archaeological or historical site would be affected, the Department of Culture, Recreation and Tourism is notified and may comment to the Coastal Management Division. The comments may establish conditions to or object to the proposed activity (see figure 5). The Department of Agriculture may comment on or object to activities that affect agricultural resources, including the use of pesticides, and the Coastal Management Division must incorporate the Department of Agriculture's comments into its permit decisions to the maximum extent practicable. However, there is no requirement in the memoranda of understanding that the Coastal Management Division condition coastal use permits so that they comply with the Department of Agriculture's regulatory requirements.

The Department of Wildlife and Fisheries' memorandum of understanding with the Coastal Management Division provides that the Department of Wildlife and Fisheries' comments on coastal use permit applications be "given full consideration in the coastal use permit decision process and summarized and responded to in the actual permit document." This would include the Department of Wildlife and Fisheries' comments under its authority over the Louisiana Natural and Scenic Rivers System as well as various wildlife and fisheries statutes. The Coastal Management Division evaluates comments by the other agencies not involving violations of their regulatory authority but expressing other policy concerns for consistency with the Coastal Resources Management Act and may or may not act upon them (Rives 1988). The Coastal Management Division also reviews comments of other state and federal agencies and incorporates those that do not conflict with the Coastal Resources Management Act (Rives 1988).

An in-lieu permitting system has been established by the Coastal Resources Management Act and further developed in a memorandum of understanding between the Coastal Management Division and the Office of Conservation of the Department of Natural Resources. This system divides permitting authority for oil-and-gas-related activities between the two agencies. Thus, for example, the siting and drilling of oil or gas wells require permits from the Office of Conservation instead of a coastal use permit. However, if access to the drill site requires dredging a canal or building a board road in the coastal zone, a coastal use permit is required for that activity in addition to the Office of Conservation permit.

The Coastal Resources Management Act also provides for the establishment of local coastal management programs under which the local program may assume the permitting authority for activities in the coastal zone defined by the Coastal Resources Management Act as "uses of local concern." La. Rev. Stat. Ann. §49.213.9 (1989). In accordance with this system, approved local programs have been established and have assumed permitting authority from the Coastal Management Division over certain coastal uses. Under the Coastal Resources Management Act a marsh management plan that intersected only one body of water and that utilized a water control structure costing less than $15,000 would be a use of local concern and would require a parish permit rather than a coastal use permit. La. Rev. Stat. Ann. §49.213.5A(1)(a), (2)(j) (1989). In addition, the approved local programs are given the authority to comment on coastal use permit applications being reviewed by the Coastal Management Division (Rives 1988). The Coastal Management Division tries to accommodate these comments if they concern something specifically addressed in the parish program or relate to something of local concern and are not contrary to state policy (Rives 1988).

Federal Permitting Network

At the federal level the Corps of Engineers regulates marsh management activities involving dredge or fill in navigable waters including wetlands, 33 U.S.C. §403 §1342, 1344 (1989), or structures blocking navigable waters, 33 U.S.C. §403 (1989). This permitting jurisdiction is statewide and is not limited to the statutorily defined coastal zone as is the jurisdiction of the Coastal Management Division (see figures 3, 4, 7). 33 U.S.C. §1362(12) (1989); 33 U.S.C. §403 (1989). Other agencies have commenting authority: the Fish and Wildlife Service and the Department of Wildlife and Fisheries under the Fish and Wildlife Coordination Act, 16 U.S.C. §661-666(c) (1989), and through a memorandum of agreement between the Fish and Wildlife Service and the Corps of Engineers (see appendix C and figure 7). The National Marine Fisheries Service, though not specifically listed in the Fish and Wildlife Coordination Act, comments under authority of that act because it was formerly the Bureau of Commercial Fisheries within the Fish and Wildlife Service. That bureau and its functions were transferred to the Department of Commerce in the 1970 reorganization. 35 Fed. Reg. 15627 (1970). Thus, the National Marine Fisheries Service retained the commenting authority it had under the Fish and Wildlife Coordination Act as the Bureau of Commercial Fisheries in the Fish and Wildlife Service. 35 Fed. Reg. 15627 (1970). The National Marine Fisheries Service also comments under authority of a memorandum of agreement with the Corps of Engineers and various other federal statutes that grant the National Marine Fisheries Service responsibility for protecting the habitat of living marine resources. The Environmental Protection Agency comments under the authority of the Federal Water Pollution Control Act, 33 U.S.C. §1344(c) (1989), the Clean Air Act, 42 U.S.C. §7609 (1989), and a memorandum of agreement with the Corps of Engineers (see appendix B and figure 7).

The memoranda of agreement between the Corps of Engineers and the other three federal agencies (the Environmental Protection Agency, the National Marine Fisheries Service, and the Fish and Wildlife Service) also give them the authority to request referral of a district engineer's decision to issue a permit (see appendix C). This means that the decision will be reviewed at a higher level within the Corps of Engineers (see figure 7). This process is called "elevation" and occurs when the district engineer's office notifies the agency of its intent to issue the permit without recommended conditions despite the fact that the commenting agency either recommends denial of the permit or recommends conditions to the permit and warns that elevation will be sought if the conditions are not accepted.

In actuality the Corps of Engineers and the commenting agencies attempt to resolve conflicts through standard procedures before the elevation step is reached (Bosenberg 1988). Some of these procedures are outlined in the memoranda of agreement; others are based on informal agreements between the agencies. One such procedure is the interagency meeting.

Interagency meetings between the Corps of Engineers, federal and state commenting agencies, and the applicant to discuss conflicts and possible solutions or alternatives are encouraged and can be convened before an application is filed as well as during the permit evaluation process (Bosenberg 1988). These meetings can and often do include site visits to the proposed plan area. Project modifications proposed or permit conditions recommended by commenting agencies often precipitate discussions between the agencies and the applicant. Agency comments accompanied by an appropriately signed statement to seek elevation if their recommendations or proposed modifications are not incorporated into the project must be dealt with slightly differently and nearly always result in a dialogue between the interested parties (Bosenberg 1988). Often such agency positions reflect differences in the policies of the various agencies (Bosenberg 1988). Nonetheless, in many cases, remaining differences are often resolved at this point without elevation. This is generally accomplished by formulating permit conditions that are acceptable to the applicant and the agency (Bosenberg 1988). Usually, the agency will withdraw its objection and request for elevation. Infrequently, an agency may maintain its objection but withdraw its request to elevate (Bosenberg 1988). However, the Corps of Engineers will make a decision to issue or deny a permit even if an impasse exists because an applicant refused to modify the proposed project or address the agency's concerns, or because the agency maintains its objection to the project and retains its right to elevate (Bosenberg 1988).

The process of referral and elevation can significantly delay (90 to 120 days or more) the processing of a permit (Bosenberg 1988). Because of the time and effort associated with elevation, the Corps of Engineers often attempts to avoid it by postponing its permit decision in hopes of a compromise between the applicant and the commenting agency (Clark 1988). Sometimes this can slow the permitting process almost as much as an elevation request does.

In addition to its authority to request elevation under the memorandum of agreement, the Environmental Protection Agency is given the authority by the Federal Water Pollution Control Act to establish, after consultation with the Corps of Engineers, substantive guidelines to be used by the Corps of Engineers in their evaluation of §404 permit applications. 33 U.S.C. §1344(b) (1989). The act further provides that the Environmental Protection Agency may prohibit the specification of any defined area as a disposal site for dredged or fill material either before or after a §404 permit has been issued if it determines that such disposal will adversely affect municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas. 33 U.S.C. §1344(c) (1989) (see figure 7). This in effect gives the Environmental Protection Agency veto authority over the Corps of Engineers' decisions before or after the permit is issued.

The Corps of Engineers' §404 permit decisions are also affected by the comments and regulatory requirements of certain state agencies. Under the federal consistency requirements of the Coastal Zone Management Act of 1972, as amended, federal agencies, including the Corps of Engineers, are required to "conduct or support activities which directly affect the coastal zone of a state in such a manner which is to the maximum extent practicable consistent with approved state management programs." 16 U.S.C.§1457 (1989) and 15 C.F.R.§§930.1-930.134 (1989). In accordance with this mandate the Corps of Engineers will not issue a §404 or §10 permit for a project over which the Coastal Management Division has jurisdiction unless the Coastal Management Division has either issued a coastal use permit or has made a determination that the project is consistent with the Louisiana Coastal Resources Program, whichever is appropriate (Clark 1988). Nor may the Corps of Engineers issue a §404 or §10 permit with conditions that are inconsistent with an existing coastal use permit (Clark 1988). Thus, to obtain a §10 or §404 permit for projects in the coastal zone, the applicant not only must satisfy the regulatory requirements of the Coastal Management Division but also those of other state agencies with which it has a memorandum of understanding. In the case of blockage or usurpation of state water bottoms, the Division of State Lands may, therefore, delay issuance of a §404 permit by raising an objection to a coastal use permit application that the Coastal Management Division considers sufficient to deny the permit. The denial of the coastal use permit would, in effect, be a determination of inconsistency with the Louisiana Coastal Resources Program and thereby prohibit the Corps of Engineers from issuing the §404 permit. The Division of State Lands may also object directly to the Corps concerning §404 permit applications even if the Coastal Management Division has determined that the project does not require a coastal use permit or has issued a consistency determination. The Division of State Lands may also object to projects outside the coastal zone and therefore not within the Coastal Management Division's jurisdiction (Gonzales 1988). This authority of the Division of State Lands to veto a §404 or §10 permit comes from longstanding Corps of Engineers policy based on several judicial decisions that the authority of a state to prohibit obstructions in navigable waters is not superceded by the Rivers and Harbors Act, and therefore the state's consent to such an obstruction is a prerequisite to issuance of the federal permit. Cummings v. Chicago, Ill. 188 U.S. 410 (1903).

Section 401 of the Federal Water Pollution Control Act requires that an applicant for a federal license or permit for any discharge into navigable waters obtain a certification from the state that the discharge will comply with the applicable provisions of the act. 33 U.S.C. §1341(a)(1) (1989). Under this provision the Corps of Engineers is prohibited from issuing a §404 permit in Louisiana unless the applicant has obtained a water quality certification from the Department of Environmental Quality or such certification has been waived by the Department of Environmental Quality (see figure 7). This requirement is not limited to the coastal zone but has statewide application. The certification process involves a public notice and comment period, and the Department of Environmental Quality usually attaches conditions to its certifications (Wiesepape 1988).

The Federal Water Pollution Act, 33 U.S.C. 1319 (1989), and the Coastal Resources Management Act, La. Rev. Stat. Ann. §49:213.17 (1989), specify penalties for violations of their provisions, and both the Corps of Engineers and the Coastal Management Division employ enforcement personnel. The Corps of Engineers uses an after-the-fact permitting system in which those who perform activities without a §10 or §404 permit may obtain a permit after the work is completed if legal considerations allow (Serio 1988). The Coastal Management Division will issue after-the-fact permits only for activities performed in emergencies (Clark 1988).

LAWS AND REGULATIONS

Federal Regulation

The two main federal statutes affecting marsh management are §10 of the Rivers and Harbors Act of 1899 and §404 of the Federal Water Pollution Control Act, both administered by the Corps of Engineers.

Section 10 of the Rivers and Harbors Act of 1899 prohibits the creation of any obstruction, excavation (dredging), or filling in a navigable water of the United States. 33 U.S.C. §403 (1989). For §10 purposes, navigable waters are defined as "waters of the United States that are subject to the ebb and flow of the tide shoreward to the mean high water mark and/or are presently used, or have been used in the past, or may be susceptible to use to transport interstate or foreign commerce." 33 C.F.R. §§321.2(a), 322.2(a), 329.4 (1989). The jurisdiction applies to artificially constructed as well as natural water bodies throughout the state.

A §10 permit is required for any marsh management practices that use a dam (earthen or shell waterway closure or plug), weir, or other structure or work in navigable waters. Such permits are susceptible to objection by the Division of State Lands on the basis of the prohibition in the Louisiana Constitution against the alienation of state water bottoms. The Corps of Engineers withdraws §10 permits when such objections are raised (Ventola 1988).

Section 301 of the Federal Water Pollution Control prohibits the discharge of any pollutant into waters of the United States except under permits issued by the Environmental Protection Agency. 33 U.S.C. §1311 (1989). However, in the case of the discharge of dredged or fill material, the permitting agency is the Corps of Engineers, in accordance with §404 of the act. 33 U.S.C. §1344 (1989). The definition of "waters of the United States" for §404 purposes is broader than the §10 definition. It includes, in part, waters that are used or have been used or are susceptible to use in interstate or foreign commerce, waters (including wetlands) the degradation of which could affect interstate or foreign commerce, and wetlands that are adjacent to such waters. All waters subject to the ebb and flow of the tide are considered to meet the interstate or foreign commerce use test. 33 C.F.R. §328.3 (1989). The definition of navigable waters under §404 is broad and covers almost any body of water except certain isolated waters, including isolated wetlands, not affecting interstate commerce. A considerable amount of litigation has occurred in the battle to delineate the scope of the definition of adjacent wetlands (see, for example, U.S. v. Riverside Bayview Homes Inc., 474 U.S. 121 (1985)) and to determine the extent of effect on interstate commerce required to include isolated wetlands in §404 jurisdiction. Because it is unlikely that any significant wetlands in Louisiana, especially in the coastal area, do not meet the §404 test for waters of the United States, it will be assumed for this discussion that Louisiana wetlands are subject to §404 requirements. It should be noted, however, that there is an ongoing legal controversy over §404's applicability to "adjacent" and "isolated" wetlands.

Marsh management that involves the discharge of dredged or fill material into U.S. waters, such as would be involved with earthen dams (waterway closures or plugs) and levees, requires a §404 permit. (It also requires a §10 permit if the structure is to be constructed in waters defined as navigable for §10 purposes.) The Environmental Protection Agency has authority under §404(b) to "guide" the Corps of Engineers in its permitting of disposal sites for dredged or fill material and has done so under the §404(b)(1) guidelines (see appendix D). 40 C.F.R. §§230.1230.80 (1989). These guidelines provide substantive criteria for the Corps of Engineers' evaluation of proposed disposal sites, including certain mandated requirements. The Environmental Protection Agency may veto the permitting of specified disposal sites if it finds that there would be "an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreation areas." 33 U.S.C.§404(c) (1989). The Environmental Protection Agency has rarely used this veto authority, but recent cases indicate that it may be more inclined to do so in the future. Bersani v. Robichaud, 850 F.2d 36 (2nd. Cir., 1988).

When the discharge of material is not intended as fill but has the effect of changing the character of the disposal area to dry land or raising the level of a non-navigable water bottom, a permit is required from the Environmental Protection Agency under §402 of the Federal Water Pollution Control Act rather than a §404 permit. 33 C.F.R. §323.2(k) (1989); 49 C.F.R. §122.2 (1989). This is the result of different definitions of "fill" material used by the Corps of Engineers and the Environmental Protection Agency in their respective regulations. The Environmental Protection Agency's definition is broader, allowing regulation of discharges that would not be regulated under the Corps of Engineers' definition of fill. Section 402 of the Federal Water Pollution Control Act also regulates discharges of any other pollutant. There are some exceptions for agricultural purposes, such as agricultural return flows. 33 U.S.C. §1342(1)(1) (1989).

Under the Fish and Wildlife Coordination Act, 16 U.S.C. §662(a) (1989), the Fish and Wildlife Service, the National Marine Fisheries Service, and the Department of Wildlife and Fisheries are given authority to comment and make recommendations on proposed alterations to any stream or other body of water by a federal agency or under federal permit or license. Such consultation is mandatory and, although the commenting agencies do not have veto authority, the Corps of Engineers is required to consider their comments. Furthermore, where feasible, their recommendations are required to be implemented as part of the project to maintain "maximum overall project benefits" and wildlife conservation and enhancement. 16 U.S.C. §662(b) (1989). This does not mean that the comments will necessarily be reflected in the permit conditions.

In addition, under the memoranda of understanding discussed above, the federal agencies have the authority to request elevation if the Corps of Engineers does not act upon their comments and suggestions. Thus a proposed marsh management project could be modified or possibly denied by the permitting agency (in this case the Corps or the Environmental Protection Agency) in response to the comments and recommendations of other agencies. At the very least, adverse comments from the other agencies usually cause considerable delays in obtaining the permit. This is because, although the Corps of Engineers makes the ultimate decision and has authority to override the recommendations of the commenting agencies, it may withhold its permit decision while attempting to bring about an agreement between the adverse parties.

The Magnuson Fishery Conservation and Management Act, 16 U.S.C. §§1801-1882 (1989), seeks "to conserve and manage the fishery resources found off the coasts of the United States and the anadromous species and Continental Shelf fishery resources of the United States." This is primarily accomplished through the regional fishery management councils that develop fishery management plans for various fisheries. The plans attempt to maintain the optimum sustainable yield from each fishery. Included in the considerations of the plans is habitat (including wetlands) protection. The National Marine Fisheries Service is a voting member of the councils and is responsible for implementation of the plans. Thus its commenting authority is influenced by its perception of how marsh management plans may affect marine fishery stocks.

Another federal statute that affects marsh management activities is the Endangered Species Act, 16 U.S.C. §1531-1543 (1989), which protects animals and plants listed as endangered or threatened. Federal agencies are required to carry out their activities, including licensing and permitting, in a manner that gives strong consideration to protecting critical habitat of endangered or threatened species. 16 U.S.C. §1536 (1989). Critical habitat is an area either within or outside the geographic range of an endangered or threatened species that possesses the qualities essential for the conservation of the species. 16 U.S.C. §1532(5)(A) (1989). Through the consultation process mandated by the Endangered Species Act, 16 U.S.C. §1536 (1989), a federal agency can be prohibited from carrying out its project or from licensing or permitting an activity if critical habitat would be destroyed or adversely affected. The Fish and Wildlife Service and the National Marine Fisheries Service have been delegated the responsibility of enforcing the provisions of the Endangered Species Act, which gives these federal agencies another avenue of commenting authority. The Endangered Species Act and the regulations promulgated pursuant to it also contain prohibitions against anyone (including private citizens) harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing, or collecting an endangered or threatened species. 16 U.S.C. §1538 (1989). The presence of an endangered or threatened species or its critical habitat within or in proximity to a proposed marsh management area could give rise to challenges to certain activities under the Endangered Species Act by the Fish and Wildlife Service, the National Marine Fisheries Service, or other parties. Several endangered or threatened species of animals and plants inhabit Louisiana for at least part of the year. The recent controversy over turtle excluder devices underscores the problems that could be encountered under this law. Conversely, it is conceivable that marsh management practices could benefit threatened or endangered species by habitat improvement.

State Laws Affecting Marsh Management

The primary state laws that affect marsh management are the Coastal Resources Management Act, La. Rev. Stat. Ann. §49:213.1-213.22 (1989), and various state constitutional provisions and statutes that distinguish private and state ownership of land. Other state laws that could affect marsh management are those that protect water quality, historic and archaeological sites, and Natural and Scenic Rivers; provide for mariculture; and regulate marsh burning.

The state's Coastal Resources Management Act is administered by the Coastal Management Division, which operates under the declared public policy "to protect, develop, and, where feasible, restore or enhance the resources of the state's coastal zone." La. Rev. Stat. Ann. §49:213.2, (1989). The coastal zone is geographically delineated in the Coastal Resources Management Act, La. Rev. Stat. Ann. §49:213.2, 213.4 (1989). Also provided for in the act are some of the uses and activities in the coastal zone subject to the coastal use permitting requirements and the authority to develop guidelines to further delineate such uses. La. Rev. Stat. Ann. §49:213.5 (1989). Marsh management activities, as defined above, require a coastal use permit; guidelines have been developed for the initial permitting process and for establishing conditions for the permit (see appendix E). Among other things, these guidelines require that marsh management plans "result in an overall benefit to the productivity of the area"; that water control structures result in minimum obstruction of the migration of aquatic organisms and permit tidal exchange in tidal areas; and that impoundments that do hinder normal tidal exchange or aquatic organism migration, to the maximum extent practicable, not be constructed in brackish or saline areas (U.S. Department of Commerce and Louisiana Department of Natural Resources 1980).

Under the guidelines, marsh management plans are required to include marsh management goals; a history of the area; description of the type of habitat; description of the location, construction, and operation of water control structures; a monitoring plan; and specification of activities other than marsh management to be carried out in the plan area. The monitoring plan requires data on water quality, vegetation, the land/water ratio, and wildlife so that the effectiveness of the plan may be evaluated. A marsh management coastal use permit is limited to five years, and the monitoring data are considered in deciding whether or not to renew the permit.

The Coastal Management Division is presently formulating new guidelines for marsh management permitting that will be used by all divisions of the Department of Natural Resources (see appendix E).

The Louisiana Constitution, Civil Code Articles and other statutes, and case law that deal with state ownership of land have the potential for greatly affecting marsh management. These laws provide that the state of Louisiana owns as public property the running waters within the state, the waters and bottoms of natural navigable water bodies (rivers, streams, bayous, and lakes), the territorial sea, the seashore, La. Civ. Code art. 450 (1988), and the banks of navigable lakes. Miami Corp. v. State, 173 So. 315, 325 (La. 1936). Such ownership by the state is analogous to ownership under the common law doctrine of public trust. Public property is held by the state for the benefit of its people; the state's "ownership" therefore is more like guardianship. As such, public property is inalienable, imprescriptible, and exempt from seizure (Yiannopoulos 1980:§34). Although it seems to have been widely ignored by the courts, Louisiana law also provides that the state owns the waters and beds of all the rivers, streams, lagoons, lakes, and bays, whether they are navigable or not, that were not under direct ownership as of August 12, 1910. La. Rev. Stat. Ann. §9:1101 (1989). In addition, Louisiana claims ownership of the waters, beds, and shores of the Gulf of Mexico and "arms" of the Gulf and the lands covered by those waters at high tide within the state's boundaries. La. Rev. Stat. Ann. §49:3 (1989). An arm of the sea has been defined as "a body of water located in the immediate vicinity of the open Gulf that is directly overflowed by the tides" (Yiannopoulos 1980:§45). The Louisiana Constitution prohibits the alienation of the beds of navigable water bodies except for reclamation of eroded land by the affected landowner, La. Const. art IX, §3, which must be permitted by the Department of State Lands. La. Rev. Stat. Ann. §41:1702 (1989).

The banks of navigable rivers, streams, and lakes are defined as the area of land between ordinary low- and high-water marks. La. Civ. Code art. 456 (1988). The seashore is the land between the low-water mark and the mark of the highest winter tides. La. Civ. Code art. 451 (1988). The banks of rivers and streams may be and usually are privately owned, but in the case of navigable rivers and streams, such ownership is subject to the right of public use. La. Civ. Code art. 456 (1988). The beds of non-navigable rivers and streams belong to the riparian landowners (owners of the land adjoining the river or streams), La. Civ. Code art. 506 (1988), and the beds of non-navigable lakes are subject to private ownership. Again, this may be limited to those beds privately owned before August 12, 1910, by La. Rev. Stat. Ann. 9§1101.

Louisiana law defines the buildup of sediments or accretion successively and imperceptibly formed on the bank of a river or stream as "alluvion." The same law defines land exposed by water receding imperceptibly from a bank of a river or stream as "dereliction." In either case the newly formed land belongs to the riparian landowner. La. Civ. Code art. 499 (1988). This private right to alluvion or dereliction does not exist on the seashore or lakeshores, La. Civ. Code art. 500 (1988); in those instances the newly formed land belongs to the state. Conversely, when the shore of the sea or a navigable lake, river, or stream erodes, the newly formed water bottom becomes state property unless the owner of the eroded land takes the statutorily required steps to reclaim it. Miami Corp. v. State, 173 So. 315, 325 (La. 1936). Such reclamation can be very expensive and is rarely attempted when the erosion is extensive.

Artificial water courses (canals) constructed on state-owned land are public water bodies subject to public use (Yiannopoulos 1980:§47). Canals publicly constructed on private land pursuant to a right-of-way servitude are private property subject to public use. Hunter Co. v. Ulrich, 8 So. 2d 531 (La. 1942). Canals constructed on private land for private purposes have been held to be private property with no right of public use. Vaughn v. Vermilion Corp. 444 U.S. 206 (1979). Therefore, if the owner of a private canal decided to prevent public use of the canal, he or she legally could erect barricades to keep out boat traffic. The same right would apply to a non-navigable, privately owned river or stream.

The right to exclude the public from privately owned rivers, streams, and canals has been challenged both in court and by legal commentators. One theory, based on a strict reading of La. Civ. Code art. 450 and dictum in the case of Chaney v. State Mineral Board, 444 So. 2d 105 (La. 1983), is that because the state owns all the running waters in public trust, it is illegal for the owners of the bed and banks of these water bodies to deny public access to the water in them (Ketchum 1988). This theory is questionable since the language relied on in Chaney is dictum (an observation made by the court not necessary for adjudication of the case) and not the holding of the case. The theory also contravenes other Louisiana cases as well as opinions issued by the Louisiana Attorney General's Office. Op. Att'y Gen. 81785, 873 (1981); Op. Att'y Gen. 82102 (1982). Opinions of the Louisiana attorney general, while not binding as legal precedent, are persuasive authority that can be relied on by administrative agencies.

An alternative theory supporting the right of public access to private canals has been presented in two important cases. In Vaughn v. Vermilion Corp., a Louisiana case, the U.S. Supreme Court held that, under federal law, the owner of a private canal could deny public access even though the canal was navigable and joined with navigable waters of the United States. Vaughn v. Vermilion Corp., 444 U.S. 206 (1979). The court's holding, however, anticipated an exception to this rule: when a private canal diverts or destroys a preexisting natural navigable waterway, the canal may be subject to a public right of use. Vaughn v. Vermilion Corp., 444 U.S. at 209 (1979).

The holding in Vaughn formed part of the basis for Louisiana's current lawsuit against the Lafourche Realty Company over the closure of the Tidewater Canal System. Summersgill Dardar, et al. v. Lafourche Realty Co., et. al., No. 85-1015 (E.D. La. filed Aug. 6, 1985). The defendant, Lafourche Realty Company, had obtained a coastal use permit and a §404 permit to implement a marsh management plan by erecting water control structures in a privately owned wetland that the company claims is being degraded by saltwater intrusion. The defendant also obtained a §10 permit from the Corps of Engineers to erect barricades to control boat traffic through the Tidewater Canal System. The defendant built the barricades, posted armed guards at them, and began selectively denying access to the canal. The canal system had been dug in the privately owned marsh and provided access to the marsh by connecting to natural navigable waterways. It also had been used by the public for many years as a short cut to prime fishing grounds. The canal system was blocked ostensibly to prevent vandalism to the water control structures so that they could operate properly. Summersgill Dardar, et al. v. Lafourche Realty Co., et. al., No. 85-1015 (E.D. La. filed Aug. 6, 1985).

The state argued in part that the construction of the Tidewater Canal System, along with other human activities in the area, has diverted or destroyed the original system of natural navigable waterways so that the existing canal system has superceded the natural system. Thus, under Vaughn, the state argued, the public has a right of use that cannot be denied by the defendant's boat barricades. Summersgill Dardar, et al. v. Lafourche Realty Co., et al., No. 85-1015 (E.D. La filed Aug. 6, 1985).

The court, ruling on a motion for dismissal or summary judgement, stated that if a situation contemplated in Vaughn existed it would be grounds to invalidate the permit. They then found that the Corps of Engineers had failed to establish in the administrative record a factual basis sufficient to support their conclusion (that there had been no diversion or destruction of navigable waterways) and denied its motion for dismissal. The court later ruled that the Corps of Engineers' issuance of the permit was not arbitrary and capricious and therefore valid.

The court withheld for later argument decision of whether or not Lafourche Realty can actually use the boat barricades to exclude the public. This will depend on the ruling on another of the state's arguments, that is, that within the marsh management area are state-owned water bottoms, and Lafourche Realty may not prevent public access to these water bottoms with the boat barricades. The Division of State Lands could have objected to the Corps of Engineers' permit and prevented its issuance if it had been aware at the time that there was a basis for the state to claim ownership of some water bottoms within the marsh management area. This issue will turn on the success of the state's claim of ownership to these water bottoms, which in turn could be strongly influenced by the recent U.S. Supreme Court case, Phillips Petroleum Co. v. Mississippi, discussed later in this section.

It is evident that the legal issues and technical aspects of state property ownership and public access rights are relevant to marsh management because certain practices associated with marsh management are considered by the Division of State Lands to be an unconstitutional alienation (divesting or loss of ownership by sale, donation, or other transfer) of state property or a usurpation of public right (Morgan 1988). Such activities would include depositing of fill on state-owned water bottoms, thereby changing their character to dry land, or placing boat barricades across state-owned water bodies, thereby preventing public access. Weirs may be used if they do not hinder normal boat traffic (Morgan 1988). The Division of State Lands does require, however, that the owner or operator of the weir purchase a waterway right-of-way grant (easement) from the state for maintaining the structure on a state-owned water bottom. La. Rev. Stat. Ann §41:1702 (1989). The Division of State Lands opposes levees and dams for impoundments and water control in state-owned water bottoms even when they are associated with marsh management (Morgan 1988). Although the Division of State Lands has no enforcement authority, it does officially comment to the Coastal Management Division, and the Coastal Management Division has denied coastal use permits on the basis of the Division of State Lands' objections (Clark 1988). And the Division of State Lands can veto §10 and §404 permits by objecting on state law grounds. In addition, the Division of State Lands refers cases to the Louisiana Attorney General's Office for enforcement (Morgan 1988).

Louisiana has always claimed ownership in public trust of the beds of natural navigable water bodies, defined by the state as water bodies susceptible of use as highways of commerce by customary modes of water transportation as of Louisiana's admission to statehood in 1812, regardless of whether or not they remain so today. State v. Aucoin, 20 So. 2d 136, 158 (La. 1944). A recent U.S. Supreme Court decision, however, indicates that under federal law Louisiana was granted more land in public trust at statehood than just the navigable natural water bottoms to which it claims ownership today. In the case of Phillips Petroleum Co. v. Mississippi, the U.S. Supreme Court decided an issue of state ownership of tidelands by giving a broad interpretation to the equal-footing doctrine. Phillips Petroleum Co. v. Mississippi, 108 S.Ct. 791 (1988). This doctrine says that all states were admitted to statehood on an equal footing. The Court held that this "equal footing" meant that all lands subject to the influence of the tides, whether or not navigable, as well as all other natural water bodies that were navigable, were transferred at statehood to each state in public trust in its capacity as a sovereign. Phillip Petroleum Co. v. Mississippi, 108 S.Ct. 791 (1988). Because Mississippi had never alienated these non-navigable tidelands and had always claimed ownership to all land under tidally influenced water, the title of Phillips Petroleum, which could be traced back to prestatehood Spanish land grants, was null and void.

The effect of this decision on Louisiana property law has yet to be decided. Some legal scholars theorize that Phillips Petroleum could pave the way for Louisiana to reclaim ownership in public trust of privately owned lands under non-navigable natural water bodies (Yiannopoulos 1988). Their reasoning is that Louisiana, like Mississippi, has never affirmatively alienated the lands in question. This is partly due to confusing definitions under Louisiana law of swamplands subject to tidal overflow and water bottoms subject to tidal ebb and flow, the former of which could be alienated whereas the latter could not (Yiannopoulos 1988). The state sold large tracts of unsurveyed land to private parties in the 1800s. These tracts often contained navigable water bodies and lands subject to tidal influence, and the question arises whether or not the state intended to alienate them (Yiannopoulos 1988). Alternatively, even if it had alienated them, to do so was against the public trust and public policy of the state and therefore such alienations are void (Yiannopoulos 1988). Under Louisiana Constitution Article IX §3, which prohibits the alienation of navigable water bodies, and according to Gulf Oil Corporation v. State Mineral Board, 317 So. 2d 576 (La. 1975), the state may assert ownership to navigable water bodies that it has alienated (Yiannopoulos 1988). This appears to form a foundation for the state to assert ownership of the non-navigable tidelands that it has alienated. Both navigable water bodies and non-navigable tidally influenced waters were part of the public trust lands given to the state under federal law. Therefore, the same public policy should apply to navigable water bodies and non-navigable tidelands (Yiannopoulos 1988).

Other scholars maintain that the Phillips Petroleum decision will have little effect on titles to land in Louisiana because the state made the conscious decision to alienate the non-navigable tidelands. In addition, legal arguments aside, many argue that when presented with unclear cases of state alienation of tidelands, Louisiana courts may well be reluctant (for political reasons) to overturn long-established ownership rights: this should be within the province of the legislature.

The legal theories behind the ownership issues are more complex than they appear from this discussion. Nevertheless, the possibility of far-reaching ramifications of Phillips Petroleum should not be discounted. Of paramount importance to Louisiana landowners is, of course, the possibility of losing ownership. In addition, the Phillips decision could have an important impact on marsh management. If the state were to assert its ownership of tidelands in managed areas, it could impose restrictions against alienation of state lands. Marsh landowners might also be discouraged from undertaking management of the marsh if they thought the land actually belonged to the state. Nor, presumably, could the state afford to manage all of the newly acquired marshland itself. The possibility of such additional regulatory and financial burdens makes these ownership issues worthy of close scrutiny.

A marsh management plan that calls for reclamation of an area of land that had been lost through erosion of the shore or bank of a state-owned water bottom would fall under the statutes dealing with state water-bottom management administered by the Division of State Lands. A permit is required for such reclamation, and a prerequisite to obtaining such a permit is proof of ownership and of the boundaries of the eroded lands. Permits may also be required for other structural encroachments on state-owned water bottoms, such as pilings, breakwaters, and piers. La. Rev. Stat. Ann. §41:1701-1714 (1987).

If the marsh management activity affects a river or stream or segment of one that is included in the Louisiana Natural and Scenic Rivers Systems (La. Rev. Stat. Ann. 56:1840-1856 (1989)), a permit may be required from the Department of Wildlife and Fisheries. Activities that could require permits include but are not limited to channelization or alteration of flow, other dredging and filling, and discharges into such rivers and streams.

Nonstructural Marsh Management Activities

There are several other activities that do not include using structures to manipulate hydrology but still are sometimes considered components of marsh management. These activities, which may also be regulated, include marsh burning, pesticide use, hunting and trapping, mariculture, and boat barricades.

Marsh is often burned to prevent plant succession and to promote the growth of new vegetation. Burning is regulated under La. Rev. Stat. 56:107, which prevents anyone from setting fires to marshland except an owner attempting to improve food conditions for wildlife. Such burning must be done under permit and supervision of the Department of Wildlife and Fisheries. La. Rev. Stat. Ann. 56:107 (1989). Because this provision apparently is widely unenforced, marsh burning is essentially unregulated (Vidrine 1988).

Pesticide use is regulated by the Department of Agriculture. Some landowners use herbicides to control what are considered noxious weeds. Another practice, and one that is currently being promoted by the Department of Wildlife and Fisheries in their Acres For Wildlife Program, is the use of herbicides to increase open water in marshes and improve waterfowl habitat (Vice 1988). Hunting and trapping to harvest the natural resources of marshland and to control destructive animals, such as muskrat, are considered by many to be sound marsh management practices. These activities are regulated under the appropriate Wildlife and Fisheries statutes. La. Rev. Stat. §56 (1989).

One of the most controversial practices associated with marsh management is mariculture. These operations received much attention after the 1987 session of the Louisiana legislature, when two conflicting bills providing for the establishment of mariculture operations were passed. La. Rev. Stat. Ann. §56:13,579.1 (1989). La. Rev. Stat. §56:579.1 allows the Department of Wildlife and Fisheries to issue a maximum of ten mariculture permits. La. Rev. Stat. Ann. §56:579.1(B) (1989). Each permitted area cannot exceed 8,000 acres and must be within marsh areas being managed under valid coastal use permits. It also requires that the permits have a duration of no more than five years and that all fishery stocks utilized in the operation be "purchased from a legal source." In effect, this requires the use of stocked rather than wild organisms.

The other mariculture law, La. Rev. Stat. §56:13, provided authority for the Department of Wildlife and Fisheries to issue "special fish and wildlife harvesting permits" to "owners and operators who filed a marsh management plan." La. Rev. Stat. Ann. §56:13 (1989). It set no limit on the number of permits, the duration, or the acreage involved, and did not require that stocked fish be used.

Both mariculture laws exempted marsh management operators from La. Rev. Stat. 56:329, which prohibits the obstruction of the free passage of fish in any body of water, excepting water control structures or dams for the retention of water for conservation purposes. La. Rev. Stat. Ann. §56:13,579.1 (1989). Under R.S. 56:13, certain operators were allowed to place screens on the access routes of their impounded marshes to trap wild fish. The fish were allowed to grow within the impoundment and were harvested when they reached a marketable size. This practice raised a storm of controversy when these operators "harvested" red drum, which at the time were protected by closed commercial and recreational fisheries for that species. The Department of Wildlife and Fisheries was later able to prevent the harvest of red drum by interpreting R.S 56:13 as not overriding the Department of Wildlife and Fisheries rulings on limitations or closures of fisheries (Watson 1988). This action did not quell the controversy surrounding R.S. 56:13, however, and it was repealed in the 1988 regular session. The debate over mariculture still rages and is discussed in more detail in chapter 4 of this report.

There is an apparent conflict between the Coastal Management Division's permitting of marsh management plans and the Department of Wildlife and Fisheries' permitting of mariculture operations within those areas covered by the plans. The Coastal Management Division does not consider mariculture operations to be marsh management; indeed, its policy as set forth in the Coastal Use Guidelines is that the restriction of ingress and egress of marine organisms should be minimized in wetlands that are not completely impounded (U.S. Department of Commerce and Louisiana Department of Natural Resources 1980). Placing screens or nets across access routes in wetlands requires a coastal use permit from the Coastal Management Division as well as a mariculture permit from the Department of Wildlife and Fisheries. In addition, under La. Rev. Stat. 56:579.1, an owner or operator must obtain a coastal use permit for a marsh management plan as a prerequisite to obtaining a mariculture permit. Most of the existing marsh management permits were issued before the passage of the mariculture law and with no consideration by the Coastal Management Division of possible future mariculture operations. If a marsh management plan does not include the use of screens or nets to restrict migration and the owner or operator later uses such devices under the mariculture permit, he or she would be in apparent violation of the coastal use permit for the marsh management operation. The question is whether the legislature intended to exempt mariculture practices that obstruct marine organism ingress and egress from coastal use permit requirements. The language in La. Rev. Stat. 56:579.1B begins, "notwithstanding any other provision of law to the contrary." Does this merely exempt mariculture from other wildlife and fisheries laws, as the illustrative list would indicate? This issue needs to be resolved because future conflicts between the permitting authority of the Coastal Management Division and the Department of Wildlife and Fisheries could leave marsh managers who also carry out mariculture operations unable to comply with all pertinent regulatory requirements.

Some owners and operators of wetland areas place barricades across waterways to block boat traffic, ostensibly to reduce erosion from boat wakes and prevent vandalism to water control structures. This activity would require a §10 permit from the Corps of Engineers, but if the barricade were placed across a naturally navigable waterway the Division of State Lands would object to it as an unconstitutional alienation of state lands (Morgan 1988). The objection probably would result in the Corps of Engineers and the Coastal Management Division either denying or withdrawing the respective permits (Ventola 1988). The current controversy over the Tidewater Canal System underscores the problems in this area of the law.

CONCLUSION

The state and federal regulatory and permitting network that affects structural marsh management in Louisiana's coastal zone is complex and often contradictory. The intricate interactions between the permitting agencies and the commenting agencies are designed to safeguard various widely divergent public interest goals. This system can present a confusing front to prospective marsh managers, some of whom already believe themselves to be overregulated. The lengthy process of obtaining the required permits has left some applicants discouraged and frustrated with the system.

The legal foundations of the regulatory and commenting agencies' policies are also complex and constantly evolving. This evolution is now being significantly influenced by growing awareness of the seriousness of the coastal land loss problem. The public interest goals and policy decisions affecting the regulatory scheme are more thoroughly discussed in chapter 4 of this report.

Chapter 4

PUBLIC INTEREST GOALS AFFECTING MARSH MANAGEMENT IN LOUISIANA

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INTRODUCTION

This report was prepared during a period of many events and changes in public interest goals, agency guidelines and policies, legislation, judicial decisions, and scientific knowledge of the effects of marsh management practices. All of these factors interact in sometimes complicated ways to affect marsh management in Louisiana.

Very few state or federal laws deal specifically with marsh management, and therefore the guidelines and policies of most of the administrative agencies discussed in this report are not fully, if at all, developed or formalized. The embryonic nature of laws and agency policies can make it difficult for the regulated community (and sometimes the agencies themselves) to understand and predict how marsh management will be affected by regulation. Because administrative agencies have had very few marsh management goals established for them by law, it is often necessary to attempt to infer such goals by examining an agency's policies toward and guidelines for marsh management. Additionally, most of the agencies have not officially promulgated guidelines and policies. In these situations it is necessary to examine draft guidelines and policies and internal agency documents, and to communicate personally with agency personnel to determine current agency policy.

Given the fluid nature of the subject matter, some of the information contained in this report will be obsolete by the time it is published. This is analogous to taking a snapshot in the early stages of a foot race. We will attempt to prepare a disclaimer shortly before publishing which lists major changes that have taken place since the report was submitted.

Most agencies discussed in this report have no mandated goal either to encourage or discourage marsh management practices. In most cases their statutorily mandated goals are the protection and conservation of one or more natural resources. If these agencies determine from scientific and other information that marsh management harms the resource they are mandated to protect, they will probably use their regulatory power to prohibit marsh management practices. The converse would be true if they determine marsh management to be beneficial to the resource they protect.

The various governmental and private entities with interests in Louisiana's coastal zone often have widely divergent goals. Indeed, some of these goals are diametrically opposed. This fact, coupled with the lack of definitive scientific data about the causes of land loss, has prevented the establishment of a uniform public policy on marsh management. It is difficult to establish a policy towards a management practice when its short- and long-term effects are unknown. Conversely, policy that is predisposed toward a particular activity may influence the level of effort expended toward answering important scientific questions, such as: Can marsh management help prevent land loss by protecting vegetation from saltwater intrusion and promoting revegetation of open water? Does marsh management increase land loss by altering hydrologic regimes and thereby blocking the introduction of sediment needed to counteract subsidence and sea level rise? Are gated water control structures less detrimental to estuarine and marine fisheries than fixed-crest weirs? Are the benefits of marsh management worth the loss in fisheries resources?

Once the environmental effects of certain marsh management practices have been scientifically established, regulators can make more effective policy decisions. Policy, however, is not and should not be static. What was thought to be a good management practice under one set of environmental conditions may not be appropriate after natural or human-induced changes occur. Scientific understanding of the whole process will help keep policies in step with changing conditions.

In this volume the major public and private interests that affect the regulation of marsh management will be identified. We will examine how their goals, as reflected in the policy of the various governmental agencies and the endeavors of private landowners, and as influenced by available scientific data, promote or retard marsh management in coastal Louisiana.

This report will discuss eight major public interest goals or topics associated with or affecting marsh management. There are others, but these are the most controversial and have the greatest impact on marsh management: land loss prevention, estuarine and marine organism access, public access, state and private ownership rights, mariculture, monoculture or target species management, monitoring, and freshwater and sediment diversion projects. Although they are discussed separately for the sake of clarity, some of these goals are interrelated.

The primary federal and state agencies involved in marsh management are the Fish and Wildlife Service, the National Marine Fisheries Service, the Environmental Protection Agency, the Corps of Engineers, the Soil Conservation Service, the Coastal Management Division of the Department of Natural Resources, the Department of Wildlife and Fisheries, the Division of State Lands of the Department of Natural Resources (transferred to the Division of Administration in 1989), and the Louisiana Attorney General's Office. Also involved in influencing public interest goals and policy are the Coastal Restoration Division of the Department of Natural Resources, the Coastal Restoration Policy and Technical Committees of the Governor's Office, landowners, and citizen-based environmental groups.

Some of the terms used in this report will not be familiar to some people. The following definitions will apply unless otherwise stated in the text.

Goal - used synonymously with objective and mission, this term refers to an end toward which an effort is directed. Usually an administrative agency's goals are established by legislation (law) and are therefore stated goals. Often, however, situations arise for which an agency has no legislative directive. In that case an agency must develop a goal consistent with its legislatively mandated goal(s). This would be an unstated goal and may be inferred from an agency's policies.

An example of a legislatively mandated goal discussed in this report is that of the Fish and Wildlife Service, which is to conserve, protect, and enhance fish and wildlife and their habitats for the continuing benefit of the American people.

Inferred goal - a goal that is not stated but that may be inferred or discerned from an agency's policies and guidelines.

Marsh management - the use of structures to manipulate local hydrology for the purpose of reducing or reversing wetland loss and/or enhancing productivity of natural renewable resources.

Policies - actions or procedures and statements thereof, sometimes as part of a plan, designed to achieve a goal or goals.

Guidelines - formally promulgated (i.e., as regulations) procedures and substantive criteria designed to define and implement an agency's policies.

PUBLIC INTEREST GOALS

Land Loss Prevention

The retardation, prevention, and reversal of land loss is most often cited as the primary goal of modern marsh management practices. Historically, water control in Louisiana wetlands has been exercised for other reasons, including draining wetlands for agriculture; creating aquaculture or mariculture impoundments; improving habitat for waterfowl, furbearers, and alligators; and preventing saltwater intrusion. When salt water moves into fresh and intermediate marsh, it often kills the vegetation; without the root structure, the marsh soil erodes easily, turning marsh into open water (U.S. Soil Conservation Service 1988a). Use of marsh management mainly as a tool to prevent land loss is, however, a relatively recent occurrence (Day et al. 1986).

Federal

The Fish and Wildlife Service is charged with conserving, protecting, and enhancing the nation's fish and wildlife resources and their habitats. The Fish and Wildlife Service recognizes that the dredging of canals and navigation channels within Louisiana's coastal wetlands has adversely affected these wetlands via saltwater intrusion, erosion and export of marsh soils, excessive water-level and salinity fluxes, and the associated creation of numerous unintentional impoundments. These adverse impacts have contributed to wetland loss rates throughout the coastal zone. The U.S. Fish and Wildlife Service also recognizes that throughout coastal Louisiana, fresh and intermediate marshes are being converted to more saline marsh types. The conversion of those marshes to more saline vegetative types often results in extensive marsh deterioration and loss, especially where the soils have a high organic matter content. As a result of those factors, loss rates of fresh and intermediate marshes are generally higher than those of more saline marsh types. The service also recognizes that structural marsh management techniques can be implemented to preserve and even revegetate deteriorated wetlands, especially when active marsh management techniques are applied in fresher marsh types (Cowan et al. 1988). With this goal in mind, the Lafayette, Louisiana, field office of the U.S. Fish and Wildlife Service, whose habitat protection responsibilities include all wildlife and fish (freshwater and estuarine-dependent fish and shellfish), developed draft guidelines geared toward conservation, restoration, and enhancement of deteriorating vegetated wetlands. In fresh and intermediate marshes those guidelines also emphasize enhancement of waterfowl and wildlife habitat, while allowing ingress and egress of estuarine-dependent organisms to the extent that the primary goals are not threatened. In brackish and saline marshes, those guidelines attempt to balance the conservation of deteriorating emergent marsh against the restriction of ingress and egress of estuarine organisms. However, because brackish and saline marshes provide high quality nursery habitat for estuarine-dependent organisms, ingress and egress of estuarine organisms is permitted to the extent that no substantial adverse effects occur to marsh habitat. Management of healthy brackish and saline marshes is generally not supported (see section on estuarine and marine organisms).

The National Marine Fisheries Service's goal is "to achieve a continued optimum utilization of living marine resources for the benefit of the Nation," 489 Fed. Reg. 53142 (1983). Although attainment of this goal includes a policy of habitat protection (including wetlands), the National Marine Fisheries Service is not yet convinced that marsh management techniques are effective in reducing or reversing land loss. In fact, it points to some scientific data indicating that marsh management may even increase land loss under certain conditions (e.g., Cowan et al. 1988). These results, coupled with concern over the impacts on marine fisheries resources, have led the National Marine Fisheries Service to take a stance against most wetland marsh management plans until more conclusive scientific data are accrued (Ruebsamen 1988). The National Marine Fisheries Service also argues that the cumulative effect of marsh management projects already permitted, as well as that of large individual projects, constitutes a major federal action such that an environmental impact statement should be prepared before further permitting.

The Environmental Protection Agency is not convinced that marsh management effectively controls or prevents land loss and points to some studies that indicate a detrimental effect on emergent marsh (Saunders 1988). The Environmental Protection Agency has no specific mission to protect certain groups of organisms as do the National Marine Fisheries Service and the Fish and Wildlife Service. The Environmental Protection Agency's policies are derived from the Federal Water Pollution Control Act §404(b)(1) guidelines, which have a broader perspective than the mandates of the National Marine Fisheries Service and Fish and Wildlife Service. 40 C.F.R. §230.1-230.80 (1989). Under these guidelines, the Environmental Protection Agency's goal is to review marsh management plans on a case-by-case basis and attempt to balance the usefulness of the activities in preventing land loss against their impacts on water quality; freshwater, marine, and estuarine organisms; waterfowl and other wildlife; municipal water supplies; recreational areas; and aesthetic values. 40 C.F.R. §230.22, 30, 31, 32 (1989). This broad-based approach coupled with the scientific controversy over the effectiveness of marsh management plans often leads the Environmental Protection Agency to take the stance that the regulatory agencies should not yet give a general endorsement to marsh management but should wait until its effectiveness is conclusively proven (Environmental Protection Agency 1989). This is an important policy in light of the Environmental Protection Agency's authority under §404(c) of the Federal Water Pollution Control Act to "veto" marsh management permits. This power has been used more frequently in recent years (46 Fed. Reg. 10203 (1981), 49 Fed. Reg. 29142 (1984), 49 Fed. Reg. 30112 (1984), 50 Fed. Reg. 47267 (1985), 51 Fed. Reg. 22977 (1986), 52 Fed. Reg. 29431 (1987), 52 Fed. Reg. 38519 (1987), 52 Fed. Reg. 49082 (1987), 54 Fed. Reg. 33608 (1989)).

The Corps of Engineers does not appear to have formed a policy for or against marsh management. The Corps of Engineers performs a public interest review and an environmental review, which includes the §404(b)(1) guidelines, taking into account the comments of the other agencies (Serio 1988). The Corps of Engineers has, however, published a brochure, "Crisis on Louisiana's Coast . . . America's Loss," which lists barrier island protection, freshwater and sediment diversions, and marsh creation by disposal of dredged spoil as steps that can be taken to combat land loss (U.S. Army Corps of Engineers n.d.).

The National Environmental Policy Act, 42 U.S.C.A. §4321-4370(a) (1989), requires preparation of an environmental impact statement for major federal actions (e.g., permit issuances) that would significantly affect the quality of the human environment. Given the history of marsh management permitting and the expected proliferation of requests for permits to implement marsh management plans, the Corps of Engineers believes that significant cumulative effects are reasonably foreseeable and environmental impact statements therefore necessary. The Corps of Engineers intends to prepare a programmatic environmental impact statement on marsh management; the scoping process has been completed and is awaiting the results of the Minerals Management Service study on marsh management. Meanwhile, the Corps of Engineers continues to evaluate marsh management permit requests on a case-by-case basis. The Corps of Engineers has issued and is prepared to continue to issue permits for individual marsh management plans for which cumulative effects are not considered significant (Bosenberg 1988).

The Soil Conservation Service provides free expertise and technical assistance to landowners. Although the Soil Conservation Service has no regulatory authority, it is an important link in the process because many landowners could not afford to devise and implement marsh management plans without technical assistance (see figure 3, chapter 3). The Soil Conservation Service has a set of general environmental policies and guidelines (Soil Conservation Service Environmental Policy and Technical Assistance Guidelines) that apply to all assistance the Soil Conservation Service administers to landowners and managers of upland and wetland habitats alike. These policies and guidelines, therefore, apply to assistance administered to landowners or managers implementing marsh management plans (see appendix F). The policy promoted by these extensive guidelines attempts to strike "a balance between use, management, conservation, and preservation of the Nation's natural resource base" (see appendix F). The policy states that environmental quality is to be given consideration "equal to economic, social, and other factors in decision making." The Soil Conservation Service policy takes into account threatened and endangered species, and scenic beauty. The Soil Conservation Service considers marsh management in certain situations to be effective in promoting revegetation and thus retarding land loss.

State

The Coastal Management Division's policy on marsh management is based largely on its belief that such activities are effective in reducing and reversing land loss (Clark 1988). This is consistent with the state's public policy in the State and Local Coastal Resources Management Act of 1978, which is "to protect, develop, and where feasible restore or enhance the resources of the state's coastal zone," La. Rev. Stat. 49:214.22 (1989). From this policy it is reasonable to infer that a goal of the state is to protect, maintain, and enhance wetlands. The current draft of the new Department of Natural Resources Wetland Management Policies and Guidelines lists reduction of land loss, creation of additional wetland acreage, and maintenance of freshwater and sediment diversions as three of the seven goals of marsh management in coastal Louisiana (see appendix F).

The Department of Wildlife and Fisheries' policy favors certain marsh management policies considered to be potentially effective tools for combatting land loss (Chatry 1988). This policy is reflected in the guidelines being developed by the Department of Wildlife and Fisheries for dealing with marsh management practices (Chatry 1988). These guidelines list as a primary objective the prevention of deterioration and loss of emergent marsh of all types (Chatry 1988). This goal is in line with the Department of Wildlife and Fisheries' general mandate, which is in part "the control and supervision of programs relating to the management, protection, conservation, and replenishment of wildlife, fish, and aquatic life in the state" La. Rev. Stat. 36:602 (1989). The Department of Wildlife and Fisheries; policy on marsh management and land loss prevention is also influenced by practical economic considerations (Chatry 1988). The Department of Wildlife and Fisheries believes that the task of protecting and restoring Louisiana's coastal wetlands will fall primarily on the shoulders of private landowners because most of the state's coastal wetlands are privately owned (Chatry 1988). Indeed, in its present financial situation, the state cannot afford to fund all of the efforts needed to protect and restore these areas. Therefore, the Department of Wildlife and Fisheries supports marsh management projects that follow the best possible plan for marsh protection while still allowing the landowner to enhance conditions for production of one or more commercially important species, such as waterfowl, furbearers, and alligators (Chatry 1988). The Department of Wildlife and Fisheries' policy enlists the help of the private sector in furthering the public goal of marsh protection. The private landowner in turn will be compensated for the considerable expense of achieving that public goal by being allowed to increase profits from hunting, fishing, and fur and alligator production. Until enough public funds are available to solve Louisiana's coastal erosion problems, the Department of Wildlife and Fisheries thinks such a trade-off is necessary (Chatry 1988).

The Division of State Lands realizes the magnitude of Louisiana's coastal erosion problem and is generally in favor of measures taken to alleviate it (Morgan 1988). The Division of State Lands, however, is charged by the Louisiana Constitution and statutes (La. Rev. Stat. 41:2 et seq. (1989)) to prevent the alienation of state water bottoms and with this goal in mind has a policy of objecting to certain work or structures associated with marsh management. This will be more fully discussed in the sections on state and private ownership rights and human access.

<u>Landowners and Public Interest Groups</u>

As would be expected, landowners and private managers have a perspective on marsh management different from that of the regulatory agencies. When interviewed about marsh management issues, landowners freely admit that there is a profit motive attached to marsh management, either from associated mariculture or habitat enhancement for commercially important species (Donahue and Edwards 1988). This, they say, does not compromise to any great extent their main goal of preventing land loss, but helps provide incentive for implementing the costly projects involved in a marsh management plan (Donahue and Edwards 1988). The main goal of some landowners is undoubtedly waterfowl habitat enhancement, but the Coastal Management Division and other agencies attempt to refine such plans more toward preventing land loss before permits are issued (Clark 1988). The landowners argue that marsh management plans are not carried out in pristine marsh but almost always in areas heavily affected by such human activities as canal and levee construction. Thus the natural hydrology is already so altered that marsh management is far more beneficial in restoring a semblance of a natural system than taking no action (Donahue and Edwards 1988). Landowners are convinced that marsh management helps protect and restore emergent marsh (Donahue and Edwards 1988).

Certain environmental groups have taken positions for or against marsh management. In a recent report by the Coalition to Restore Coastal Louisiana, several citizen's environmental groups, including local chapters of the Audubon Society and Sierra Club, the Louisiana Wildlife Federation, the Environmental Defense Fund, the Natural Resources Defense Council, the Environmental Policy Institute, and Save Our Coast, expressed concern about regulatory policies concerning marsh management (Coalition to Restore Coastal Louisiana 1987). The report stated that marsh management plans have been and are implemented for reasons besides marsh protection, such as to establish private boundaries and enhance habitat for fisheries and waterfowl (Coalition to Restore Coastal Louisiana 1987). The report also states that marsh management plans could have significant cumulative impacts on marine fisheries and the overall coastal restoration effort by inhibiting the movement of marine organisms and blocking freshwater and sediment diversions. The report recommends that the Coastal Management Division and the Corps of Engineers discontinue issuing permits for marsh management plans encompassing more than 500 acres until a programmatic environmental impact statement is prepared to address the effectiveness of these plans in preventing land loss and their compatibility with other planned coastal restoration efforts (Coalition to Restore Coastal Louisiana 1987). It also recommends that the Coastal Restoration Division of the Department of Natural Resources review all proposed marsh management plans to determine their consistency with Louisiana's comprehensive coastal restoration plan, which now includes some marsh management plans (Coalition to Restore Coastal Louisiana 1987).

The managers of the National Audubon Society's Paul J. Rainey Wildlife Refuge and Game Preserve in Vermilion Parish, Louisiana, have a somewhat different philosophy than the local chapter concerning water control structures. The managers employ fixed-crest weirs and an experimental rock weir as part of a marsh management plan on the refuge (Meeder 1988).

Issues and Evaluations

The most important issue is whether or not marsh management actually does prevent or reverse land loss. Some agencies claim that there is ample scientific evidence to reasonably conclude that marsh management is an effective tool in preventing land loss under certain conditions. Other agencies, however, believe that not only is there insufficient evidence to support such an assumption, but that some studies have indicated that marsh management can accelerate land loss under certain conditions. This issue will have to be resolved by thorough scientific examination, which will take time. Many argue that too much time will be required, and the resource will be irreparably damaged before a scientific consensus will be reached. The resolution of this issue would go a long way towards resolving other issues surrounding marsh management.

Estuarine and Marine Organism Access

Scientific studies have shown that fixed-crest weirs significantly affect the ingress and egress of organisms (fish, crustaceans, etc.) in marsh areas (Herke 1971, 1979; Herke et al. 1987b, 1987c). The scientific community generally agrees that other water control structures have a similar impact. This impact could be more or less severe, depending on the operation of the structure. Many commercially valuable species as well as other organisms that form vital links in the estuarine and marine ecosystems use these marshes at important stages in their life cycles. Therefore, the potential for significant impact on fisheries exists if marsh management becomes widespread. The extent of such an impact has been hotly debated and the controversy has become a major sticking point in the federal permitting process.

Federal

The Fish and Wildlife Service recognizes that the use of structural marsh management techniques (water control structures) to preserve or revegetate wetlands may reduce ingress and egress opportunities for estuarine and marine organisms. However, in its opinion, because access into the marsh by these organisms has been increased through human activities, such as canal dredging, and because prime habitat for estuarine organisms (saline and brackish marsh) is expanding at the expense of fresher habitats, some reduction in estuarine organism usage of managed marshes is therefore acceptable. To achieve its mission of conserving, protecting, and enhancing the nation's fish and wildlife resources, the Fish and Wildlife Service has developed guidelines that differentiate between marsh types and the amount of recent deterioration. The guidelines for fresh marsh make provisions for enhancing waterfowl habitat and protecting emergent marsh while minimizing adverse impacts to alligators, furbearers, and other wildlife. In intermediate and deteriorated brackish marsh, estuarine organism access is accommodated to various degrees depending upon the history of the area and provided that estuarine organism access results in no substantial adverse effects to marsh habitat. Under these guidelines, water control structures are unacceptable in healthy brackish and saline marsh except in narrow circumstances, and even then should allow estuarine organism access.

The National Marine Fisheries Service, whose mission is "to achieve a continued optimum utilization of living marine resources for the benefit of the Nation," 48 Fed. Reg. 53142 (1983), is primarily concerned with the effect marsh management plans have on marine fisheries resources and their habitats. The agency is generally opposed to structures that inhibit the movement of organisms that must migrate to and from marsh areas at certain points in their life cycles (Ruebsamen 1988). This fact, coupled with skepticism about the utility of marsh management plans in preventing land loss or enhancing fisheries, frequently causes the National Marine Fisheries Service to oppose such plans (Ruebsamen 1988). Another concern of the National Marine Fisheries Service is that marshes in subsiding environments will continue to deteriorate despite water control structures, and that the structures will greatly diminish the value of whatever fisheries the marsh would have continued to support while deteriorating. Therefore, in most cases marsh management should not be implemented until an adequate data base is established to allow informed decision making (Ruebsamen 1988).

The Environmental Protection Agency is concerned with protection of the whole range of wetland functions and values including habitats for marine organisms. The agency questions whether or not water control structures can function as intended and still accommodate marine organism access (Environmental Protection Agency 1989). The Environmental Protection Agency is not convinced of the utility of marsh management in preventing land loss and therefore is not sure if it is worth the loss in marine organism access (Saunders 1988).

The Corps of Engineers apparently has no stated or inferred goals or policies toward marine organism access. It is, however, bound to follow the §404(b)(1) guidelines established by the Environmental Protection Agency.

The Soil Conservation Service has no policy specific to marine organism access in marsh management projects. The Soil Conservation Service does, however, have an environmental policy and technical assistance guidelines that apply to all assistance given to landowners. The stated goal is "to provide assistance that will allow use and management of ecological, cultural, natural, physical, social and economic resources by striving for a balance between use management, conservation and preservation of the Nation's natural resource base" (Louisiana Coastal Resources Program 1988). Although the guidelines do not specifically mention marine organism access, the Soil Conservation Service's practice of writing marsh management plans implies that it is willing to accept the trade-off in loss of marine organism access.

State

The Coastal Management Division has attempted to achieve its goal of protecting and enhancing all coastal resources (inferred from the policy of the State and Local Coastal Resources Management Act) by placing provisions in its current and proposed guidelines that attempt to mitigate the effects of water control structures on estuarine and marine organism access (see appendix

F). This includes standards for placing water control structures in fresh and intermediate marsh that differ from standards for brackish and saline marshes, where estuarine organism populations are larger. Some of the recommendations include prohibiting total impoundments in tidal areas, requiring that structures allow more organism access in brackish and saline areas, encouraging new designs for structures to allow greater organism access while maintaining water control, and placing a greater overall emphasis on fisheries in brackish and saline areas (see appendix F). Although some trade-offs are inevitable because all of the current water control structures will have some effect on organism access, the Coastal Management Division's position is that preserving marshland will have long-term benefits to fisheries that will more than offset the short-term detriment (DeMond 1988).

The Department of Wildlife and Fisheries has yet to promulgate guidelines for reviewing marsh management projects, but its draft guidelines indicate policies for estuarine and marine organism access similar to those of the Fish and Wildlife Service. This is in line with Wildlife and Fisheries' mission to "control and supervise all wildlife of the state, including fish and all other aquatic life." La. Rev. Stat. 36:602 (1989).

Landowners and Public Interest Groups

Landowners, though willing to accommodate marine and estuarine organism access as much as possible, believe that some loss of access is inevitable in achieving their primary goal of land loss prevention (Donahue and Edwards 1988).

Several environmental groups, as mentioned, are concerned with the impacts to marine and estuarine organism access. In their opinion, the speculative value of marsh management projects in preventing land loss does not justify the impacts of some projects (Coalition to Restore Coastal Louisiana 1987).

Issues and Evaluation

The major issue in marine organism access is whether the benefits in land loss prevention outweigh the negative impacts to marine and estuarine organisms. This issue is clouded for those not yet convinced that marsh management effectively prevents land loss.

Public Access

The effects of water control structures on the public's right of access to wetland areas is becoming one of the most serious marsh management issues. This issue is closely related to state and private ownership rights, discussed in the next section. The public's long-held belief that it has the right to traverse all rivers, streams, and canals in the state is perhaps best expressed by the colloquialism, "where the water can flow the people can go." This belief, coupled with disagreement in the legal community about the interpretation of the state's property laws, has led to some heated disputes. The most recent illustration of this controversy arose over the Lafourche

Realty Company's placement of boat barricades and armed guards on the Tidewater Canal in Lafourche Parish southeast of Golden Meadow, Louisiana.

Federal

The Fish and Wildlife Service has no statutorily defined responsibilities to uphold state property laws. Nevertheless, the service states in its marsh management guidelines that restriction of public access is not acceptable unless the water control structures are necessary to restore "badly deteriorated marshes."

The Corps of Engineers, whose mission under the Rivers and Harbors Act of 1899 is to protect navigation, has an interest in public access to truly navigable and tidally influenced waters. Additionally, the Corps of Engineers is required to coordinate with the states before permitting obstructions to water bodies, especially those wholly within the borders of the state. Cummings v. Chicago Ill. 188 U.S. 410 (1903). Therefore, Corps of Engineers policy is not to issue §9 or §10 permits if the obstruction contravenes state law.

The National Marine Fisheries Service, Environmental Protection Agency, and the Soil Conservation Service have no statutory requirements to consider public access in their regulatory programs, if applicable, or services to the public. These agencies may as a matter of internal policy take public access into consideration, but no evidence was found to substantiate this.

State

The state agencies apparently have different opinions and policies concerning the effects of marsh management on public access. The Tidewater Canal case, Summersgill Dardar et al. v. Lafourche Realty Co., No. 85-1015 (E.D. La. filed Aug. 6, 1985), is a good illustration of this point. The Lafourche Realty Company (the defendant) established a marsh management plan under a coastal use permit from the Coastal Management Division and §10 and §404 permits from the Corps of Engineers. Under the marsh management plan, water control structures were placed on several canals and tidal streams. In addition, under the §10 permit, boat barricades were placed on the tidewater canal to control boat traffic. To prevent destruction of the barricades, armed guards were stationed at them. Lafourche Realty claimed that the boat barricades were necessary to prevent vandalism to the water control structures.

The most interesting aspect of this dispute is the State of Louisiana's position on marsh management. In arguing against the actions of the defendant, the state charged, among other things, that the Corps of Engineers failed to prepare an environmental impact statement. The state maintained that an environmental impact statement was required by the National Environmental Policy Act before a §404 permit could be issued. A key point in the state's argument is that the cumulative effects of multipurpose marsh management have a significant adverse effect on the human environment. Summersgill Dardar v. Lafourche Realty Co., No. 85-1015 (E.D. La. filed Aug. 6, 1985). Thus the state Attorney General's Office, at least in this case, seems to have taken the position that marsh management is detrimental to the marsh ecosystem. This policy directly conflicts with that of the Coastal

Management Division, which issued a permit for the plan with no initial objection from the Division of State Lands or the Department of Wildlife and Fisheries. The Division of State Lands later objected when it discovered that state-owned water bottoms lay within the marsh management area to which the public was denied access. The Coastal Management Division does not condone or issue permits for barricades except in rare instances, for example, when a problem may exist with state lands or oyster leases. The Coastal Management Division does, however, issue permits for water control structures associated with marsh management plans. These water control structures block public access, but apparently the Coastal Management Division considers the loss of public access a worthwhile trade-off (DeMond 1988). The Department of Wildlife and Fisheries guidelines appear to take a similar approach by stating that restriction of public access is not acceptable unless the water control structures are necessary to restore "badly deteriorating marshes."

Neither of these agencies, however, has any statutory requirement to protect public access or state ownership rights. The Division of State Lands is given primary responsibility for protecting state ownership rights, a component of which is maintaining public access. With this goal in mind, the Division of State Lands' policy seems to be that the loss of access to state water bottoms is not worth the benefits of marsh management. This is discussed in more detail in the next section on state and private ownership rights.

The Attorney General's Office is responsible for prosecuting violations of state laws including those administered by the Division of State Lands. The Attorney General's and thus the state's position in the LaFourche Realty case is that marsh management is detrimental to wetlands and, even if that were not the case, is not worth the loss of public access.

Landowners and Public Interest Groups

Public access is a very important issue to the general public and to landowners. This is evident from the controversy that led to the Lafourche Realty case. The goal of the general public, as reflected in the law of public property and the policies of the Division of State Lands, is to maintain public access to state-owned water bottoms. User groups, such as commercial and recreational fishermen, have protested strongly to actions such as those taken by Lafourche Realty.

Those landowners who wish to restrict public access may have several goals in mind. One goal cited by Lafourche Realty in the current case is to prevent increased erosion from boat wakes. Another goal of some landowners is to reduce exposure to liability for injuries suffered by members of the public while on their property (Donahue and Edwards 1988). This is usually in association with the use of private canals. Some have suggested that one motive of limiting public access is to allow the landowner to monopolize fisheries resources.

Issues and Evaluations

Private ownership and associated rights are some of the rights most cherished by the American people. Thus it is not surprising that policies and interests surrounding this issue are widely separated. The inevitable conflicts have become increasingly frequent as the population has expanded. The concepts of private ownership of land and the right to harvest the fruits of that land have not kept pace with shrinking resource shares. The state faces a dilemma: it can assure public access to marshlands at the possible expense of serious damage or loss of those lands, or it can promote marsh management to help save the marsh, but at the same time it must limit public access to it. The state's position on marsh management in the Tidewater Canal case may merely be an attempt to strengthen its argument against the actions of the defendant without really establishing a policy against marsh management in general. On the other hand, this position may reflect the adoption of a policy against marsh management. Whether or not this is a true schism in the state's marsh management policy remains to be seen.

Another issue is whether some landowners' real motive in blocking public access is to prevent the public from harvesting the fisheries resources. This accusation has been made repeatedly in some of the disputes discussed herein, especially by commercial fishermen.

State and Private Ownership Rights

The division between state and private ownership of wetlands, another important issue, is closely related to public access. An extensive body of law defines state-owned water bottoms, and a constitutional mandate exists to maintain that ownership.

Federal

Except for the Corps of Engineers' requirements to consider state law when issuing §9 and §10 permits (as discussed in the previous section), the federal agencies are not required to protect state property rights. These agencies may, as a matter of internal policy, consider state property ownership if their own regulatory requirements are not compromised, but no evidence was found to substantiate this.

State

The Coastal Management Division is required to coordinate with other state agencies in its regulatory process and has done so in a memorandum of understanding with the Division of State Lands. Under this memorandum the Coastal Management Division follows the Division of State Lands' regulatory requirements in its permitting process.

The Division of State Lands' policy on structures restricting public access stems from its mission to protect state ownership of water bottoms (Morgan 1988). A structure, such as a weir or dam, across a state-owned body of water that does not make allowance for boat traffic transfers access rights from state to private control and is viewed by the Division of State Lands as an alienation of that water body (Morgan 1988). Likewise, due to the state laws governing accretion, placing fill adjacent to the shore in state waters is prohibited because that body of water may be classified as river or stream (Morgan 1988). In that case the accretion (fill area) would become the property of the riparian landowner. This includes earthen dams and levees for marsh management plans and even marsh creation projects where fill is used to rebuild eroded marsh adjacent to state water bodies. La. Civ. Code art.

499 (1988). There is an exception to the prohibition when following procedures outlined in the reclamation statute for reclaiming eroded land. La. Rev. Stat. §41:1702 (1988). Marsh creation in eroded interior marshes is allowed (Morgan 1988).

Landowners and Public Interest Groups

Just as the state is concerned about protecting its property rights, so are private landowners. Thus, the goal of some landowners in establishing marsh management plans is undoubtedly to protect property ownership by retarding erosion or fixing property lines to maintain control over resources such as oil and gas (Coalition to Restore Coastal Louisiana 1987).

Issues and Evaluations

The Division of State Lands' policy on the effect of marsh management structures on state waterbottom ownership is not likely to change as long as the statutory requirements regarding state and private ownership remain the same and the state's financial problems continue. The state will be reluctant to change its laws if it means giving up any land, especially where a potential for oil revenues exists. The issues raised by the Phillips Petroleum case are likely to affect state policy regarding ownership of state water bottoms. What the effect might be cannot be accurately predicted at this time.

Another issue relates to the use of marsh management to fix property boundaries. The question is whether, by putting up levees and making impoundments to fix boundaries, some landowners actually cause or accelerate land loss. This could result from sediment starvation of the impounded area as a result of altering the hydrology.

Mariculture

Although it is not considered to be a marsh management practice by the agencies involved, mariculture in wetlands is often associated with marsh management plans. This association is due to the physical nature of marsh management plans and recent legislation concerning mariculture. By definition, marsh management involves some structural restriction of water flow to and from the wetland area being managed. As currently practiced in wetlands, mariculture is profitable only if the ingress and egress of the organisms being cultured can be controlled. The water control structures used in marsh management provide that control. This is usually accomplished by placing screens or nets on the water control structures.

Federal

The Fish and Wildlife Service, in keeping with its goal of conserving, protecting, and enhancing the nation's fish and wildlife resources, follows a policy of recommending that marsh management permits issued by the Corps of Engineers contain the condition that no mariculture operations are to take place in the area affected by the plan. The National Marine Fisheries Service opposes mariculture operations for the same reason it generally opposes any structures that hinder marine organism access. The opposition is even stronger to mariculture structures designed to prevent the ingress and egress of estuarine and marine organisms. The blockage of access to habitat is in direct opposition to the goal of the National Marine Fisheries Service to protect marine fisheries and their habitats.

The other federal agencies have no established policy concerning mariculture operations associated with marsh management projects, except when they have an effect that comes under the regulatory responsibility of the agency. An example of this would be an obstruction to navigation, which would be regulated by the Corps of Engineers. The policy of the Corps of Engineers in this situation would presumably be the same as with any other structure blocking navigation.

<u>State</u>

Placing screens or nets across any state-owned body of water or waters connecting with them is prohibited by statute. La. Rev. Stat. §56:339 (1988). This law reflects the long-standing policy of the Department of Wildlife and Fisheries concerning mariculture or aquaculture harvesting operations in natural water bodies, including wetlands. The policy stems from the agency's goal of protecting, conserving, and replenishing the wildlife, fish, and aquatic life of the state. The legislature altered the Department of Wildlife and Fisheries' policy somewhat in 1986 when it passed a resolution directing the department to "support wetland management efforts of private landowners" and "to issue special fish and wildlife harvesting permits to owners with wetland management programs upon approval of a submitted written plan." H.R. Con. Res. 185 (1986). The next year the legislature enacted a statute directing the Department of Wildlife and Fisheries to issue up to 10 fish and wildlife harvesting permits to approved marsh management operators, but under fairly strict limitations. La. Rev. Stat. 56 §5791 (1988). The legislature, therefore, has assumed the position of promoting limited mariculture and associating it with marsh management plans. This mariculture and aquaculture policy, adopted by the legislature and carried out by the Department of Wildlife and Fisheries at the legislature's direction, runs contrary to the policy of the Coastal Management Division (see appendix F).

The Coastal Management Division is generally opposed to mariculture except in fastlands, uplands, or areas that are already totally impounded or severely degraded (Clark 1988). The Coastal Management Division considers such operations in healthy natural areas contrary to their goal of protecting the resources of the coastal zone. The draft Department of Natural Resources guidelines state that marsh management and mariculture or aquaculture may be contradictory activities (see appendix F).

The Division of State Lands objects to mariculture structures that block navigation on state-owned water bottoms. This policy is based on its statutorily mandated goal of protecting the state's ownership rights.

<u>Landowners and Public Interest Groups</u>

All 10 of the fish and wildlife harvesting permits authorized by La. Rev. Stat. 579.1 have been issued to owners or managers of land under an approved marsh management plan. There were more applicants than permits. It is safe to say that at least one goal, if not the main goal, for some marsh managers is to earn profits from mariculture operations in natural waters.

Some environmental groups, whose goal it is to protect the total marsh ecosystem, are concerned that overemphasis on such activities as mariculture will detract from what they see as the prime objective of marsh management: the protection and restoration of vegetated wetlands. Thus they have urged that marsh management permit applications be evaluated to assure that the plan is designed to benefit vegetated wetlands rather than to be used primarily for other purposes such as mariculture.

Issues and Evaluations

The Coastal Management Division's policy against mariculture in wetlands and the statute requiring the Department of Wildlife and Fisheries to issue mariculture permits leave the permitting process open to an impasse that could hinder the development of marsh management. Mariculture and aquaculture in the coastal zone require a coastal use permit from the Coastal Management Division. If a landowner obtains a marsh management permit from the Coastal Management Division but does not also obtain a mariculture or aquaculture permit from the Coastal Management Division, he or she would be in violation of the coastal use permit if mariculture operations were carried out under the Department of Wildlife and Fisheries fish or wildlife harvesting permit. This is because the Coastal Management Division would not have considered mariculture activities when it issued the marsh management coastal use permit. Mariculture activities may not be compatible with what the Coastal Management Division considers the primary goal of a marsh management plan: the protection and enhancement of vegetated wetlands and their overall biological productivity. The landowner would then be in danger of having the marsh management permit revoked, and without it he or she would not be eligible under the mariculture statute for a fish or wildlife harvesting permit. Thus there exists a situation in which two agencies share permitting responsibility for the same activity but have contradictory policies regarding that activity. The Coastal Management Division has begun issuing marsh management permits with anti-mariculture clauses to avoid having its authority over these activities superceded (Clark 1988).

Monoculture or Target-Species Management

Related to mariculture and aquaculture is the issue of marsh management techniques designed to maximize the production of certain commercially valuable species (target species). For example, it is common to hold water in the marsh during normally low-water winter periods to enhance winter waterfowl habitat. Similarly, water levels are often raised to allow human access to the marsh for trapping furbearers and alligators.

Such techniques may not always be consistent with the best possible plan for protecting the marsh. This has contributed to the establishment of anti-marsh-management policies by agencies that see habitat enhancement for target species as the main goal of marsh management rather than the prevention of land loss or the improvement of overall biological productivity.

Federal

The Fish and Wildlife Service's draft guidelines regarding marsh management in coastal Louisiana are tailored foremost to the conservation, restoration, and enhancement of deteriorating coastal marshes. Such measures often result in the enhancement of waterfowl and wildlife habitat, but additional enhancement measures may be allowed depending upon marsh type, area history, and amount of deterioration. In fresh and intermediate marsh, and brackish marsh that was fresh or intermediate in 1968, the enhancement of waterfowl and wildlife habitat is given a high priority provided that the ability to conserve and restore project-area marshes is not adversely impacted. In deteriorated brackish marsh, such waterfowl habitat enhancement is given a lower priority in order to more successfully accommodate ingress and egress of estuarine-dependent organisms. In healthy brackish and saline marshes, no provisions are made for waterfowl habitat enhancement because structural management might impair the ability of that marsh to maintain itself and would likely result in unnecessary adverse impacts to estuarine-dependent organisms.

The Fish and Wildlife Service waterfowl policy is influenced by the North American Waterfowl Management Plan, which resulted from an agreement between the United States and Canada to promote and enhance waterfowl stocks. Enhancing waterfowl habitat is a goal of that plan (U.S. Fish and Wildlife Service 1987).

The National Marine Fisheries Service is generally opposed to unproven wildlife habitat enhancement activities that significantly restrict estuarine and marine organism access, for example, holding water in the marsh to accommodate waterfowl or draining it for prolonged periods for revegetation. This policy applies to all marsh types accessible to marine species and to watershed impoundments (see appendix F) and stems from the agency's goal of protecting marine fisheries and their habitats.

The Environmental Protection Agency's goal under the 404(b)(1) guidelines is to balance the benefits to wildlife and waterfowl with those to estuarine organisms. Even though the Environmental Protection Agency evaluates each marsh management plan separately, the agency is skeptical of the benefits of marsh management, especially when the main goal appears to be target-species management, and the agency's comments so far have been generally negative (Environmental Protection Agency 1989; Saunders 1988).

The Soil Conservation Service provides technical advice to landowners regarding management techniques to improve habitat for waterfowl, furbearers, alligators, and other organisms (Louisiana Coastal Resources Program 1988). The Soil Conservation Service's Environmental Policy and Technical Assistance Guidelines (Louisiana Coastal Resource Program 1988) do not mention target-species management. From this it can be inferred that the Soil Conservation Service views target-species management as a valid marsh management goal in conjunction with wetland protection, as long as it would not be detrimental to sustained total resource productivity of the wetland.

State

The Coastal Management Division and the Department of Natural Resources draft guidelines policy on monoculture is that it should be discouraged if provisions are not also made to satisfy the other guidelines (see appendix F). This is because the Coastal Management Division's goal is to protect, enhance, and restore the overall coastal resources. Thus, some target-species habitat enhancement is allowed as long as land loss prevention measures are maintained, overall productivity is increased, and estuarine organism access is not too severely restricted (see appendix F). The guidelines, like those of the Fish and Wildlife Service, allow more provisions for wildlife habitat enhancement in fresh and intermediate marsh than in brackish and saline areas because of the prevalence of estuarine organisms in the latter two marsh types. The Coastal Management Division's position is that in many situations a landowner can enhance habitat while still protecting the marsh and increasing productivity (DeMond 1988).

The Department of Wildlife and Fisheries provides wetland managers with technical advice on target-species management. Additionally, their draft guidelines provide for such management techniques in certain situations similar to the scheme used by the Fish and Wildlife Service's marsh management guidelines. The Department of Wildlife and Fisheries supports marsh management projects that follow the best possible plan for marsh protection while still allowing the landowner to enhance conditions for the production of one or more commercially important species. This is viewed as an incentive to encourage landowners to bear the considerable costs involved in wetlands protection (Chatry 1988). The agency's policy is derived from their goal of protecting the wildlife, fish, and aquatic life of the state (La. Rev. Stat. 36:602 (1989)).

Landowners and Public Interest Groups

The goals and policies of landowners and environmental groups with respect to target-species management in marsh management projects are basically the same as those regarding mariculture. The landowners' goal is to earn some returns from land under a marsh management plan to help defray the costs of preventing land loss (Donahue and Edwards 1988), but sometimes target-species management is the major goal. Environmental groups are concerned that if target species management is the main goal of a marsh management plan, the goal of land loss protection will be compromised (Coalition to Restore Coastal Louisiana 1987).

Issues and Evaluations

The main issue concerning marsh management and target-species management is whether or not target-species management compromises the primary goal of preventing land loss. If the two goals are not compatible, what incentives are necessary to encourage landowners to undertake costly land loss prevention measures?

Monitoring

A marsh management plan's effectiveness is often difficult to assess, much less predict. Monitoring certain parameters, such as salinity, percentage of vegetated marsh and aquatic organism populations, is often the only method of determining whether a marsh management plan is successful.

Monitoring marsh management can be a costly endeavor; even without monitoring, landowners often conduct marsh management programs with little or no profit margin. To some landowners the additional cost of monitoring may be decisive in whether or not the marsh management plan is implemented (Coastal Restoration Technical Committee 1988). Attempts to prevent and reverse land loss can be thwarted by monitoring plans that are so expensive they discourage landowners from implementing them. On the other hand, the regulatory agencies must have feedback on their regulatory and permitting decisions in order to assess their effectiveness in achieving public interest goals. Certain management decisions depend on meteorological, hydrological, and biological changes. Monitoring is often necessary to modify operating procedures as dictated by these changes (DeMond 1988).

<u>Federal</u>

The Fish and Wildlife Service draft guidelines, recognizing that monitoring can be a significant deterrent to marsh management, state that the Fish and Wildlife Service will not recommend monitoring for nonessential data as a condition to obtaining a permit. The agency's position is that the effectiveness of a marsh management plan can best be evaluated through ongoing research.

The policy of the National Marine Fisheries Service is that monitoring is an essential cost of doing business because little scientific data are available to allow informed decision making prior to permitting. In line with its goal of protecting marine fisheries stocks, the two most important monitoring parameters for this agency are the level of success in revegetation or vegetation maintenance and the impact on fisheries production within the managed area. These data are viewed as essential for determining the need for project modification or abandonment and site restoration. The policy is that data must be obtained on a site-specific basis because the uniqueness of each area and plan necessitates individual evaluation (Ruebsamen 1988).

The Environmental Protection Agency's policy is that monitoring must be required (Environmental Protection Agency 1989). The agency believes that plans should be evaluated on a case-by-case basis. The Environmental Protection Agency goal under the §404(b)(1) guidelines is to ensure that the plans continue to represent sound management practices.

The Soil Conservation Service monitors some marsh management plans under a contract with the Coastal Management Division. The service also provides some monitoring services at landowners' request. The Soil Conservation Service's Environmental Policy and Technical Assistance Guidelines state that one of the environmental policies is to "encourage local sponsors to review with interested publics the operation and maintenance programs of completed projects to insure that environmental quality is not degraded" (Louisiana Coastal Resources Program 1988). From this policy it can be inferred that the Soil Conservation Service favors monitoring as a necessary element in achieving its goal of soil conservation. The agency does not favor requiring the landowner to carry out a monitoring plan as a condition of the permit.

State

To avoid permitting plans that could have unforeseen detrimental effects on wetlands, the Coastal Management Division has employed two safeguards. First, marsh management permits are limited to five-year terms (Clark 1988). Thus, the Coastal Management Division reviews the effectiveness of each marsh management plan and makes new permitting decisions at relatively short intervals. Second, the Coastal Management Division guidelines require that such variables as water quality, vegetation change, and wildlife stocks be monitored to evaluate a plan's success (see appendix F). This allows more frequent scrutiny of the plan, enabling suggested changes to be implemented between permitting decisions. Some permits call for interagency review after three years so that a "second-phase" schedule of operations can be developed that effects necessary adjustments (DeMond 1988). The Coastal Management Division is attempting to address the monitoring dilemma in its draft guidelines by keeping the level of monitoring required in the current guidelines to a basic minimum, consisting of monthly data on salinity and water levels, annual land/water ratios, and annual wildlife harvests. The guidelines further state that more extensive monitoring should be carried on by governmental agencies (see appendix F).

The Department of Wildlife and Fisheries has yet to promulgate guidelines on monitoring marsh management projects. An early set of draft guidelines, however, had taken a position similar to that of the Fish and Wildlife Service.

Landowners and Public Interest Groups

Landowners, though understanding the need to monitor the success of their marsh management plans, are concerned about the costs of extensive monitoring. Some believe that regulatory agencies should bear some of the expense of monitoring (Coastal Restoration Technical Committee 1988).

Issues and Evaluations

As more marsh management plans are instituted, the monitoring issue is likely to intensify. Given the disagreement over the effectiveness of marsh management in preventing land loss, some agencies are certain to continue to insist on extensive monitoring. Some level of monitoring seems necessary as the only way to determine the success of marsh management. Will such requirements prove too onerous for many landowners, thus discouraging them from undertaking marsh management activities? Should monitoring requirements be minimized, or should the government bear a greater part of the burden of extensive monitoring programs?

Freshwater and Sediment Diversion Projects

Many reputable scientists and policymakers have concluded that a key factor in the Louisiana coastal land loss problem is the alteration and reduction of the flow of sediment-laden fresh water through wetlands, which results in saltwater intrusion and sediment starvation (Coalition to Restore Coastal Louisiana 1987). These result in the loss of salt-intolerant vegetation and increased land loss because subsidence and sea level rise are not counteracted by sediment deposition. Many scientists and government officials consider projects designed to introduce fresh water and sediment into the marsh to be far superior to marsh management as tools to combat land loss (Coalition to Restore Coastal Louisiana 1987).

Marsh management projects by their nature alter water flow patterns. Marsh management plans near freshwater or sediment diversion projects could reduce the effectiveness of the diversions by blocking the water flow from them. Conversely, marsh management techniques could be beneficial to some aspects of water diversion projects. How these two activities will be incorporated into an overall coastal restoration plan is unclear. Some agencies have developed policies and guidelines on this subject, while others have not.

Federal

The Fish and Wildlife Service states in its draft guidelines that semi-impoundment of wetlands near freshwater diversion projects is not acceptable unless it can be shown that the diversion would not benefit the area even if it had not been impounded. The National Marine Fisheries Service has no stated policy regarding diversion projects and marsh management projects. However, the fact that the National Marine Fisheries Service recommended denial of a Corps of Engineers permit to implement the Lake Lery marsh management plan for the area near the Caernarvon freshwater diversion project indicates that its policy is to favor diversion projects, when feasible, as a better method to restore wetlands.

The Corps of Engineers has made no formal statement of its policy regarding the interaction between water diversion projects and marsh management projects. The Corps of Engineers is, however, heavily involved in the development of freshwater diversion projects and considers such projects very important in wetland protection and restoration (U.S. Army Corps of Engineers n.d.).

State

The Coastal Management Division states in its draft guidelines that marsh management "plans should be developed to take advantage of existing and planned diversions of freshwater, sediments, and nutrients and should not be developed to block the beneficial effects of such activities" (appendix F). The Coastal Management Division, however, disagrees with the National Marine Fisheries Service's evaluation of the Lake Lery marsh management plan's potential effect on the Caernarvon freshwater diversion project and intends to issue the permit for the marsh management plan.

The Department of Wildlife and Fisheries has yet to promulgate its final marsh management guidelines. An earlier draft of these guidelines indicated that Wildlife and Fisheries policy on freshwater diversions and marsh management plans was similar to that of the Fish and Wildlife Service.

The environmental groups involved in the report of the Coalition to Restore Coastal Louisiana ("Coastal Louisiana: Here Today Gone Tomorrow?")

state that marsh management plans should be coordinated so that they are consistent with the state's comprehensive coastal restoration plan. They view freshwater and sediment diversions as key components of that plan.

Issues and Evaluations

Policies are now being considered that place marsh management in a role subsidiary to freshwater and sediment diversions (Coastal Restoration Technical Committee 1988). The probable result of this is that, in areas where freshwater and sediment diversions are feasible, marsh management plans will be closely scrutinized to make sure that they do not alter the hydrologic regime in ways that interfere with the diversion projects. These considerations can and probably will result in denial of some marsh management permit applications. As discussed above, the National Marine Fisheries Service recently recommended that the Corps deny the permit for the Lake Lery marsh management plan because the area is in the path of the Caernarvon freshwater diversion project. Where diversion projects are impossible or impractical, marsh management plans could become the "next best option" in marsh protection (Coastal Restoration Technical Committee 1988).

POLICY EVOLUTION

State and federal marsh management policies are undergoing considerable change. As this report goes to press, several important events have recently occurred or will occur in the near future that are likely to profoundly affect state and federal regulation of marsh management in Louisiana.

Federal

At the federal level, the Fish and Wildlife Service is significantly changing its draft marsh management guidelines. The Environmental Protection Agency and the Corps of Engineers have developed a new memorandum of understanding concerning their authorities under §404 of the Federal Water Pollution Control Act (appendix G). These two agencies have also developed a new manual for delineating wetlands and thereby the extent of §404 jurisdiction. The Environmental Protection Agency is revising its draft policy for marsh management (appendix F).

The Corps of Engineers is preparing a programmatic environmental impact statement on marsh management. This environmental impact statement will incorporate the results of the Minerals Management Service's evaluation of marsh management (for which this report was prepared). The Corps of Engineers is also involved in helping to develop and implement the Louisiana Coastal Protection Master Plan, which will guide state and federal activities concerning coastal and wetlands protection in Louisiana (U.S. Army Corps of Engineers n.d.). Additionally, the Corps of Engineers' wetlands protection policy under §404 is evolving. This is in response to a change in policy by the Bush Administration that places significantly more emphasis on environmental protection than did the previous administration (Wood 1989). An element of the administration's policy is the report of the National Wetlands

Policy Forum, which made several recommendations for significant changes in federal and state regulatory programs affecting wetlands (National Wetlands Policy Forum 1988).

State

The Coastal Management Division and the Department of Wildlife and Fisheries are both developing new marsh management guidelines. Both sets of guidelines contain fairly detailed substantive criteria for establishing marsh management plans.

The Division of State Lands, formerly of the Department of Natural Resources, was transferred to the Office of the Governor by Act 282 of the 1989 regular session of the Louisiana legislature. The Governor's Office, in 1988, established a Coastal Restoration Policy Committee and a Coastal Restoration Technical Committee as steps toward developing a plan for coastal and wetlands conservation and restoration. The technical committee presented a report to the policy committee outlining recommended policy based on a scientific and regulatory review (Coastal Restoration Technical Committee 1988). These recommendations, which could affect several of the issues discussed in this report, include giving wetlands preservation priority in most regulatory decisions; giving priority, where feasible, to freshwater and sediment diversions rather than marsh management; evaluating marsh management plans primarily on their effectiveness in restoring wetlands rather than in enhancing habitat for target species; developing a joint position on marsh management on behalf of all the agencies involved in order to streamline the regulatory process; and providing incentives, such as rebates, tax incentives, or partial funding, to landowners who use marsh management techniques to restore or enhance wetlands.

In response to the report of the Coastal Restoration Technical and Policy Committees and to growing awareness and concern over wetland loss in Louisiana, the legislature responded in the 1989 Second Extraordinary Session by passing Act 6. This legislation outlines the most sweeping and comprehensive plan yet devised by the state for taking action towards wetlands protection. Act 6 (appendix H) contained a number of important provisions, including the creation of an Office of Coastal Restoration and Management within the Department of Natural Resources, composed of the existing Coastal Restoration and Coastal Management divisions. This office will be responsible for conservation, development, and, where feasible, restoration and enhancement of coastal wetland resources and implementation of the state's coastal vegetated wetlands conservation and restoration plan. Act 6 also created a Wetlands Conservation and Restoration Authority in the Office of the Governor composed of an executive assistant to the governor and a task force. The authority will, among other things, "develop a comprehensive policy addressing the conservation and restoration of coastal wetlands resources through the construction and management of coastal vegetated wetlands enhancement projects including privately funded marsh management projects or plans and addressing those activities requiring a coastal use permit which significantly affect such projects...." The authority will also develop a plan to be submitted to the legislature for conserving and restoring the state's coastal vegetated wetlands consistent with legislative intent and with the policy developed by the authority. The plan developed by the authority will serve as the state's overall strategy for conserving and restoring coastal wetlands through the construction and management of coastal wetlands enhancement projects including privately funded marsh management projects or plans. The plans shall be submitted to the natural resources committees of the legislature on or before March 15th of each year beginning in 1990.

Act 6 also provides that the governor shall, among other things, through the executive assistant, coordinate and focus the functions of all state agencies as they relate to wetlands conservation and restoration; review and reconcile state agency comments on federally sponsored water resources and development projects or permitted conservation and restoration activities; represent the policy and consensus viewpoint of the state at the federal, regional, state, and local levels with respect to wetlands conservation and restoration; appraise the adequacy of statutory and administrative mechanisms for coordinating the state's policies and programs with respect to wetlands conservation and restoration; and focus federal involvement in Louisiana with respect to coastal wetlands conservation and restoration.

Under Act 6 the governor through the executive assistant may, among other things, review and modify informal agency policies and procedures to require expeditious permitting of restoration projects, wetlands enhancement, or marsh management plans; review and request that agencies modify formal policies, procedures, programs, rules, and regulations that may affect restoration projects, wetlands enhancement, or marsh management plans; review and modify proposed coastal use permits that may affect wetlands conservation and restoration; and require the issuance of permits for public or private wetlands enhancement projects or plans.

Act 6 also established in the state treasury a "Wetlands Conservation and Restoration Fund" dedicated to the implementation of the program to conserve and restore Louisiana's coastal vegetated wetlands. This fund will consist of a portion of state mineral revenues to a maximum balance of $40 million. On October 7, 1989, an amendment to the Louisiana Constitution was passed in a general election that established the fund as a constitutionally protected fund dedicated to the purposes established in Act 6, including projects and structures engineered for the enhancement, creation, or restoration of coastal vegetated wetlands.

Allocations of money from the fund are to be by appropriations from the legislature upon requests by the various agencies. Such requests are to be coordinated and approved by the Wetlands Conservation and Restoration Authority.

Another state agency whose evolving policy may affect marsh management is the Department of Environmental Quality. This agency is revising its Water Quality Certification Regulations under §401 of the Federal Water Pollution Control Act in such a way that will strengthen the agency's ability to protect wetlands. The §401 Water Quality Certification can be a powerful tool in protecting wetlands affected by projects under federal license or permit.

From the foregoing discussion it is evident that several important changes are occurring in law and agency policy that will significantly affect marsh management. The most significant effects will probably be from Act 6 of 1989. How these changes will interact and what their effects will be remains to be seen.

CONCLUSION

The public interest goals that affect marsh management in Louisiana are widely divergent and sometimes contradictory. They include the desire to prevent land loss, provide incentives and cost sharing for landowners who undertake marsh management, foster marine fisheries, allow public access to wetlands, maintain state/private ownership rights, and make profits from landholdings. Several of these goals are interrelated, and the issues surrounding them are complicated by disagreements within the scientific and regulatory sectors about which techniques are most effective in preventing land loss and which have the fewest adverse effects. Disagreement about the answers to key scientific questions, combined with the narrow missions and agendas of some of the agencies involved, often leads to regulatory paralysis or at least sluggishness.

The policies of the various agencies are in a state of flux such that the regulatory processes could change significantly over the next several years. A consensus in the scientific community is needed to resolve some of the issues, but this will probably require more research. Many people believe that more than enough research has been performed to allow positive action on some problems. It may be true that it is past time for some measures to be taken, such as freshwater and sediment diversions where feasible and well-regulated marsh management where such diversions will not solve the problem. It would not be prudent, however, to discontinue research while these measures are being taken. The land loss problem and the associated scientific questions are extremely complex. Ecosystem health is influenced by both short- and long-term processes. Fifty or even one hundred years of research may not yield a complete understanding of the causes and effects.

The state and federal governmental agencies will have to make some immediate decisions that involve trade-offs and shifts in policy. While agencies should not be asked to compromise their mandates, they should immediately and seriously examine the problem to determine whether there are other ways to achieve compatibility among divergent public interest goals. Deadlocks will probably have to be broken by legislative action at both the state and federal levels.

PART III

STRUCTURAL MANAGEMENT TECHNIQUES

Chapter 5

ENGINEERING AND CONSTRUCTION TECHNIQUES OF MARSH MANAGEMENT STRUCTURES

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INTRODUCTION

In this chapter we describe the design, uses, feasibility, engineering, construction, and operation of structures used to alter or manipulate marsh water levels. There are two basic types of water level management employed in coastal Louisiana: passive and active. Passive water level management is typified by weir management techniques and other structures (e.g., plugs). These structures are not adjustable and are used to maintain minimum water levels throughout the year. Active water level management is typified by manipulated impoundments in which levees and adjustable water control structures are used in combination to alter water levels on a seasonal basis.

Several of the more common types of passive water control structures found in Louisiana wetlands are reviewed, including two recently developed designs (i.e., slotted weirs and rock weirs). A few passive structures used in other states are described, because they may be useful in Louisiana. Types of active water control structures are more numerous. Hence, they are grouped by function to facilitate description. Recently developed designs are included in this review.

PASSIVE WATER CONTROL STRUCTURES

Introduction

A fixed-crest structure is a low level dam having a crest fixed at some elevation relative to (usually lower than) the surrounding marsh surface. A typical elevation is 6" below the marsh surface. These structures are constructed across waterways to manage the hydrology for some expected benefit. Fixed-crest structures permit water exchange but generally prohibit dewatering of the marsh. They also reduce the flow rate through a channel, decreasing the erosional force of the water.

Six types of passive water control structures have been used in Louisiana and will be summarized in this report: the fixed-crest, slotted and rock weirs, plugs, levees, and trenasses.

Fixed-Crest Weirs

Fixed-crest weirs are one of the most common types of water control structures utilized in Louisiana's coastal marshes (figure 8). The Louisiana Department of Natural Resources has permitted 463 fixed-crest weirs since 1981 (Clark 1989). Prior to 1981, hundreds of weirs were installed statewide. Weirs were first installed in the early 1940s, when muskrat populations were high. Northern winds during winter cold fronts pushed water out of shallow marsh ponds and waterways, reducing access for trappers. These weirs were constructed by trappers to prevent marsh drainage, thereby providing access to trapping grounds by boat. Chabreck and Hoffpauir (1962) reported that only 2.4% of pond bottoms behind weirs became exposed during normal low tides as compared to 84% of ponds not controlled by fixed-crest weirs.

During the early 1950s, many landowners became alarmed at the deteriorating conditions of their marshes and began using weirs to manage, and hopefully improve, their marshlands. Weirs were thought to improve marsh conditions by stabilizing water levels, reducing salinity and turbidity, and improving habitat for fish and wildlife. The environmental effects of fixed-crest weirs reported in the literature by researchers are summarized in table 3. Fixed-crest weirs were thought to reduce salinity by decreasing salt water intrusion, thereby reducing land loss. However, Turner et al. (1989) reviewed previous research and concluded from this review there was little difference in salinity between weired and unweired marshes, although there was a slight skew toward higher salinities in weired areas.

The most consistently reported effect of fixed-crest weirs is the stabilization of water levels (Chabreck 1968; Larrick 1975; Larrick and Chabreck 1976; Chabreck et al. 1979; Herke et al. 1987b; Chabreck and Nyman 1989). The pool of water behind the weir may buffer high salinity tides by acting as a "mixing bowl" (Chabreck and Hoffpauir 1962), thereby decreasing the damage done to salt-intolerant vegetation. Such stabilization of pond water levels also helps the landowner by holding water on the marsh, providing feeding and resting habitat for waterfowl, and access for trapping and waterfowl hunting.

Stabilization of water levels also may encourage the growth of submergent vegetation beneficial to wildlife. Widgeongrass (Ruppia maritima) is a submerged aquatic plant commonly found in brackish marshes, whose growth is controlled primarily by turbidity and water levels (Joanen and Glasgow 1966). Widgeongrass is an important waterfowl food. Jemison and Chabreck (1962) reported over-wintering waterfowl ate only 20% of seeds available in a marsh, but consumed most of the available widgeongrass. Weirs have been reported to increase the growth of widgeongrass (Chabreck and Hoffpauir 1962; Chabreck 1968; Herke 1968, 1971; Larrick and Chabreck 1976; Wicker 1983) which increases the utilization of the marsh during the winter by feeding waterfowl (Chabreck 1968; Spiller and Chabreck 1975; Chabreck and Nyman 1989). Weirs are now commonly used in coastal wetlands to manage marshes for waterfowl.

Although weirs may improve the growth of submerged vegetation, the same may not be true for emergent vegetation. Larrick (1975) reported lower densities of emergent vegetation at three out of four sites influenced by fixed-crest weirs. Turner et al. (1989) reported pond formation was three times greater inside a weired area compared to the surrounding marsh. This negative effect of weirs on emergent vegetation is consistent with results from studies in other marshes (Turner et al. 1989) and soil Eh data. Mean water levels are higher in marshes

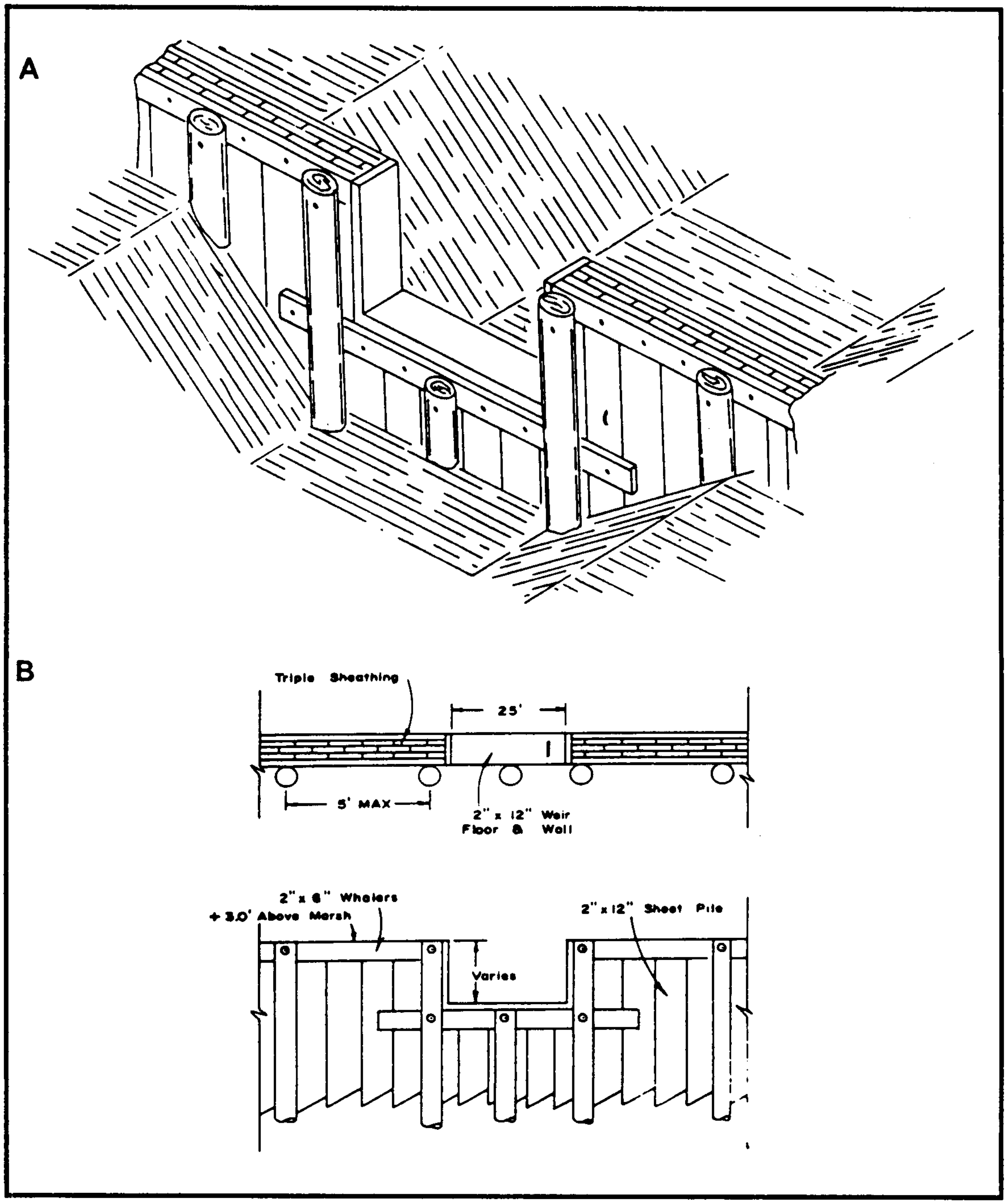


Figure 8. Fixed-crest weir: A) isometric view; B) top and side details (adapted from Broussard 1988). NOTE: conceptual drawing; not to be used for design.

Table 3. Effects of fixed-crest weirs on the marsh environment as described in the literature.

Effects
1. Facilitate access to the marsh for trappers during winter cold fronts.
2. Buffer high salinity tides.
3. Decrease water turbidity.
4. Decrease water salinities.
5. Decrease soil salinity.
6. Increase the growth and area of submerged aquatic vegetation beneficial to waterfowl.
7. Encourage emergent vegetation beneficial to wildlife.
8. Increase marsh utilization by wintering waterfowl.
9. Decrease tidal scouring.
10. Provide recreational fishing opportunities.
11. Hold water on the marsh during summer droughts.
12. Provide habitat beneficial for some species of wildlife.
13. Increase plant stress by increasing soil waterlogging.
14. Decrease the area and growth of emergent vegetation.
15. Decrease sedimentation.
16. Hold storm waters on the marsh for extended periods.
17. Decrease fishery production.
18. Stabilize water levels.

behind weirs than in nearby unweired wetlands (Broussard 1988). Higher water levels increase the duration and frequency of flooding, leading to waterlogged soils and lower soil oxidation-reduction potentials (measured by Eh). Weired marshes were reported to have lower Eh values (indicating significant waterlogging) than natural marshes (Hoar 1975). Increased waterlogging increases plant stress (Burdick and Mendelssohn 1987) and may result in plant mortality. Wicker (1983) reported units managed with fixed-crest weirs on Rockefeller Wildlife Refuge were experiencing marsh breakup, possibly due to weirs maintaining higher-than-normal water levels.

Although percent cover of emergent vegetation may be reduced by weirs, vegetation species beneficial for wildlife may be encouraged. Scirpus olneyi, an important waterfowl and furbearer food, grows best in marshes with water levels fluctuating between 2" above and below marsh level (O'Neil 1949). Because weirs tend to stabilize water levels, conditions behind weirs may be favorable for the growth of Scirpus olneyi (Chabreck and Hoffpauir 1962), particularly in conjunction with a proper burning program (Wicker 1983).

Fixed-crest weirs are believed to decrease tidal scouring by lowering the cross-sectional area of a channel, thus reducing flow rates. Chabreck and Hoffpauir (1962) cited tidal action as having a "drastic" effect on aquatic vegetation by increasing turbidity. Gagliano and Wicker (1989) reported tidal scouring after marsh die-back was an important cause of wetland loss in areas having organic soils. A negative effect of decreasing the cross-sectional area of channels has been noted after storm events. Saline waters pushed onto marshes during tropical storms and hurricanes take much longer to drain from a weired than from a natural marsh, often causing plant mortality due to high salinities and waterlogged soils. Water from heavy rainstorms also require much longer to drain off weired marshes, increasing plant stress and mortality.

One of the most important and intensively studied aspects of weirs is their effect on commercially important, estuarine-dependent fisheries production. Herke (1979) and Herke et al. (1987b) reported fixed-crest weirs delayed and decreased recruitment into marsh nursery areas and caused major reductions in both number and total weight of most of the important estuarine-dependent species migrating toward the Gulf. Konikoff and Hoese (1989) reported fewer numbers of several marine species were captured in weired as compared to natural ponds. Louisiana's wetlands provide nursery habitat for about 30% of the United States annual commercial fisheries harvest (Turner 1985). Because over 100,000 hectares in Louisiana were managed with fixed-crest weirs prior to 1967 (Knudsen et al. 1985), and more have been constructed since then, there is concern over the effect of these structures on commercial fisheries catch.

Feasibility. Fixed-crest weirs are used throughout the Louisiana coastal zone, although they are most useful in intermediate and brackish marshes. Fixed-crest weirs have limited value in saline marsh and non-tidal areas (Louisiana Department of Natural Resources and Soil Conservation Service 1988), because environmental factors for which weirs are used can not be regulated with weirs in these areas. Non-tidal areas don't experience salinity and water level fluctuations to the extent of tidal marshes, both variables cited for the construction of weirs. Also, weirs are constructed to decrease land loss. However, the majority of land loss in coastal Louisiana is occurring in intermediate and brackish marshes, not in saline marshes. Another reason fixed-crest weirs are more useful in intermediate and brackish marshes is because these marsh types are the most important waterfowl and furbearer habitats within the coastal zone, the management for which is a commonly cited reason for the use of fixed-crest weirs.

The fact that most fixed-crest weirs weigh less than many other water control structures, can be easily anchored in the underlying clay pan or supported on friction piles, and do not require levee construction allow this structure to be used in the more fluid organic soils found in the Mississippi deltaic plain as well as in the chenier plain.

Construction. The crest of fixed-crest weirs are normally set at 6" below the surrounding marsh level. However, the crest level may be set lower on channels receiving water from large drainage areas or having a high ratio of open water to vegetation.

The determination of the correct crest length is dependent primarily on the amount of area affected by the weirs; the customary weir length is 1' for every 70 acres of wetlands to be controlled (Broussard 1988; Louisiana Department of Natural Resources and Soil Conservation Service 1988). It is important that the total discharge capacity of all structures influencing a common area be adequate to provide the necessary drainage. In some cases the length of the weir crest may be limited by the size of the channel in which the structure is placed. If additional crest length is required, multiple sites should be considered. If a structure is to be placed in a channel larger than the necessary crest length, the weir crest should extend the entire width except for within 5' of the shore in channels 50' or less in width, or within 10' of shore in channels larger than 50'. The wingwalls should extend at least 10' into the top bank of the channel. Earthen embankments should be constructed to begin at the channel bank and extend 5' beyond the end of the wingwalls, otherwise water draining from a marsh will wash around the end of the weir, rendering it useless. This is to prevent water from cutting around the ends of the structure during high water and overland flow and creating a bypass channel. Any section of the weir not serving as part of the weir crest should be high enough above marsh elevation (at least 2') so as to divert flows over the crest instead of over the structure (Broussard 1988).

In addition to measures to prevent erosion, precautions should be taken in areas with very soft subsoil or extreme tidal fluctuations to prevent weirs from giving away to the pressure of unusually low tides. Once a weir begins to lean downstream it is difficult to straighten. Diagonal bracing and tie-back piling should be used where trouble is anticipated. Also, wedge-shaped weirs have been used with success at Marsh Island Refuge (Chabreck 1968).

Weirs should be set several hundred feet back from the mouths of bayous and other watercourses to prevent damage from boat wakes. Drainage systems selected for weir construction should be carefully surveyed to select the best sites. They should also be placed to take advantage of the natural hydrology of the marshes affected by the structures. The weir site should be placed in a natural low area or should intercept the existing drainage pattern. The best site is in a straight reach with well defined banks. Also, the width of the stream should be typical of adjacent portions.

Most fixed-crest weirs in Louisiana are similar in design and vary most in method of construction and materials used. Draglines are used on all large weirs for handling material and driving piling. Round timber piling, wales, and sheet piling are used. Weirs are normally constructed using metal, concrete or wooden sheet piling. Metal sheet piling of steel or aluminum has alternate interlocking grooves on each side. Metal pilings are used on larger structures, in deep channels, or where unusually long sheet piling is required. Although metal sheet piling is more costly, it is easier to install and is immune to fire damage and wood borers. Concrete sheet piling is also used to construct fixed-crest weirs. Although this material is the most durable under a wide range of environmental conditions, it is also the most expensive. Concrete sheet piles require heavy equipment and easy accessibility to the construction site. They require water jet-blasting to be driven and have a tendency to subside over a moderate period of time in unstable soil conditions (Broussard 1988).

Wooden sheet pilings are the most popular material used for weir construction. Two types of wooden sheet piling are used. One consists of 2"-by-8" or 2"-by-10" boards driven in two or three rows, with each row spliced over the seams of the previous row. The easiest method is to nail several sheets of piling together and drive them all at the same time. The other type of wooden sheet piling is 3"-by-10" boards center-matched and involves only a single row of sheet piling. Single-and double-lapped piles should only be used for minor structures in non-critical locations. All wooden materials should be creosote pressure-treated to a minimum of 12 lb retention. The use of wolmanized lumber, treated to at least 0.6 pcf, is also acceptable (Broussard 1988).

To determine the length of the sheet piling necessary, multiply the depth of the deepest part of the channel by three (Chabreck and Hoffpauir 1962). This will ensure that the majority of the sheet piling is in the ground, providing a steady weir base. However, site and soil conditions, standard economical lengths of certain size timbers, and other factors should be considered before making a final determination of sheet piling length. As a minimum, all sheet piles should be driven into firm clay or into a material of reasonable resistance. Weirs are often constructed with splash boards to prevent water from eroding and deepening the bottom as it spills over the weir. Eventually the water may erode the bottom of the channel to the depth of the sheet piling, allowing water to flow under the structure (Broussard 1988).

Generally, wooden pole pilings are included in the construction of most sheet piling type structures used in channel crossings. Minor structures in small ditches and concrete pile weirs are situations where pole pilings may not be required. Pole pilings should be creosote-treated and have a minimum diameter of 12". They should be set a maximum of 6' apart on-center and driven well into firm substratum or until refusal. Their primary function is to provide structural stability against maximum head differential expected across the structure. Pole pilings should always be located on the downstream side of a structure because of the positive force acting on the interior of the structure the majority of the time.

Batter pole pilings (diagonal bracing) are used for additional support in channels exceeding 30' in width and/or where soil conditions warrant. Based on site and soil conditions these batter piles can be placed on every piling or on every other piling within the channel. As with pole piling, they are primarily placed on the downstream side of the structure. On very large weirs or where poor soil conditions are present, batter piles may be placed on both sides of the structure.

<u>Cost</u>. The cost of weir construction will vary with size, material, and location. The wooden sheet piling weir traditionally has been the least expensive to construct and easiest weir type to install. Although wooden weirs have shorter life expectancies than those made with metal or concrete, a properly designed and constructed wooden weir can last up to 30 years (Broussard 1988). Chabreck (1968) provides a cost breakdown for steel, aluminum, and wooden sheet piling

weirs. Steel sheet piling costs the most per foot of structure ($55.55), followed by creosote-treated sheet piling ($51.11), and aluminum ($48.89). However, based on similar acreages managed by each weir, and factoring in the varying weir life expectancies, the steel weir costs the least per acre per year ($.10). The creosote-treated wooden sheet piling weir costs $.115 per acre per year while the aluminum weir was the most expensive at $.147 per acre per year. All figures quoted by Chabreck were in 1968 dollars. The Louisiana Department of Natural Resources and Soil Conservation Service (1988) provided a more up-to-date estimate of the cost of a fixed-crest weir ($285.00 per foot, wooden material).

Slotted Weirs

The slotted weir is a new structural design similar to a fixed-crest weir in that it usually has a crest set at 6" below marsh level, but has an opening running vertically from top to bottom of the weir (figure 9). The slotted weir began as an experimental weir, designed to alleviate some of the problems caused by conventional fixed-crest weirs (soil waterlogging, reduced fisheries production). This weir, or variations on it, has been used in only a few instances in Louisiana, and published reports on their effects are few (Rogers et al. 1987). As a result of the study by Rogers et al. (1987), vertical slots have been incorporated into the large fixed- and variable-crest weirs used to manage the marshlands in the Cameron-Creole watershed.

Rogers et al. (1987) reported that marshes behind slotted weirs exported significantly more organisms and more species than did marshes having fixed-crest weirs. Although trawl catches were higher in a natural than in a slotted-weir marsh, they were significantly less in a pond behind a fixed-crest weir than in a similar pond having a slotted weir. Both slotted and conventional weirs reduced salinity and water level fluctuations in managed areas, although the pond behind the fixed-crest weir had higher water levels during low water periods than did the slotted weir.

The slotted weir may be operated with the slot open for most of the year. If it is constructed as a manageable structure, the slot may be closed by lowering a vertical stop-log the size of the slot into the slot during times when salinity or water target levels are desired.

Feasibility. Slotted weirs are most feasible in areas where fixed-crest weirs may be used. They are more expensive than fixed-crest weirs and require more care in installation. For these reasons their use may not be feasible where the channel or watershed is extremely small or where numerous structures are needed.

Construction. The construction principles and materials used to build fixed-crest weirs are also valid for slotted weirs. Construction and engineering details are also the same with a few exceptions. Rip-rap on the bottom of the channel leading to both sides of the slot may be necessary to keep water passing through the slot from eroding the channel bottom and undercutting the weir. The vertical slot width in the weir studied by Rogers et al. (1987) comprised 6.5% of the weir crest length, or 1" of slot per 15.2" of weir crest length. The variable-crest weirs in the Cameron-Creole watershed each have several slots 10 cm wide. This width was not based on any relationship with crest width but was chosen as the smallest width that would allow movements of adult fishes into the managed area and was the largest width that the Soil Conservation Service engineers would agree to so that the integrity of the structure could be maintained.

Cost. The cost of a vertical slotted weir, because of the extra labor required in construction and installation, may be slightly more than that of a typical fixed crest weir made of the same material.

Rock Weirs

The rock weir, a new engineering technique, is a low-level dam composed of graded or mixed rip-rap across a channel with a height of, or just below, marsh elevation (figure 10). Rocks or concrete rip-rap may be added or removed as needed to enable the manager to employ a type of active management, using the structure in a way similar to that of a variable-crest weir. A number of rock weirs have been installed on the Audubon Society's Paul J. Rainey Wildlife Sanctuary in southern Vermilion parish, southeast from Pecan Island.

An advantage of rock weirs is that they may allow more estuarine organism movement through and over them than the traditional fixed-crest weir or culverted structures (Rogers 1989; Broussard 1988). As for maintaining water levels, the rock weir appeared to be intermediate between the fixed-crest weir and open, natural drainage areas (Rogers 1989), although the data were confounded by differences in elevation among the three study areas. Fish species composition in areas influenced by rock weirs was intermediate between those assemblages seen in marshes managed with fixed-crest weirs and natural channels (Rogers 1989). Rogers (1989) recommended that an increase in the rock sizes and/or the addition of vertical slots would enhance fisheries resources more than would the rock weir alone.

Feasibility. Rock weirs are very durable and require little maintenance as the rock or rip-rap does not corrode or wear down. However, a firm substrate must be present to prevent structure subsidence. The structure may subside because of its heavy weight or overburden (Broussard 1988). The rock weir will not maintain permanent water levels in the managed marsh, especially during droughts, because of its porous nature. Rock weirs require heavy equipment for installation in larger channels. Thus, easy site access may be a requirement.

Construction. During installation, filter cloth should be placed between the rock and the channel bottom in order to prevent erosion of the bottom by tidal currents. Rip-rap that can be handled by average sized workers makes construction easier, but the actual size depends on site characteristics and material availability. At the Paul J. Rainey Wildlife Sanctuary the rip-rap grades were mixed ranging in size from 3-33 kg (7-73 lb) with most weighing 11-33 kg (24-73 lb) (Rogers 1989).

Cost. Rock weirs cost 25% (Rogers 1989) to 33% (Broussard 1988) of wooden fixed-crest weirs to construct.

Plugs

A plug is a permanent barrier constructed across a channel to obstruct water flow (figure 11). Unlike weirs, plugs extend above water level and do not permit normal tides to enter the system. Plugs have been widely used in coastal marshes throughout the southeastern United States to improve marshes for wildlife (Chabreck 1968), but have also been used recently to block inactive oil and gas pipeline and exploration canals, thereby decreasing the hydrologic impacts of

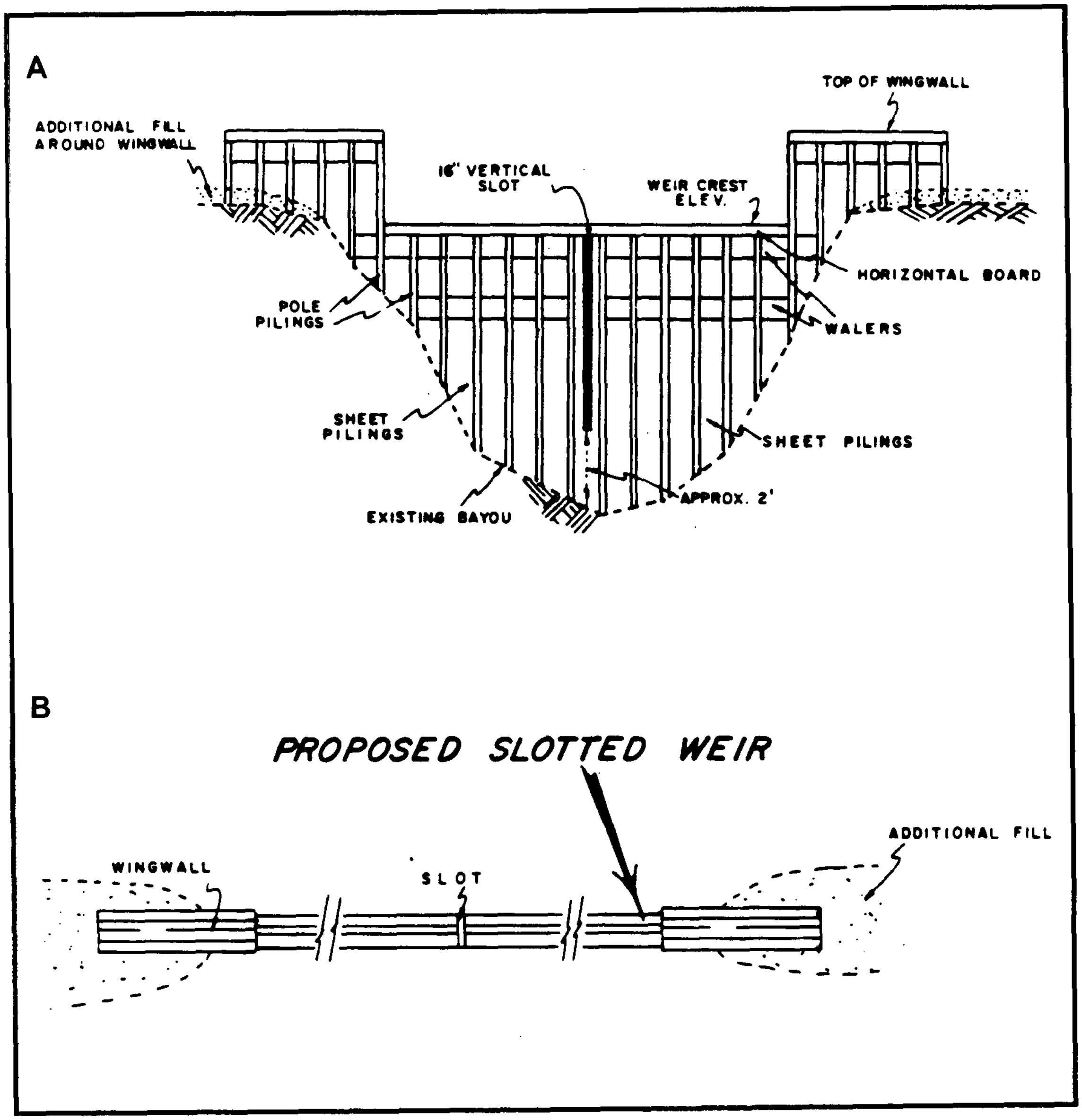


Figure 9. Slotted weir: A) cross section; B) top view (CASHCO Oil Company 1987).

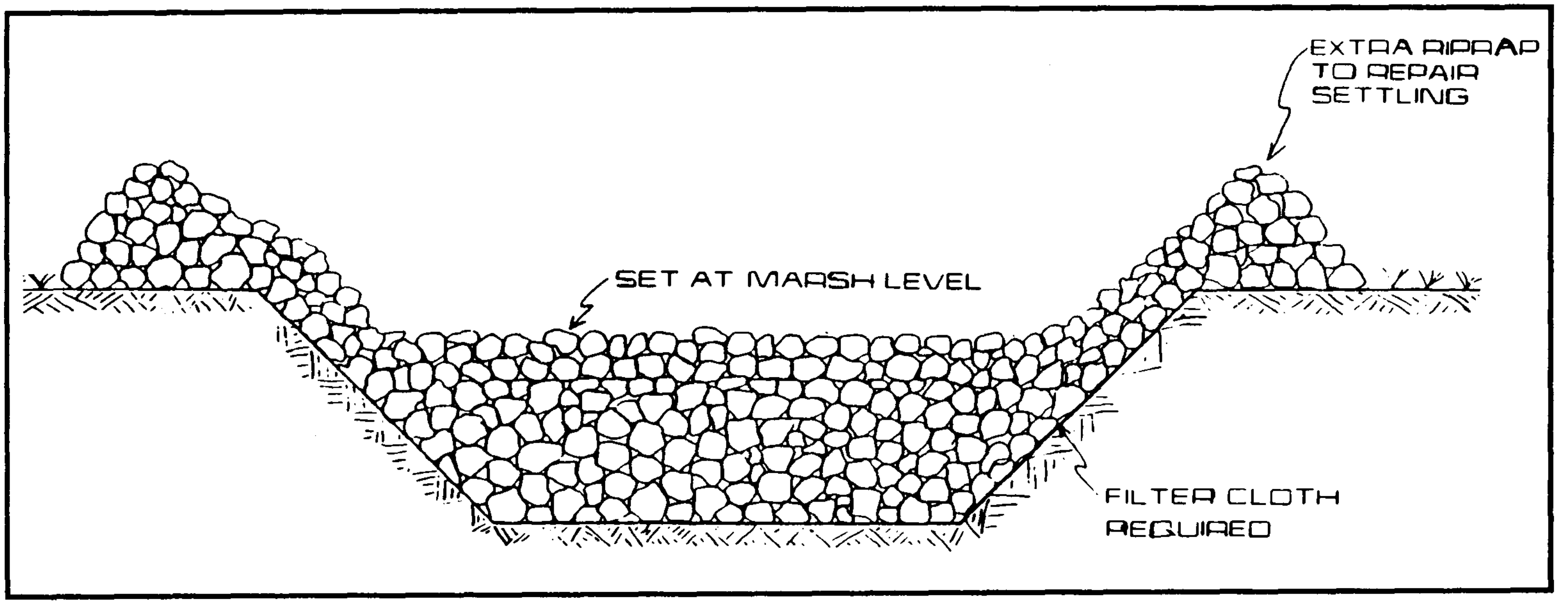


Figure 10. Rock weir (adapted from Broussard 1988). NOTE: conceptual drawing; not to be used for design.

those canals. Plugs were originally thought to reduce salinities, stabilize water levels, reduce turbidity, and restrict tidal flow (Chabreck 1968). However, all these objectives are not accomplished by this type of management. Chabreck (1959) reported higher salinities behind plugs than in nearby, natural marshes. Since areas affected by plugs are not open to normal water exchange, salinities behind plugs may increase as a result of water loss through transpiration and evaporation. Chabreck (1959) reported no difference in turbidities in marshes behind plugs as compared to natural wetlands. However, turbidities in ponds behind plugs are often caused by high fish populations, particularly striped mullet (*Mugil cephalus*) stirring up bottom sediments. The removal of these fish populations using rotenone or netting may result in lower turbidity behind plugs than in nearby areas, because fish populations would require much longer to re-establish in plugged marshes (Chabreck 1959).

Chabreck (1959) revealed that earthen plugs were ineffective in changing vegetative composition of tidal marshes. Emergent and submerged vegetation in plugged marshes remained unchanged from the nearby, natural marshes. Although plugs are ineffective in improving marsh vegetation for wildlife, the plugs provide permanent water areas for ducks and greatly benefit access to the marshes. The structures prevent marsh drainage and stabilize water levels in bayous and ponds behind them, providing year-round accessibility for hunters, trappers, and fishermen to plugged marshes. As with weirs, the plugs block navigation, but a small boat can be pulled over the plug and the marsh accessed regardless of the tide.

Feasibility. Earthen and concrete plugs are most feasible on mineral soils because their weight tends to cause compaction and subsidence of the underlying soils. Mineral soils are less conducive to compaction. Plugs may be placed on organic soils; however, they require much greater maintenance. When compared to other forms of marsh management, plugs are less expensive to install; however, fewer benefits are gained from their use. Also, it is impractical to plug major drainage outlets; plugs are more useful in smaller canals and openings.

Construction. All channel plugs must provide a positive cutoff within the channel regardless of the type of materials used in construction. The wingwalls of any channel plug should extend far enough into each adjacent embankment to divert overflows away from the ends of the plug. Overland flow in this location can cause cutting and loss of soil material, resulting in structure failure. Armor plating (cellular concrete mattress, shell, etc.) should be used to protect the face of a plug exposed to severe wave action caused by boat wakes or open water fetch (Broussard 1988). Various types of plugs include earthen dams with or without armor plating, earthen dams with a sheet piling core, or wooden, steel, or concrete sheet piling bulkheads.

Plugs should be constructed to the height required to prohibit all flow during normal high tides. Tidal height, compaction, organic deterioration, subsidence, and wave action are variables to be considered when determining the adequate elevation for the plug top. The Soil Conservation Service recommends a minimum 30% and 50% allowance for settlement in mineral and organic soils, respectively. Additional height may be required in highly organic soils to achieve a desired settled height. The use of ground stabilization fabrics (geotextiles) has been used in Louisiana where unstable soils cause problems. They serve as artificial foundations for embankments where subsoils are semi-fluid in nature and will not support the weight of earthfill. They replace the labor-intensive method of using cross-patterned willow trees or boardroads.

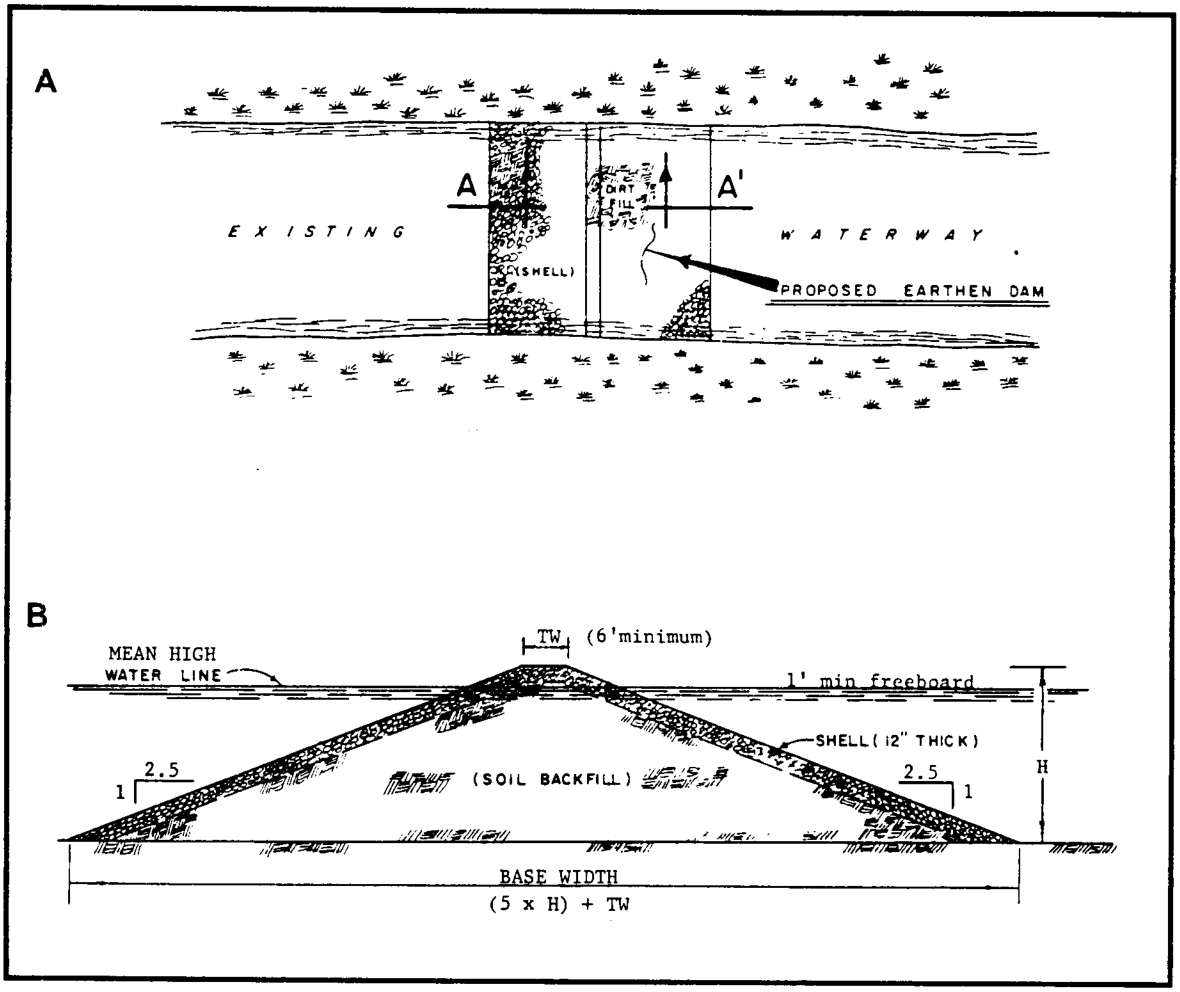


Figure 11. Typical earthen plug: A) plan; B) section A-A' (adapted from Broussard 1988). NOTE: conceptual drawing; not to be used for design.

Although the use of geotextiles is extremely effective in most areas, the cost is high and may be prohibitive for some purposes.

If the peat and muck layer overlying the mineral material does not exceed 3-4', it may be excavated from the embankment area before the embankment is constructed. One of the most successful methods used on the deeper peat and muck areas is to overbuild the embankment by placing fill material 5-10' above the elevation of the planned settled top of the embankment. The excess weight of the fill results in shear failure of the peat and causes it to flow outward. This frequently causes mounds or ridges of displaced material to appear on both sides of the embankment. After settlement has stopped, excess material may be removed from the embankment by cutting the grade to the final planned elevation.

Most plugs are constructed with draglines. Since construction equipment often must be transported on barges, and the structures are not usually large, 1/2 to 3/4 cubic yard draglines with 35-50' booms are normally used.

Specifications for earth dams are similar to those for levees. Sufficient base and top width should be provided to allow ample resistance against seepage. For plugs exceeding 5' in height, the steepest outside slope should be 2.5:1 and the inside slope 2:1. Plugs less than 5' in height which are constructed of soils that do not permit proper shaping should have a base width equal to three times the settled height of the plug plus the planned top width. If the side slopes are constructed steeper than 1.5:1, the constructed top width would need to be increased accordingly.

<u>Cost</u>. The cost of placing plugs in waterways draining a marsh vary with the width and depth of the stream, the nature of the soil, and access. Chabreck (1968) estimated the cost of constructing an earthen dam to plug a bayou 15' wide to be about $300.00. The Louisiana Department of Natural Resources and Soil Conservation Service (1988) estimated the cost of a shell armored earthen plug to be approximately $105.00 per foot. The annual maintenance cost averages about 5% of the total cost of the structure (Chabreck 1968).

<u>Levee Construction</u>

Once the decision to impound an area has been made, site selection for the levee systems must be made (figure 12). The selection is controlled by several factors, possibly the most important of which is the size of the area to be impounded. In general, several smaller impoundments are easier to manage than one large impoundment. Smaller impoundments allow greater control over hydrology and allow for the management of a wide variety of natural resources in different impoundments. Also, if one levee fails the entire impoundment system is not compromised. However, several impoundments are more expensive to build and maintain due to the more extensive levee system.

Another factor to be considered when selecting levee contours is the natural topography of the impounded area. Natural upland areas should be utilized as much as possible in lieu of levee construction. Existing spoil banks and levees should be incorporated into the system if feasible. This decreases the expense of impoundment and minimizes the habitat alteration caused by levee construction.

Levees should be constructed on, and of, firm mineral soils if possible. The higher the organic matter content, the higher the soil moisture content and the more fluid the marsh soil. Consequently, organic marsh soils support less weight and provide less solid material to make up the levee. Mineral soils will support the weight of levee material to a greater extent than organic soils, and will

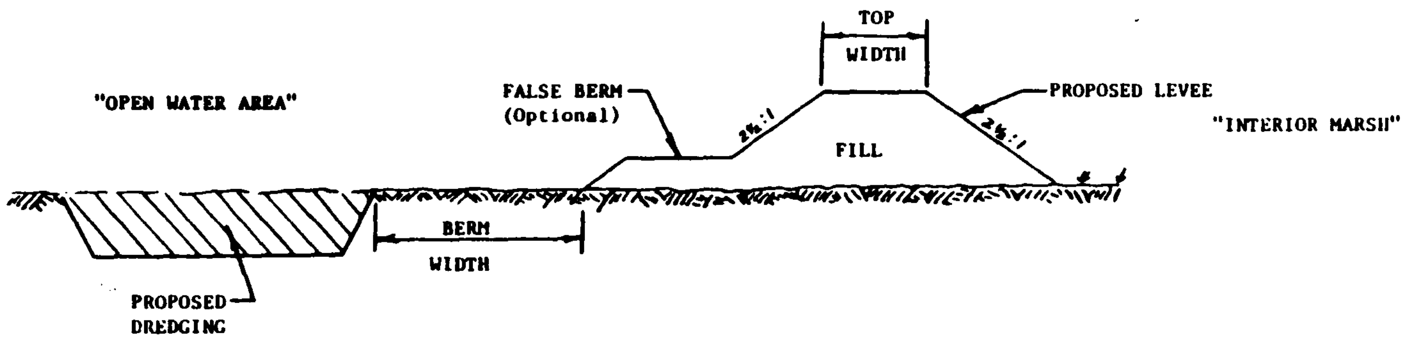


Figure 12. Typical levee cross-section (adapted from Broussard 1988). NOTE: conceptual drawing; not to be used for design.

subside less. Soil surveys may be used to aide in locating the firmest soils within the impoundment system.

Levees should be constructed on top of thick marsh vegetation as often as possible. This vegetation provides some surface strength. However, if this vegetation hides soft organic layers, compression of the soft organic layers will occur. A final but important consideration for site selection of impoundment levees is the presence of navigable waterways. Levees should not be constructed such that they block navigable channels. Not only is it illegal to block publicly-owned channels, but use of the levee for fishing and hunting access will increase maintenance costs tremendously. Levees should not be constructed immediately parallel to heavily travelled waterways. Ensminger (1963) reports the greatest damage to an impoundment levee is caused most often by boat wash. There is a direct correlation between the rate of erosion and the amount of boat traffic in a canal. Narrow berms between the canal and levee are quickly eroded away, and with heavy usage, erosion will soon attack the base of the levee. With the realization of the high cost of maintaining levees along canals used by boats, the Louisiana Wildlife and Fisheries Commission required that additional oil development on Louisiana's Rockefeller Wildlife Refuge be via board roads rather than canal systems (Ensminger 1963).

The condition of the marsh at the time of construction is of great importance. During dry periods when there is no water on the marsh, the moisture content of the material near the surface is low. This results in greater strength in the top two feet of marsh. Equally important is the better formed and higher levee that results from the drier and more compact material. When water is over the marsh, the surface layer is saturated and becomes weak and fluid. Poorly shaped levees which spread across the marsh may result when levees are constructed during this time. A good levee system is the most important component of any impoundment and should be constructed to maintain a desired height for as long as possible. Most coastal marsh soils are semi-fluid in nature, and this material must not only be used as levee material, but must often support the weight of the levee. The Louisiana Department of Natural Resources and Soil Conservation Service (1988) recommend the removal of the fluid humus material on the surface down to the firm clay before construction is begun. This is not feasible in many areas.

Most levee shrinkage and subsidence occurs during the first year after construction (Nichols 1959). Nichols (1959) divided levee loss into subsidence loss and shrinkage loss. The majority of the subsidence loss takes place immediately after levee construction within the first few weeks. This is caused primarily by compaction of the marsh surface due to the weight of the levee material and dewatering. Shrinkage loss is nearly complete at the end of the first year. This loss is caused by drying, organic compaction, and deterioration. However, subsidence usually continues throughout the life of the levee and must be offset by periodic reshaping. The thickness of the surface organic layer, and the moisture content of the marsh strata (Nichols 1959) determines the rate of immediate subsidence (Chabreck 1960); the greater the thickness of the organic layer, the greater the moisture content. The organic layer compresses to approximately 60% of its original thickness. Additional height should be added to a levee to compensate for subsidence, compaction, organic deterioration, and wave action. The Soil Conservation Service recommends a 30% allowance for settlement in mineral soils and a 50% allowance on organic soils as minimum standards (Broussard 1988). Additional lifts may be required in highly organic soils to achieve a desired settled height. After initial construction, levees should be allowed to dry and consolidate for one to two years before being reshaped and dressed to the final grade.

Fredrickson and Taylor (1982) recommend levees that are large enough to support equipment capable of mowing woody growth. Tree growth should be discouraged on levees because: 1) grasses are preferable to woody plants in decreasing erosion because they cover a greater percent of levee surface area; 2) tree roots provide pathways for water to flow between impoundments and outside waters; and 3) trees allowed to grow on levees are more susceptible to hurricane damage. When larger trees are uprooted, levees may be severely damaged and impoundment integrity compromised. Another reason for constructing larger levees is that muskrats readily burrow through small levees and allow water to escape. The construction of larger levees facilitates the control of muskrat damage.

Top surface dimensions as recommended from the literature are: 3' (Fredrickson and Taylor 1982); 18' (Ensminger 1963); 6-10' (Louisiana Department of Natural Resources and Soil Conservation Service 1988); and 6' minimum (Broussard 1988). The Louisiana Department of Natural Resources and Soil Conservation Service (1988) recommend a top width of at least 10', if the levee is to be used as a maintenance road. A slope of 3:1 to 4:1 generally suffices for the sides, but because this slope varies with soil type, an engineer's advice should be sought. A levee with a 4:1 slope is easier to maintain and mow and deters muskrats more effectively than a levee with a steeper slope. The Louisiana Department of Natural Resources and Soil Conservation Service (1988) recommend side slopes should be 2.5:1 or flatter.

During the initial construction, levees should not be constructed more than 5' high in order to prevent excessive weight from damaging the levee foundation. After drying, a finished grade of plus four feet above marsh elevation (Ensminger 1963) has been found to be adequate to exclude all but the most severe storm tides. Levees are usually designed for protection against floods of 10 to 25 year frequencies. The 25 year frequency is most desirable, especially in larger impoundments. Levees should be at least 1' taller (settled height) than the expected high water elevation in areas where there is minimal wave action and 3' higher in areas with wave action (Soil Conservation Service 1957). Fredrickson and Taylor (1982) suggest a levee height of 0.6-1.0 m above maximum high water level in marshes where major flooding rarely occurs. They suggest the constructing of a low levee in areas where inundation occurs regularly. Low wide levees that are submerged quickly and uniformly are dangered less by flooding then a larger protective levee.

Berms are marsh areas located between a levee and the nearest waterway. An adequate berm width should always be provided from the embankment to the borrow channel. If such a berm width is not provided the weight of the earth fill may cause shear failure in the foundation and result in a land slide into the borrow channel and levee collapse. Berms should be a minimum of 15' where the soil is non-caving and slowly permeable (Soil Conservation Service 1957). This width should be increased to 20' or more for more permeable soils.

In the Gulf coast berm width may be reduced to 10' for shallow organic soils if the settled height of the levee is 5' or less. Berms of at least 10' should be left between borrow pits and levees. In organic soils, this width may be increased to 25' to impede seepage and increase berm stability.

Material for the construction of levees is typically obtained from canal and other waterbody bottoms if possible. However, where this is not possible, borrow pits may supply the levee material. The Louisiana Department of Natural Resources and Soil Conservation Service (1988) state borrow pits should be cut inside the levee to allow for its use as a drainage channel and also for water storage. Such drainage channels should be cut with slopes of 1.5:1 (Louisiana Department of Natural Resources and Soil Conservation Service 1988). On channels which usually remain full of water, steeper side slopes may be used. Borrow areas inside the levee provide deeper, permanent water. An elevated access should be established across borrow areas inside a levee to ensure that equipment can be transported into the impoundment if borrow areas remain flooded. In some cases, discontinuous borrow ditches on the inside of a levee are preferable.

Inner levees may be necessary to control wave erosion in a larger impoundment. Ideally, inner levees should be as large as outer levees. When this is not possible, smaller levees can be constructed with a rice plow or a road grader. Such levees should be at least a foot higher than the expected inner water level height.

Feasibility. Several factors affect the feasibility of levee construction within impoundments, primarily soil type, impoundment size, management focus, and nearness to the gulf coast. In general, impoundments are least feasible in highly organic soils. See Hartman and Cahoon (1989) for a discussion of the effects of soil type on marsh management feasibility in general.

Cost. Costs of levee construction may vary considerably from site to site because of soil type, distance between borrow area and levee, and maintenance requirements. In 1977, costs for construction of a levee 1.2 m high and 3 m across the top averaged $30 per linear meter of levee constructed. The Louisiana Department of Natural Resources and Soil Conservation Services (1988) estimated the cost in 1986 dollars as being $13.25 per linear foot for levees with support fabric and $1.90 per foot per lift for levees without support fabric.

Trenasses

A trenasse (sometimes referred to as a level ditch) is a shallow ditch dug in a marsh to facilitate access to interior marsh areas. Trenasses were the first type of construction attempted in Louisiana's coastal marshes, dating back to the mid to late 1800s (Broussard 1986). Their sole purpose was navigation across isolated marsh areas for trapping and hunting. Today they are used in marsh management plans to enhance management in problem areas by channeling water to or away from water control structures or directing fresh water into a management area and to provide proper water distribution.

Trenasse digging is a practical way of improving a marsh for muskrats and other furbearers. Trenasses, along with their adjacent spoil banks, increase habitat available for waterfowl, furbearers, and alligators. They provide for a diversity of habitat types where previously there had been little. The spoil from the ditching provides good cover and refuge areas for waterfowl. These are ideal nesting areas for waterfowl, especially mottled ducks and fulvous whistling ducks (Louisiana Department of Natural Resources and Soil Conservation Service 1988). Also, they may be the only local source of fresh water for wildlife during severe drought conditions. Trenasses provide migrational pathways for fishery organisms to interior marsh areas, and allow for their exit from areas of poor water quality. Ditching also helps distribute water evenly over a marsh and helps in controlled burning of marshes by providing fire lanes to better manage individual tracts.

Construction. Trenasses should never be placed where they may have a negative influence on the hydrology of an area or cause erosion problems. Ends of the trenasses should be left closed or be connected to water control structures so as not to inadvertently lower the normal water table by drainage.

Trenasses are usually constructed with marsh buggy draglines and special mudboats. The use of dynamite or ammonium nitrate for blasting is rarely used today. Most trenasses are extremely narrow and shallow and are usable only with small, shallow-draft boats (mud boats, bateaus, etc.). Although the Louisiana Department of Natural Resources and Soil Conservation Service (1988) list trenasse dimensions as having a 13-15' top width and 5' depth, Darryl Clark (Louisiana Department of Natural Resources 1989) and the Soil Conservation Service (1957) suggest a 3-6' width and 2-3' depth is more desirable. The Soil Conservation Service (1957) also suggests a 400-500' spacing should be allowed between each trenasse.

Annual cleaning of trenasses is necessary to prevent them from becoming clogged with organic material or vegetation. Cleaning should be done in the fall after the plants have matured but before the ditches are needed for waterfowl hunters' or trappers' boats.

Cost. Trenasses are the least costly structures to construct and maintain. A rented trenching machine and one day's labor are often all that is needed.

ADJUSTABLE (ACTIVE) WATER CONTROL STRUCTURES

Introduction

Adjustable, or active, water control structures include variable-crest weirs, gated culverts, gated culverts with variable-crest weirs or risers, and pumps. These structures are most often used in combination with a levee or spoil bank system to help change water levels within a marsh or wetland management area (Spicer et al. 1986). Success of this type of water management depends on achieving total control of water movement through channels and across the marsh surface. This degree of water management can only be achieved when the area to be managed is completely ringed by levees and all channel flows are controlled by structures. However, many management areas have both active and passive (e.g., fixed-crest weir) structures which form a hybrid operation somewhere between both major types. The range of managed water levels varies from about 1' below marsh level to approximately 4-6" above marsh level. If the marsh is at mean sea level, which is the case for most of the deltaic plain, this range becomes -1' - + 0.5' mean sea level.

Adjustable control structures have been found in more and more permit applications in recent years. This may be due to their greater availability in the inventories of contractors, lower cost compared to fixed-crest weirs, and the greater ability of marsh managers to manipulate water levels. Clark (1988) analyzed the Coastal Management Division marsh management coastal use permit data base from 1981 to 1988. Seventy-nine (79%) of the 113 applications received for marsh management activities during that period contained either fixed-crest, variable-crest, or gated structures. Of these 79 plans, 37 plans (46%) contained variable-crest or adjustable structures, while 34 plans (43%) contained ordinary fixed-crest weirs. Forty-five of the 79 plans (57%) utilized at least some adjustable water control structures (Clark 1988).

Similar data are presented in chapter 7 from a review of coastal use permit applications from 1980 to 1988. Of 165 applications reviewed, management plans called for 266 adjustable types of structures (37% of the total), such as variable-crest weirs and gated structures. Fixed-crest weirs comprised 100 (13.8%) and plugs 101 (14%) of the total number of structures. The 1989 applications were not included in the study--a series of permit applications received from one landowner for maintenance of over 300 fixed-crest structures and plugs skewed that year's data in favor of fixed-crest weirs. Excluding 1989, adjustable-type water control structures consisted of a majority of those structures submitted for permitting during the last nine years, comprising 46% of the plans and 36.9% of the number of structures. This is contrasted to only 43% of the plans and 13.8% of the structures for fixed-crest weirs during the same period (Clark 1988; chapter 7).

Types of Structures

Under each grouping (e.g., variable-crest weirs; gated culverts; gated culverts with variable-crest weirs or risers; and pumps) the structures are listed from less-complicated to more-complicated. Because more structures are considered in this section of the chapter, the organization differs from the preceding section. Structures here are considered in groups, rather than individually, with respect to purposes, operation, feasibility, engineering, construction, and cost. The most detailed technical examination of each structure, along with bibliographic references, can be found in the engineering and construction section.

Table 4 lists the various types of adjustable structures treated in this report. They constitute the most common adjustable structures in use along the Louisiana coast for wetland management.

Purposes (Benefits and Detriments)

The general purpose of adjustable water control structures is to vary water levels within a management area to achieve the following goals (Spicer et al. 1986; Coastal Management Division-Soil Conservation Service 1988):

1) seed germination for revegetation and land loss reduction;

2) increased hydrologic movement and with it increased aquatic organism; nutrient, and sediment movement;

3) increased submerged vegetation caused by reduced turbidity and oxidized bottom sediments;

4) decreased tidal scouring and physical erosion;

5) decreased saltwater intrusion;

6) increased and more complete water level management; and

7) increased adaptability in cases of storm events.

Table 4. List of adjustable control structures used in the Louisiana coastal marshes.

Variable-crest weirs
1. Variable-crest weir of the Wakefield type (low-level water control structure)(figure 13).
2. Wooden box-type variable crest weir (figure 14).
3. Cameron Creole concrete variable-crest weir with hurricane gates (figures 15a and 15b).
Gated culverts
1. Single flap-gated culvert (figure 16).
2. Double flap-gated culvert (figure 16).
3. Single gated culvert with a screwgate (figure 17).
4. Two-way aluminum flap-gate with hoist (figure 18).
5. Open culvert with L-shaped riser (figure 19).
6. Rockefeller Refuge concrete, stainless steel, radial-lift gate control structure (figure 20).
7. Sabine National Wildlife Refuge concrete fixed-crest weir with taintergate (figures 21a and 21b).
Gated culverts with variable-crest weirs or risers
1. Two-way semi-automatic gate structure (figure 22).
2. Single flap-gated culvert with variable-crest weir (metal culvert with floodgate and weir inlet) (figure 23).
3. Culvert with screw gate and variable crest weir (figure 24).

Table 4. List of adjustable control structures used in the Louisiana coastal marshes (continued).

Gated culverts with variable-crest weirs or risers

4. Flap-gated culvert with variable-crest weir and vertical slot (figure 25).
5. Wooden box flap-gated culvert with variable-crest weir (figure 26).
6. Variable-crest weir with two-way aluminum flapgate with hoist (variable-crest gated structure) (figure 27).
7. Double flap-gated culvert with variable-crest weir (figure 28).
8. South Carolina trunk structure (double flap-gate culvert with a flashboard riser) (figure 29).
9. Culvert with floodgate and fixed riser (figure 30).
10. Rockefeller Refuge concrete variable-crest weir reversible flapgate control structure (figure 31).
11. AMOCO West Black Lake flap-gated culvert with variable-crest weir and ingress gate (figure 32).

Pumps

1. One-way pump.
2. Rockefeller Refuge double divergent pumping unit (figure 33).
3. Archimedes' screw type pump

Water levels are varied within the range of from 12 inches below to 4 inches above marsh level. In the case of variable-crest weirs, this water level control may only be good enough to lower water levels to 6" below marsh level or slightly lower. This is because of the difficulty of variable-crest weir structures in preventing water from re-entering the marsh during a water level lowering event. Other more efficient control structures such as gated culverts with variable-crest weirs or structures used in areas with pump assistance may be able to lower water levels 12" or more below marsh level. The goal is to lower levels just enough so that mud flats and some open water ponded areas are exposed to the air for a significant length of time. This exposure of bottom sediments to the air enables vegetation to germinate and revegetate the area. The ultimate goals of active marsh management are to lower water levels for a sufficient period to stimulate revegetation in the spring and summer and to increase water levels in the winter for waterfowl habitat and trapping access (Broussard 1988; Spicer et al. 1986). It is difficult to achieve the water level lowering goal in plans with variable-crest weirs without the benefit of gates which prevent the return of water during high tides. Gated control structures are prevented from efficient water lowering in certain cases, when winds and tides do not allow sufficient head differential to exist between areas inside and outside the management plan. Generally strong southerly winds and high tides during the late spring and summer make water level lowering (drawdown) difficult in management areas. Higher tides occur as spring and neap tides and during the new and full moon. This situation only serves as a problem during drawdowns in the late spring and summer. These drawdowns may have to be terminated earlier than planned in these cases because of the presence of high water outside the management plan. Of course these high tides in late spring and summer are beneficial for the movement of fish, nutrients, and sediment into the plan areas. Management plans usually take advantage of these tidal ranges and winds by incorporating the drawdowns in the early spring when northerly winds and lower tides prevail, then the structures are opened in the summer to take full advantage of the southerly winds.

Adjustable structures have the possibility of allowing more water movement into a management area during a given time interval compared to fixed-crest weirs and certainly plugs and levees mentioned in the other sections. They are able to do this because of their ability to open more of the water column in some cases to water movement. When the structures are open and stop logs removed, more water, aquatic organisms (Rogers and Herke 1987), nutrients, and sediment (Day et al. 1989) may move in and out of the management system than would usually occur in a marsh managed with fixed-crest weirs. Adjustable structures have the ability to hold higher water levels in the marsh in the winter for waterfowl habitat.

Generally, adjustable structures have been attributed some of the same benefits and impacts to the marsh ecosystem as mentioned for fixed-crest or Wakefield weirs. This is especially true during those times when the adjustable structures are operated in the fixed-crest weir position with the weir sill at -6" marsh level. Since most adjustable control structures for manipulated impoundment areas are relatively new (less than 10 years old), the body of literature reporting on studies of their effects especially in Louisiana is not great. Most of the literature is based on total impoundment or fixed-crest weir situations. Most marsh management plans which involve fixed-crest weirs and

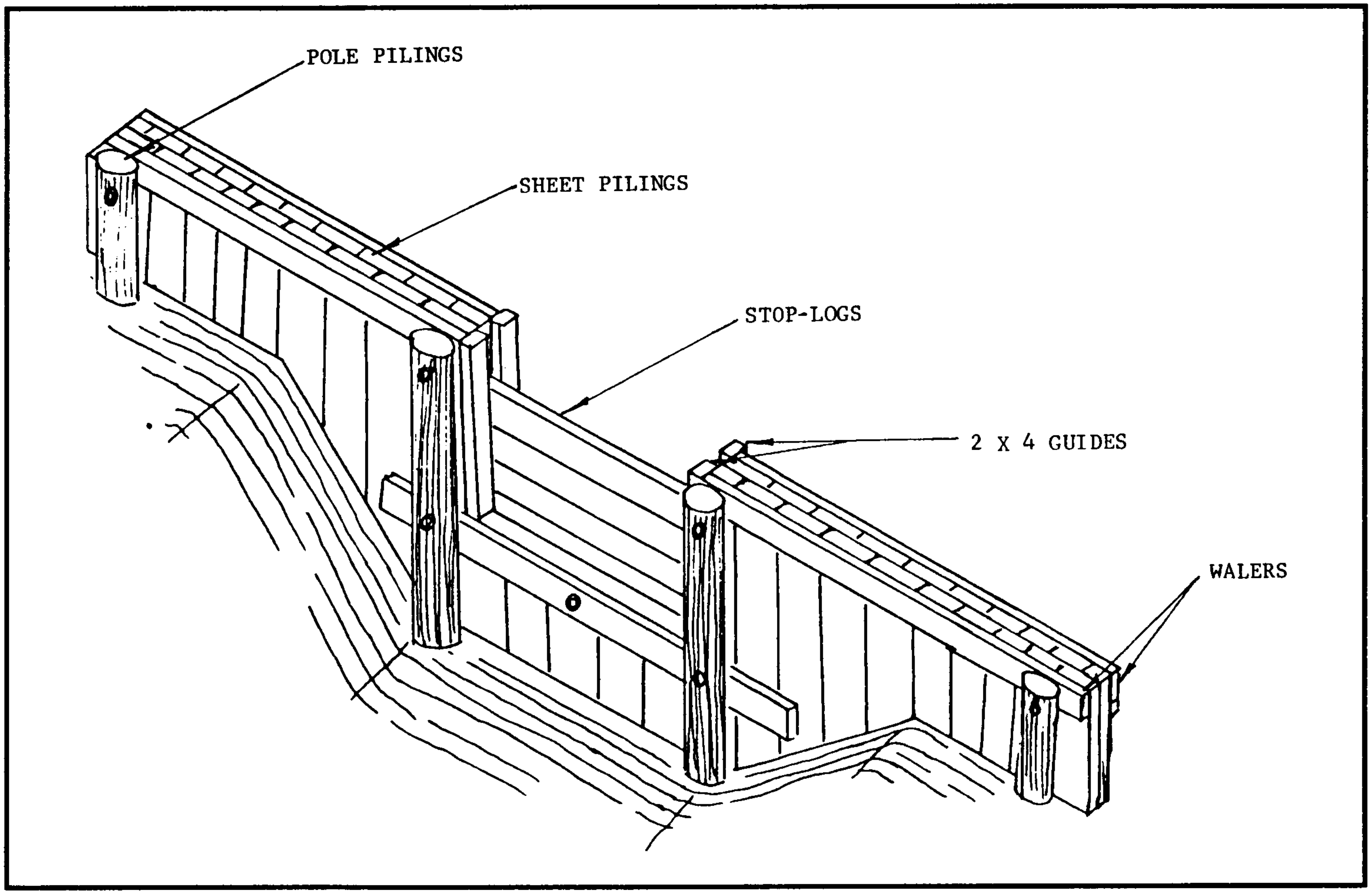


Figure 13. Variable-crest weir (adapted from Broussard 1988). NOTE: conceptual drawing; not to be used for design.

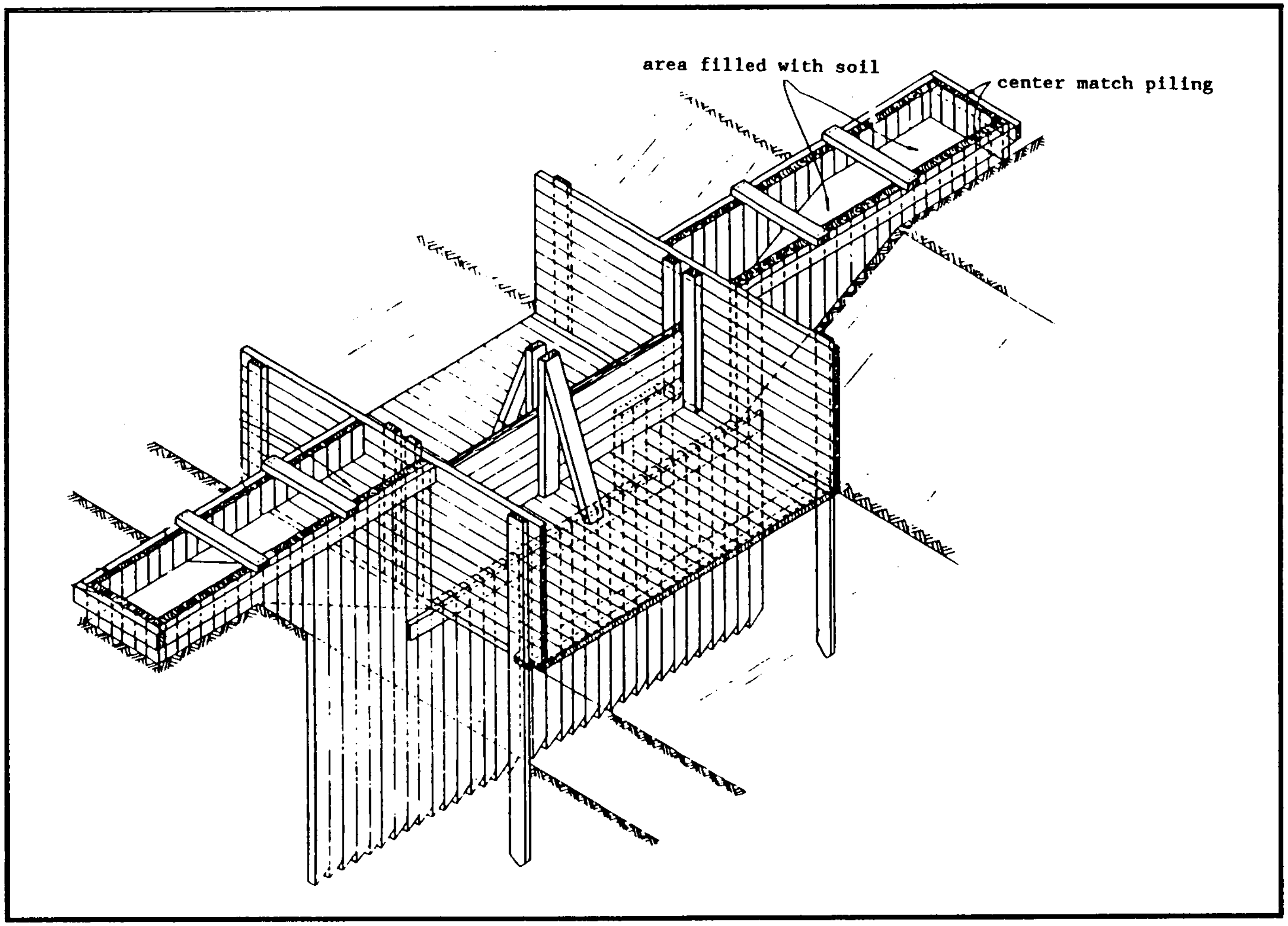


Figure 14. Wooden box weir (adapted from Brousssard 1988). NOTE: conceptual drawing; not to be used for design.

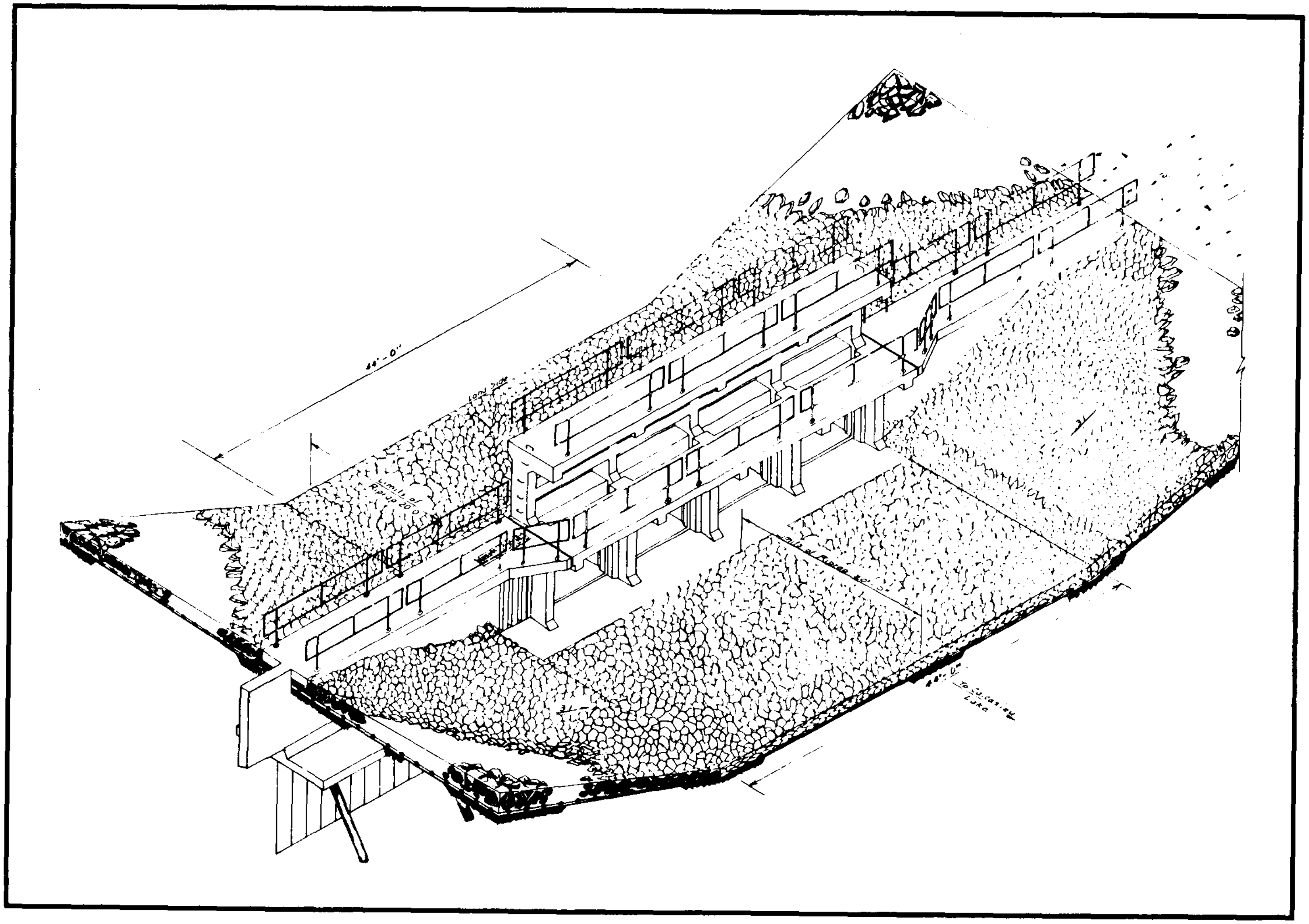


Figure 15a. Cameron-Creole variable-crest weir: isometric general plan (U.S. Department of Agriculture, Soil Conservation Service 1987). NOTE: conceptual drawing; not to be used for design.

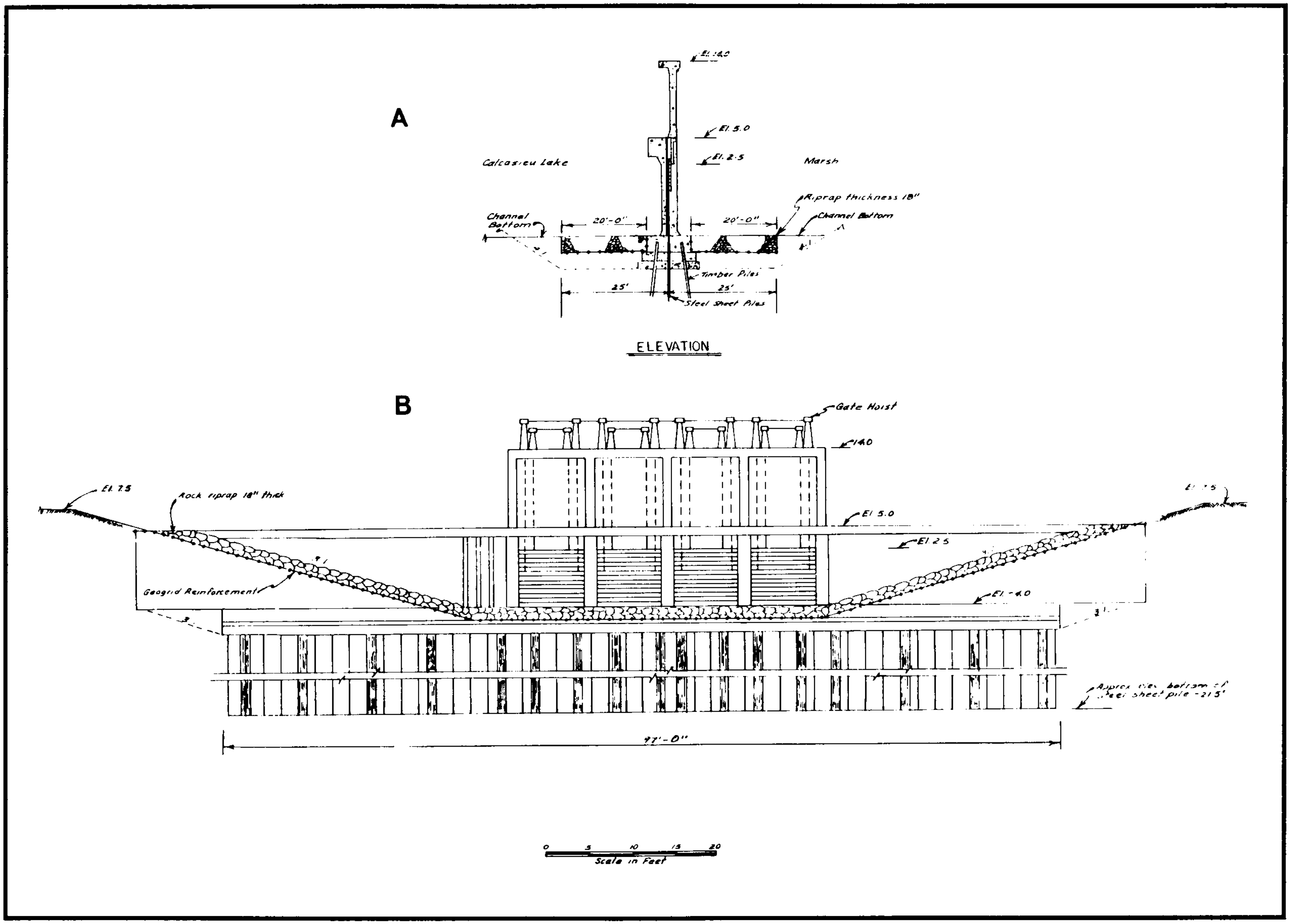


Figure 15b. Cameron-Creole variable-crest weir: A) elevation; B) profile (U.S. Department of Agriculture, Soil Conservation Service 1987). NOTE: conceptual drawing; not to be used for design.

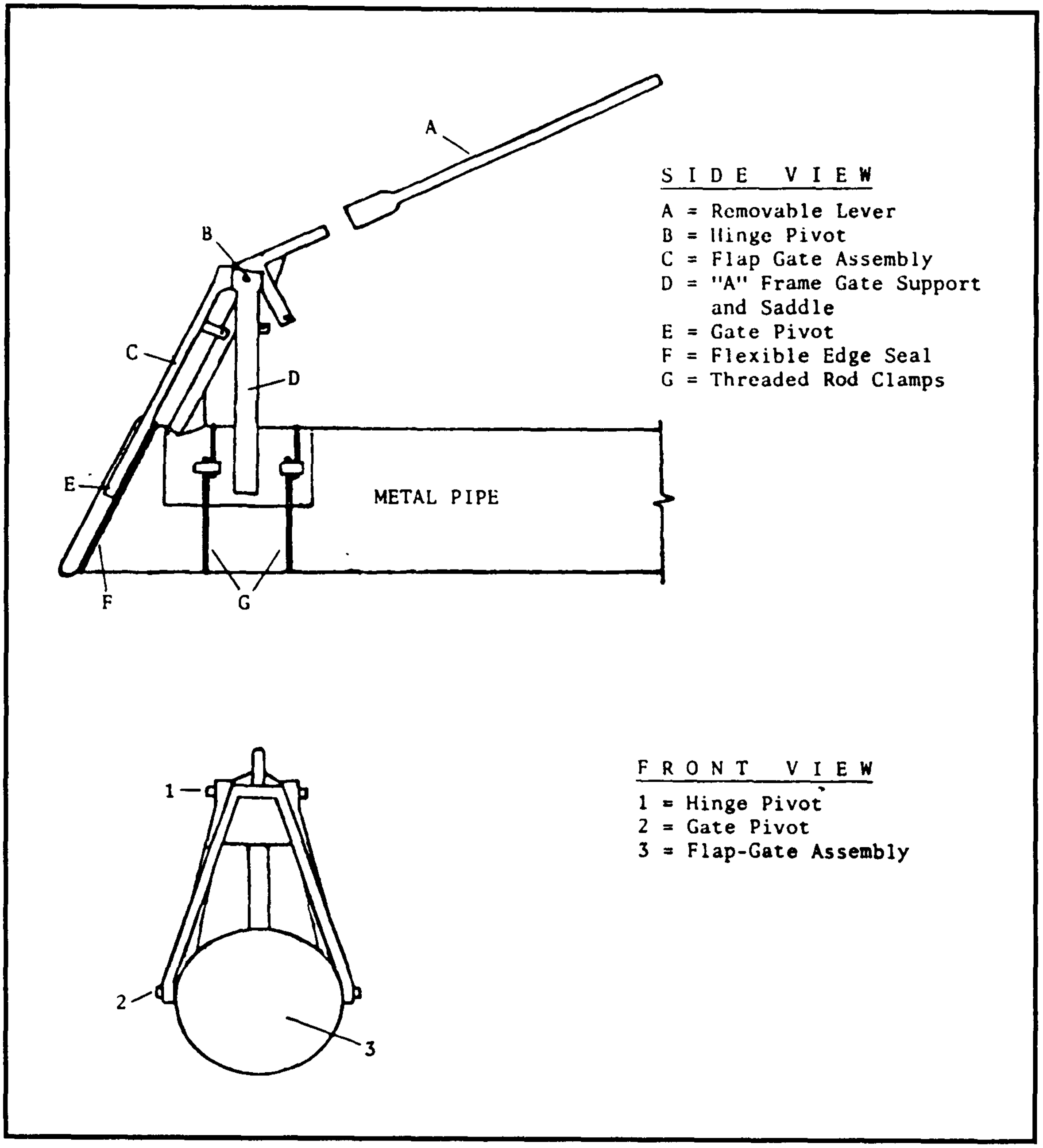


Figure 16. Single and double flap-gated culvert (Broussard 1988). NOTE: conceptual drawing; not to be used for design.

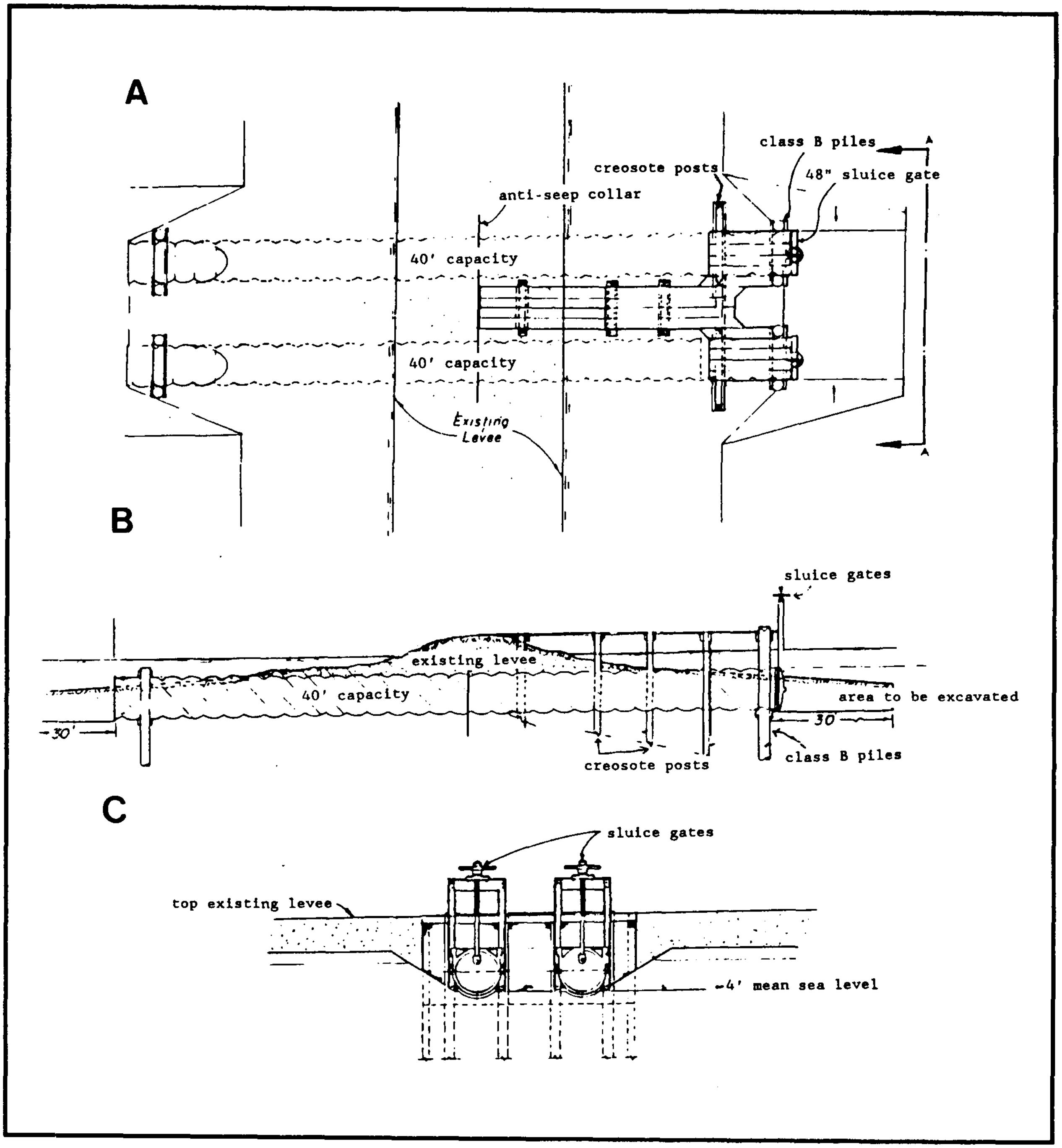


Figure 17. Single screw gate culvert: A) plan; B) cross-section at 48" sluice gate; C) view A-A' (adapted from Fenstermaker and Associates, Inc. 1985).

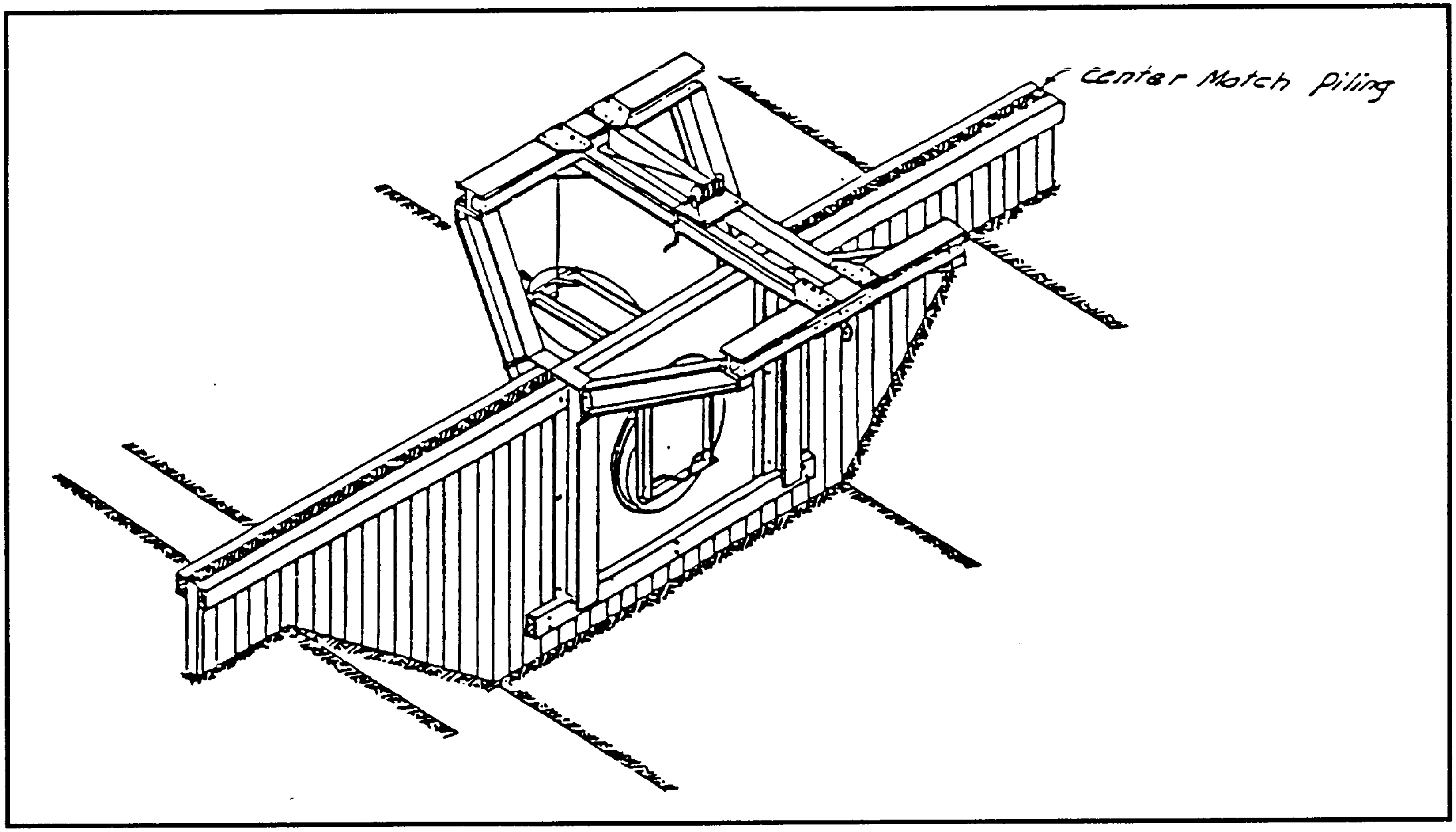


Figure 18. Two-way aluminum flapgate with hoist: isometric view (adapted from Broussard 1988). NOTE: conceptual drawing; not to be used for design.

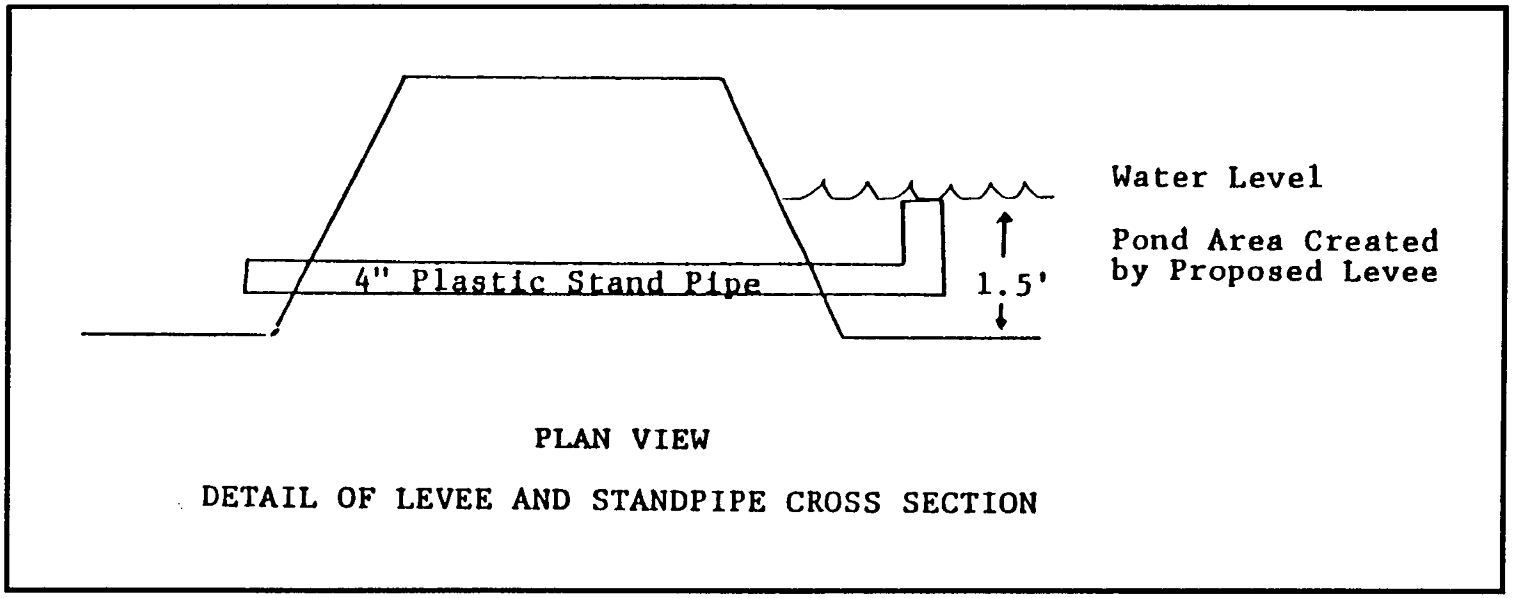


Figure 19. Culvert with L-shaped riser: detail of levee and standpipe cross section (adapted from Benoit 1986).

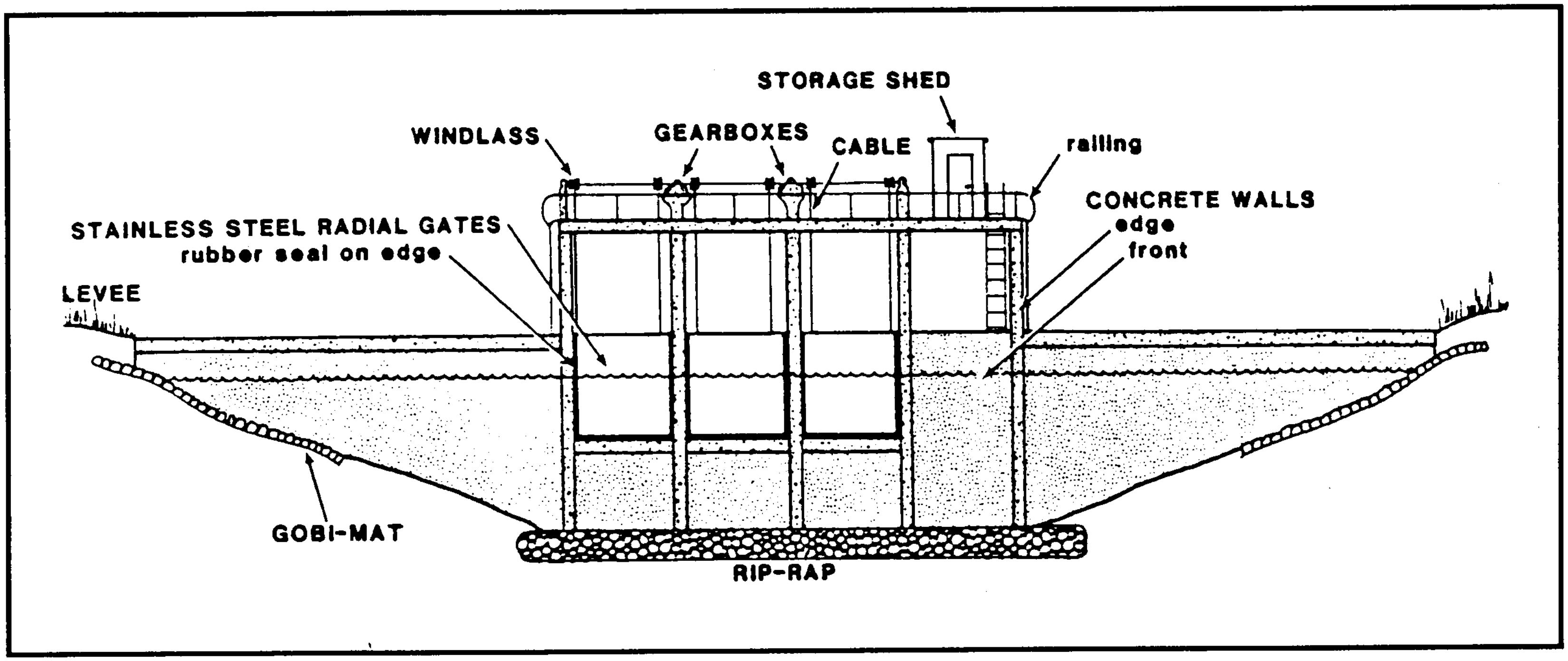


Figure 20. Rockefeller Refuge concrete radial arm lift gate: site plan (Wicker et al. 1983).

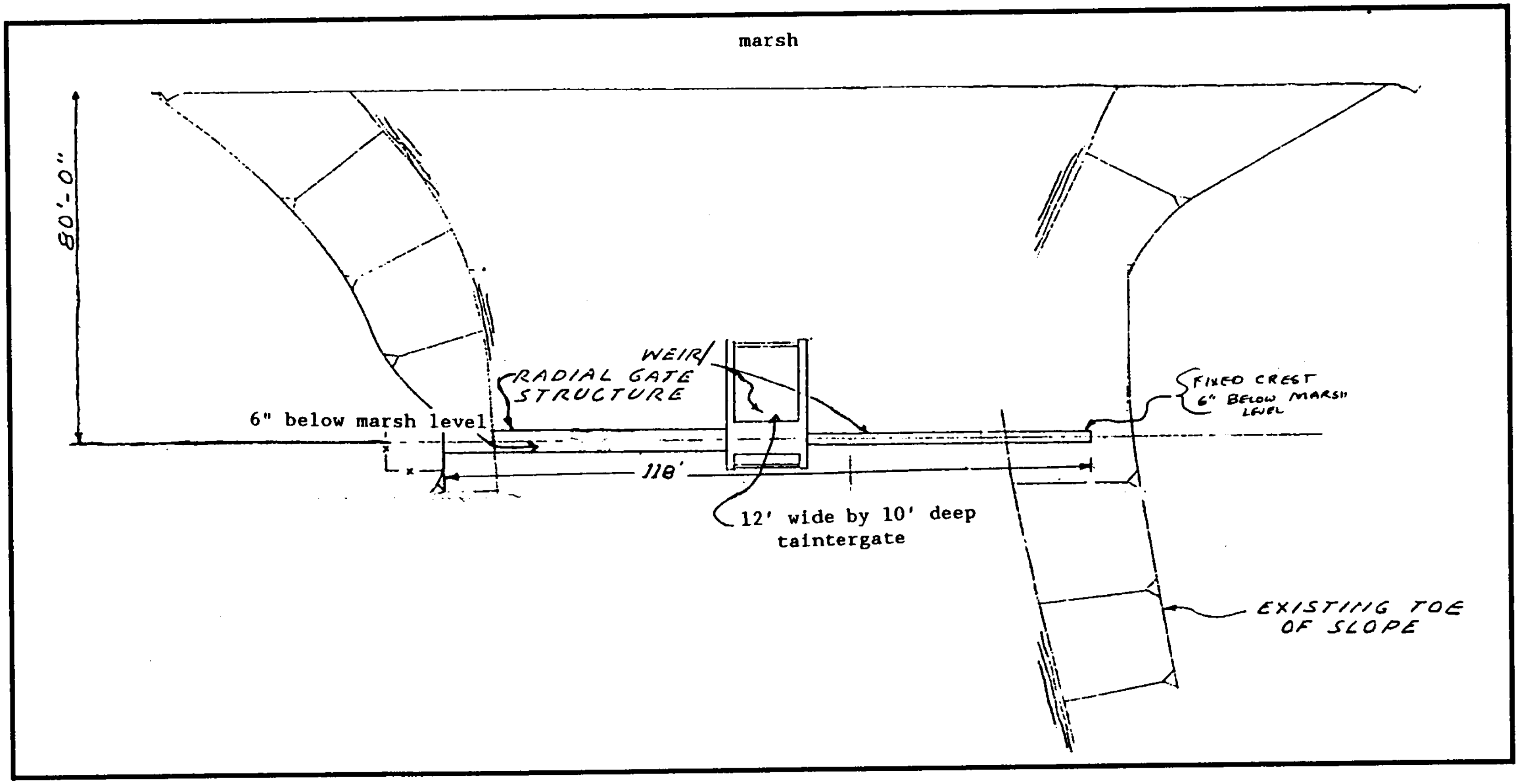


Figure 21a. Plan view of Sabine Refuge cement (concrete) taintergate: (ARMCO Steel Corp. 1980).

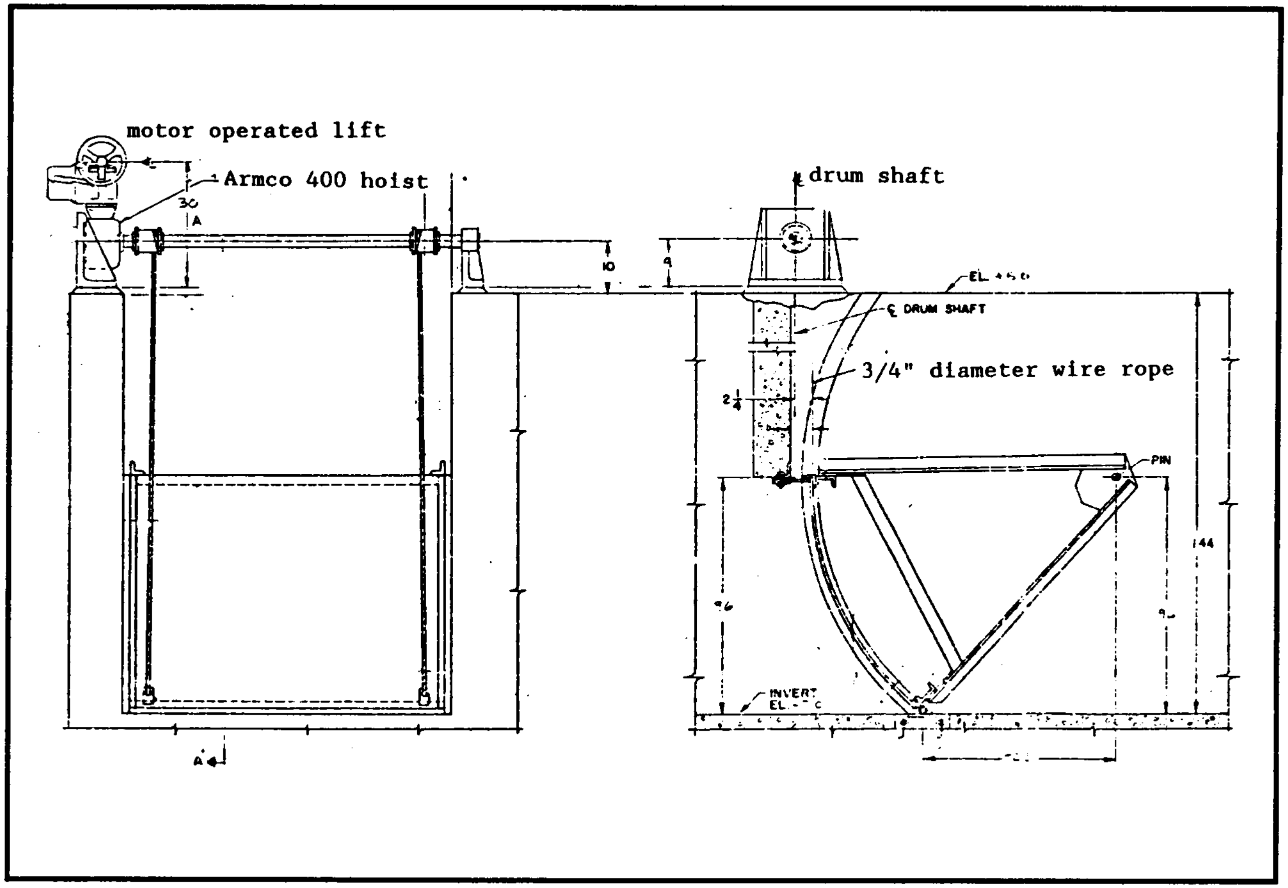


Figure 21b. Detail of Sabine Refuge cement (concrete) taintergate: (ARMCO Steel Corp. 1980).

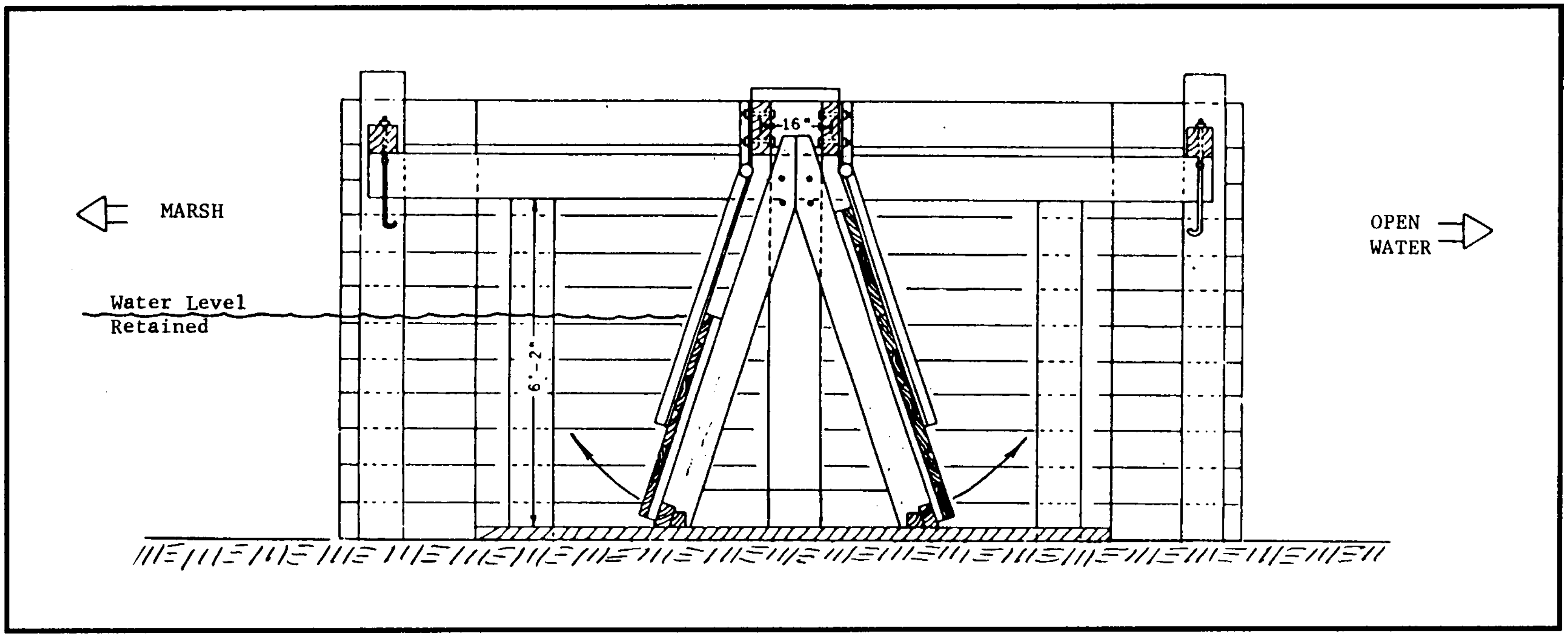


Figure 22. Two-way semi-automatic gate structure (Broussard 1988). NOTE: conceptual drawing; not to be used for design.

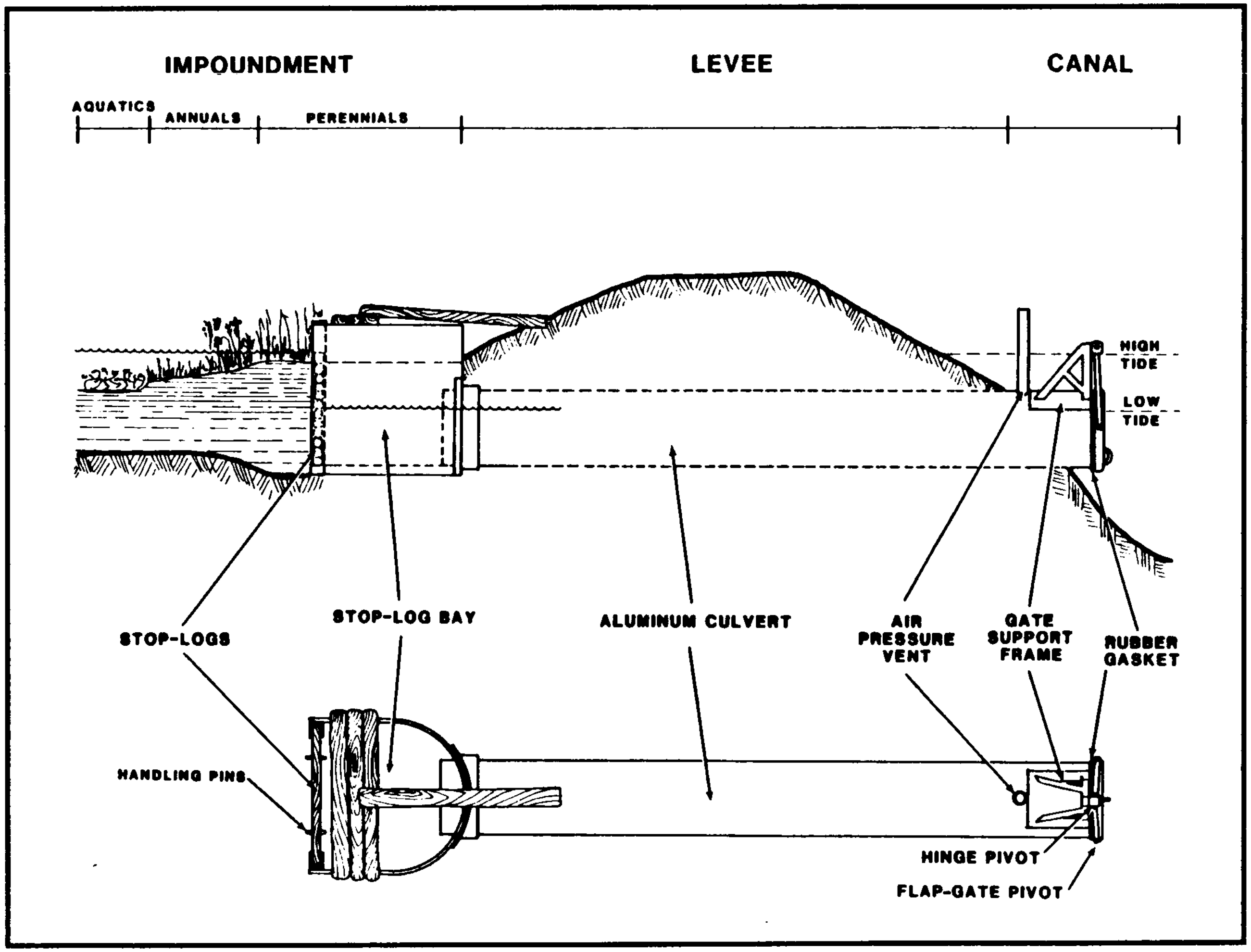


Figure 23. Single flap-gated culvert with variable-crest weir (Wicker et al. 1983). NOTE: conceptual drawing; not to be used for design.

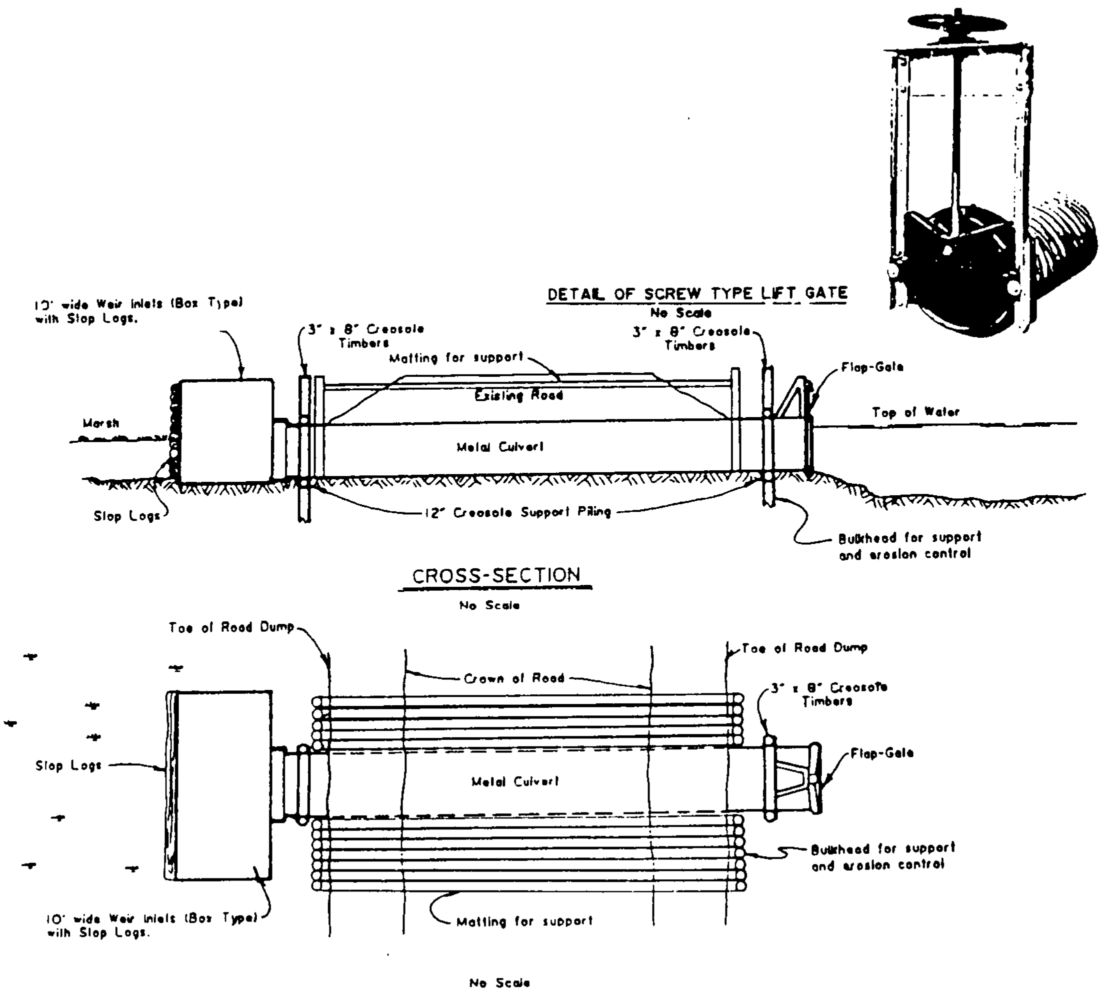


Figure 24. Culvert with screwgate and variable-crest weir: A) cross-section; B) plan (Fenstermaker and Associates Inc. 1989).

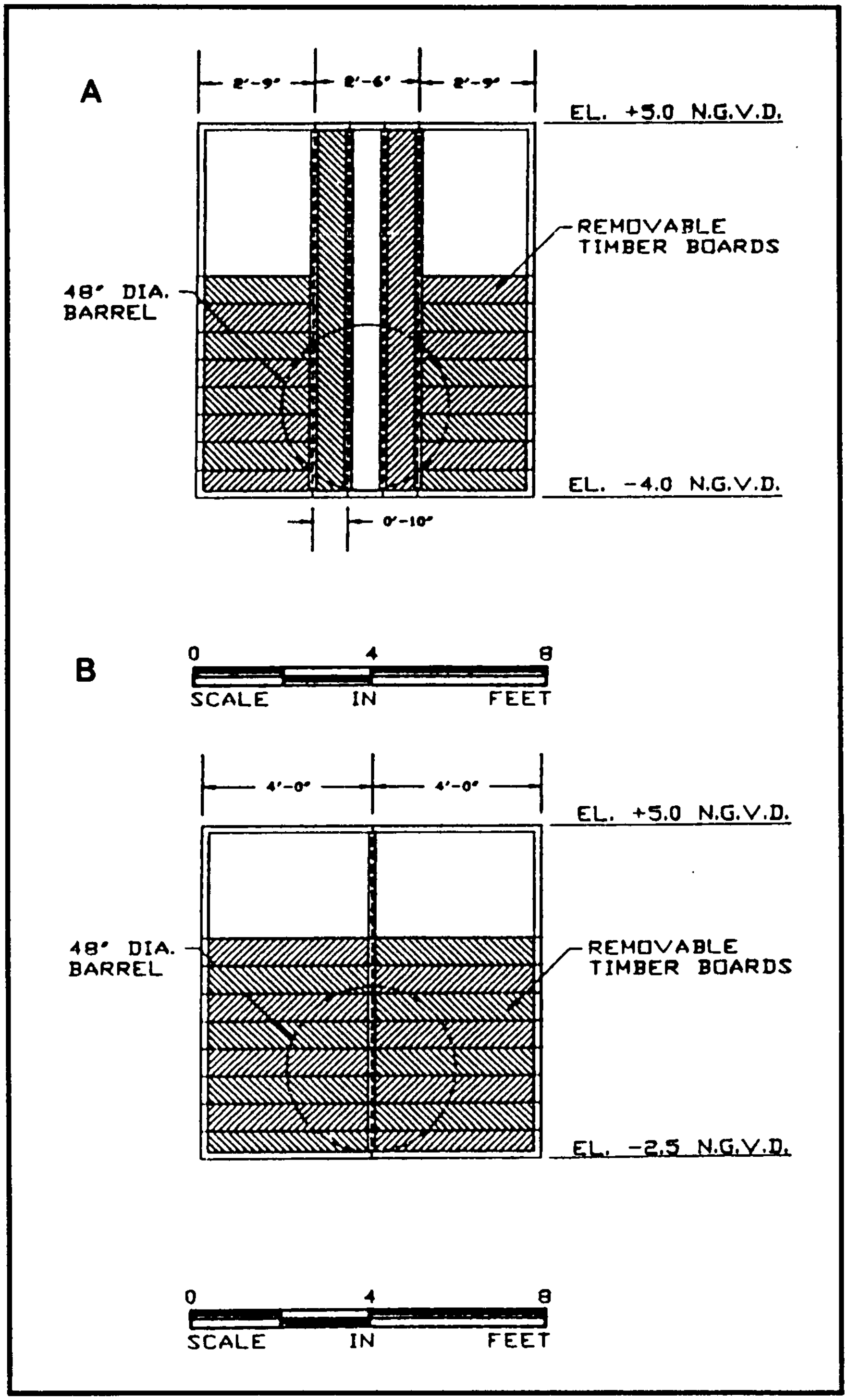


Figure 25. Flap-gated culvert with variable-crest weir and vertical slot: A) inlet structure with vertical slotted weir; B) inlet structure with horizontal weir (On Target Surveying, Inc. 1990).

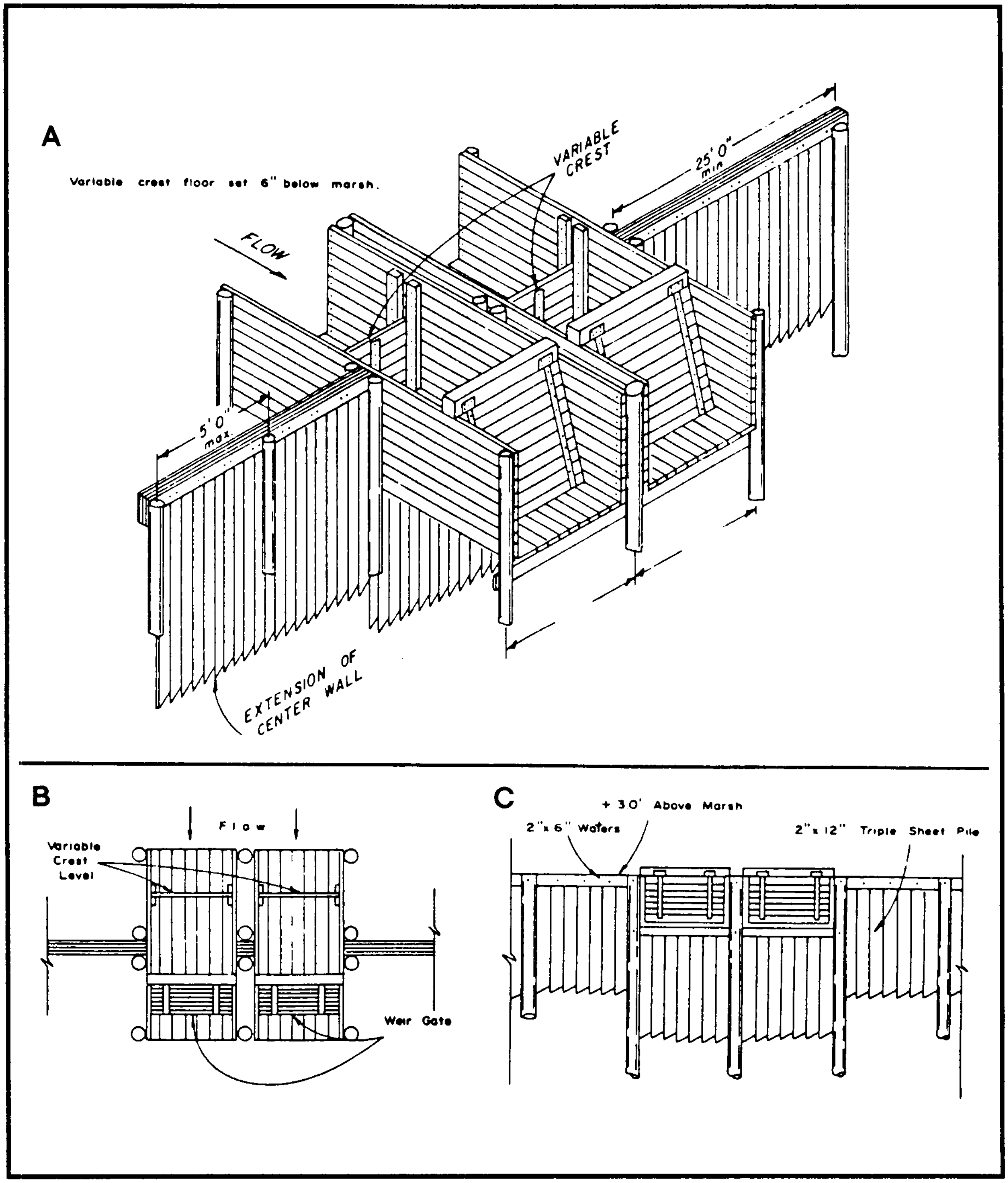


Figure 26. Wooden box flap-gated culvert with variable-crest weir: A) isometric view; B) top view; C) front view (adapted from Broussard 1988). NOTE: conceptual drawing; not to be used for design.

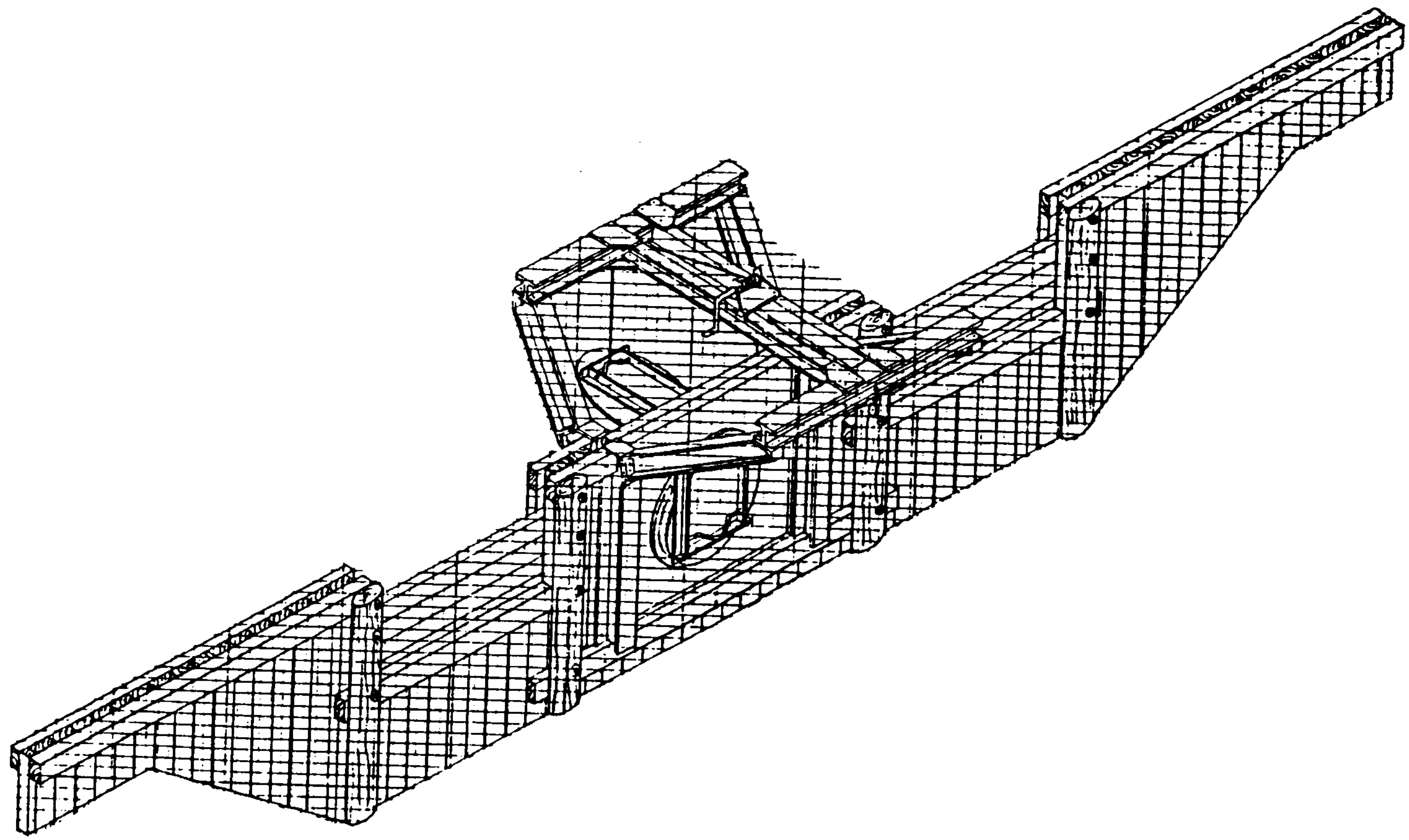


Figure 27. Variable-crest weir with 2-way aluminum flapgate with hoist (Broussard 1988). NOTE: conceptual drawing; not to be used for design.

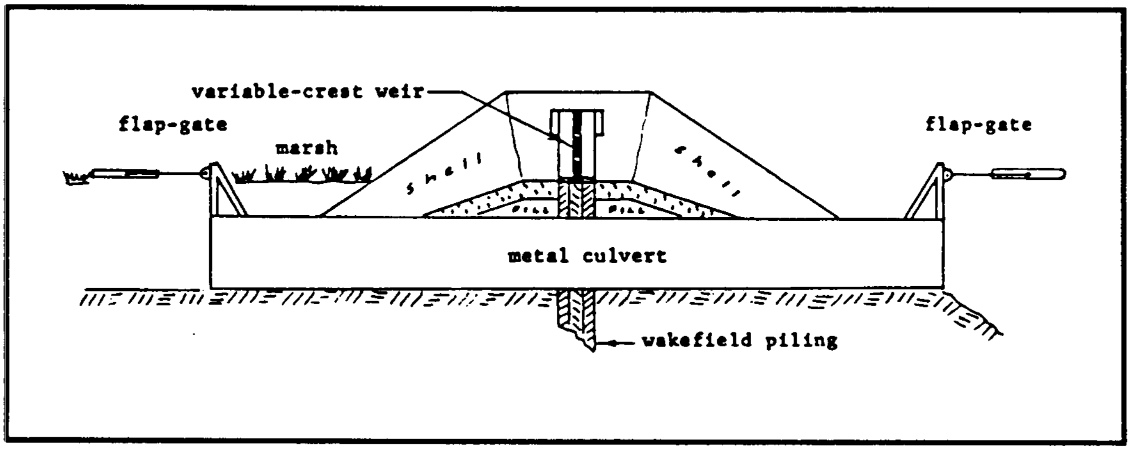


Figure 28. Double flap-gated culvert with variable-crest weir (adapted from Broussard 1988). NOTE: conceptual drawing; not to be used for design.

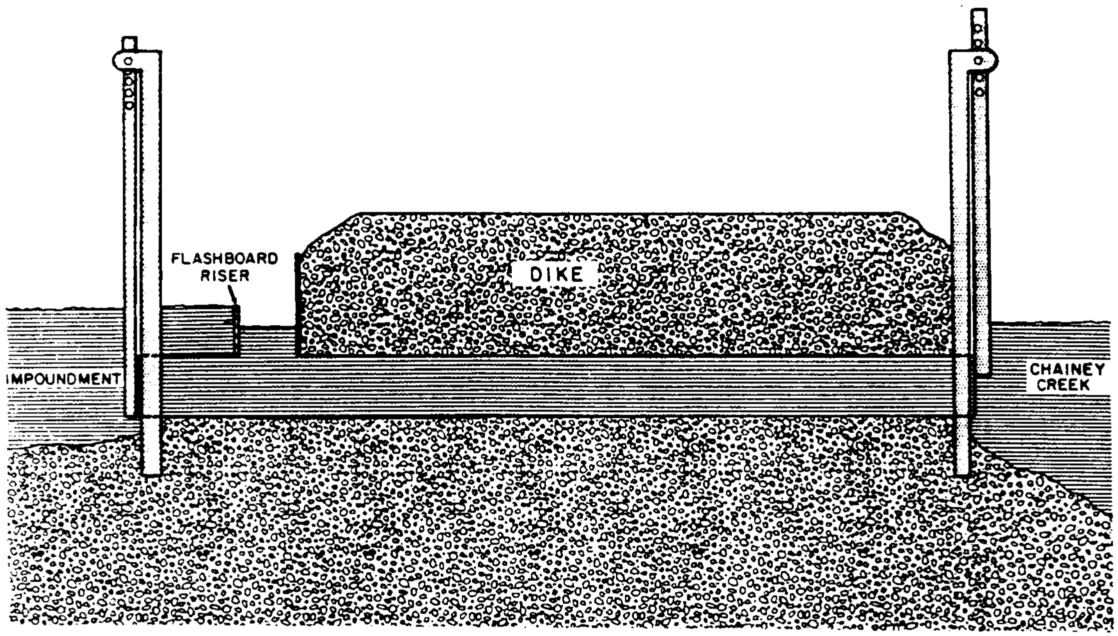


Figure 29. South Carolina trunk: cross-section schematic (ebb tide) (Olmi 1986)

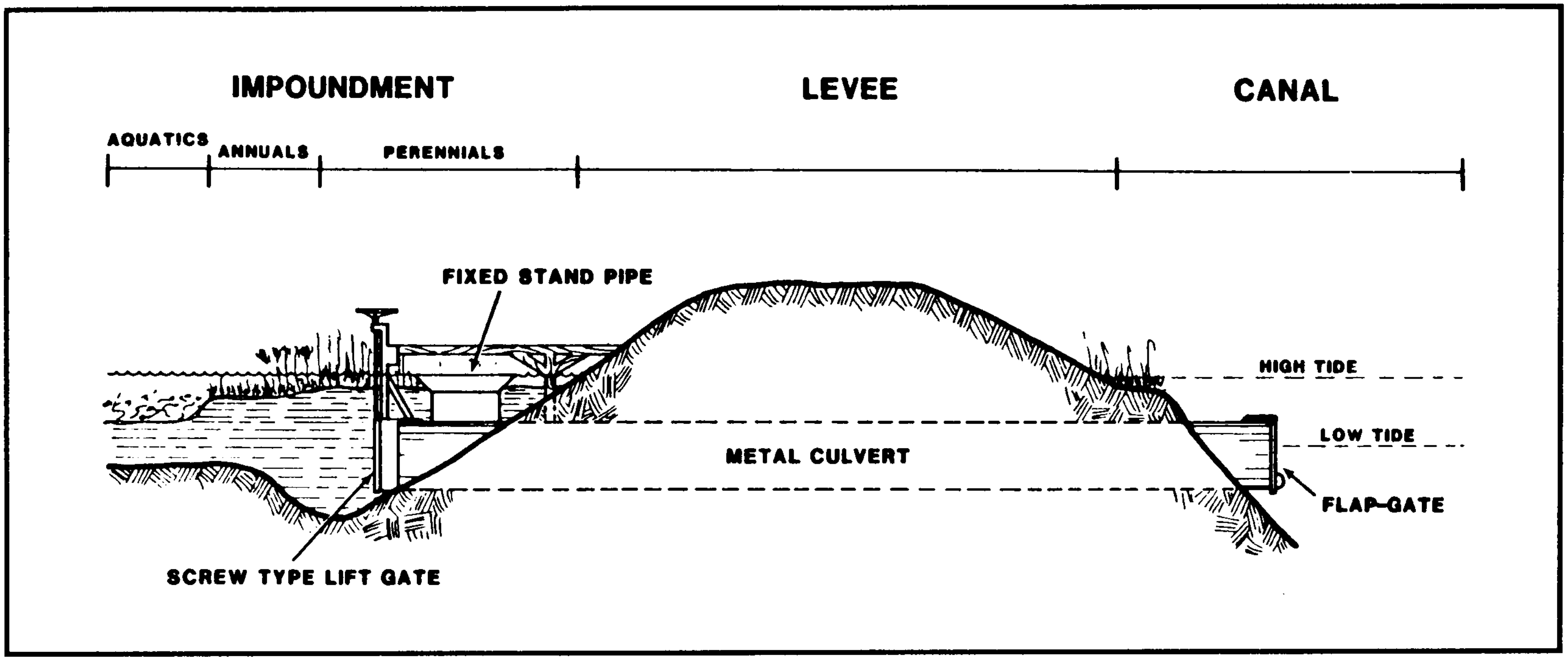


Figure 30. Culvert (conduit) with floodgate and fixed riser (Wicker et al. 1983). NOTE: conceptual drawing; not to be used for design.

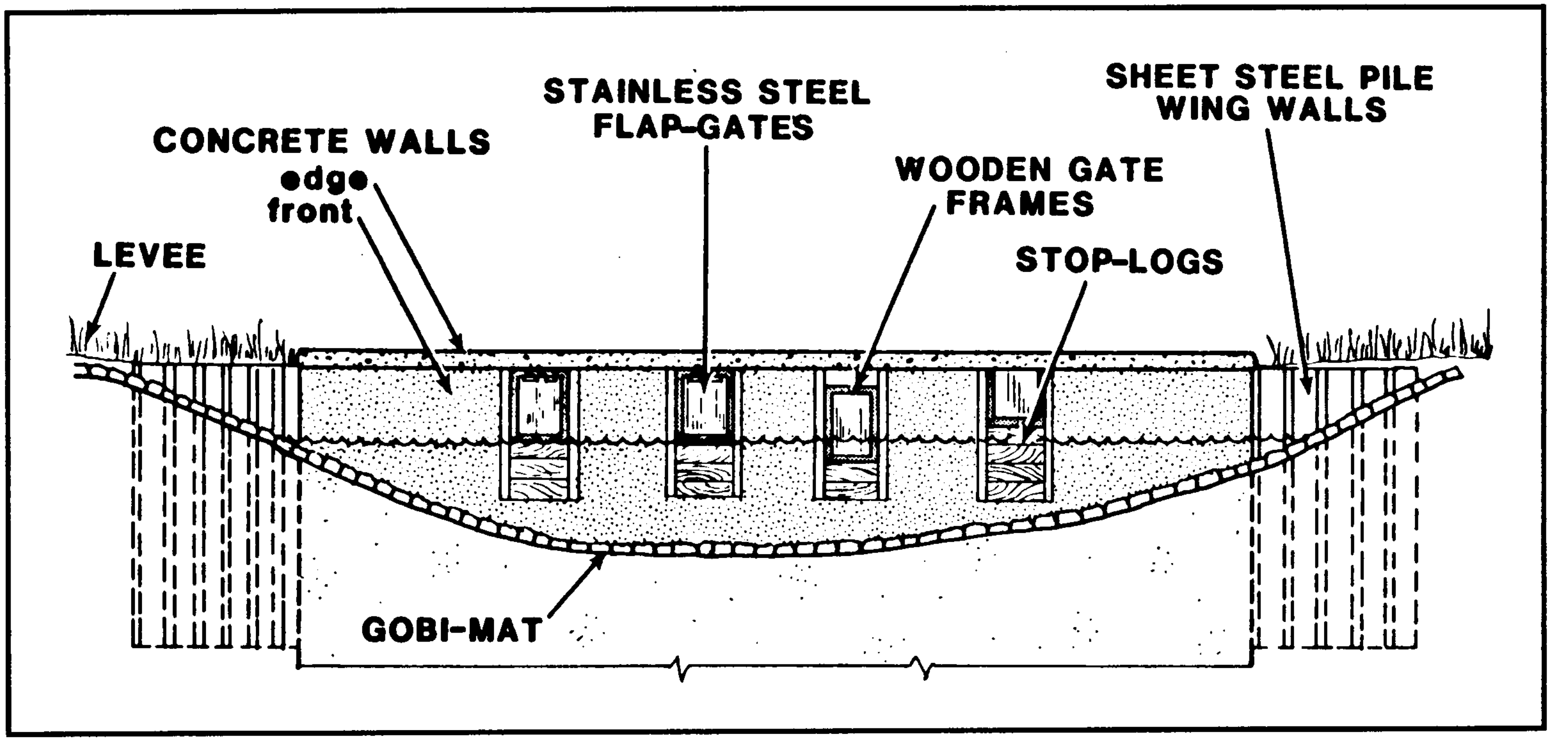


Figure 31. Rockefeller Refuge concrete variable-crest weir reversible flapgate control structure (Wicker et al. 1983)

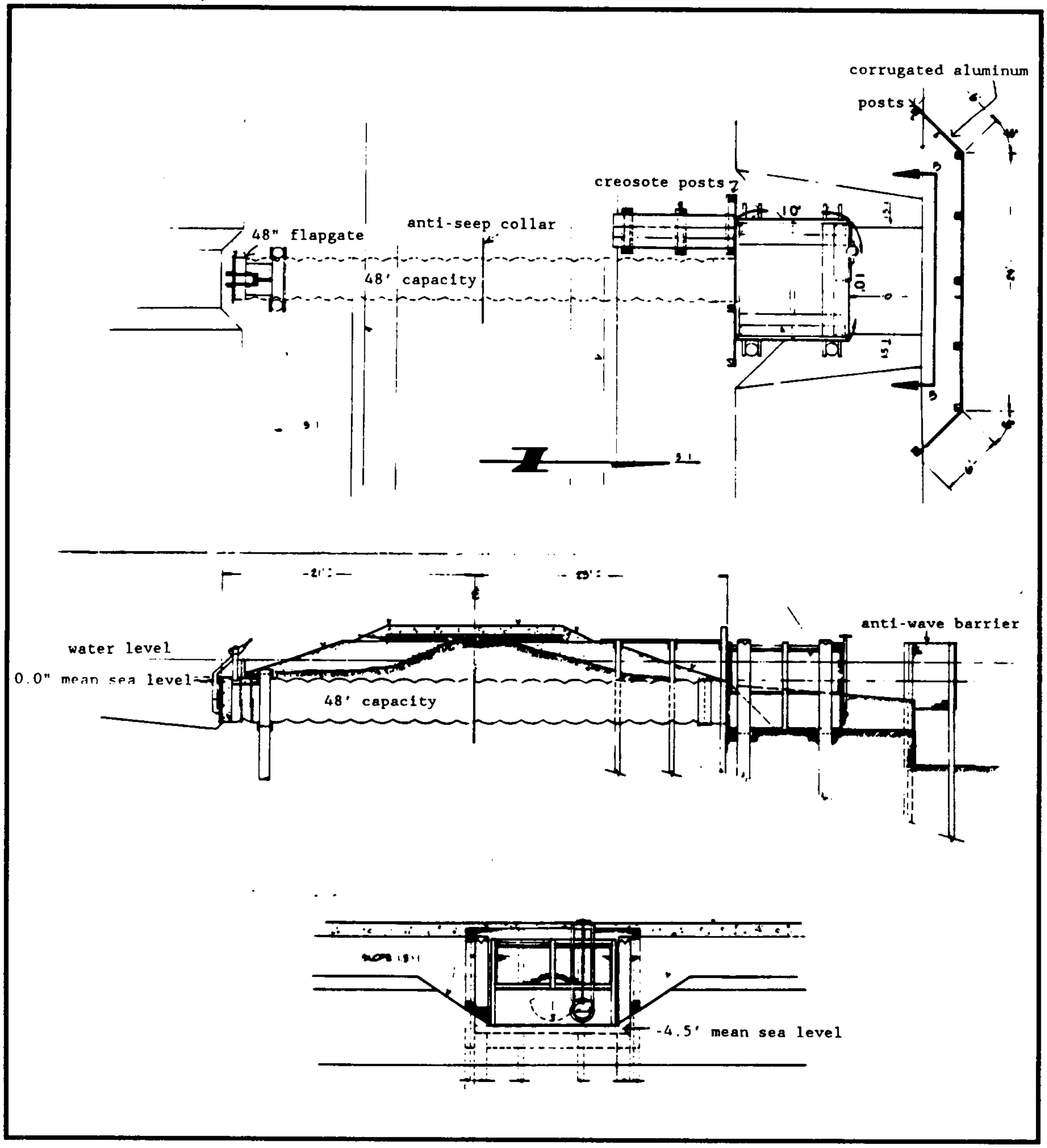


Figure 32. Amoco West Black Lake flap-gated culvert with variable-crest weir with ingress gate (Fenstermaker and Associates, Inc. 1985)

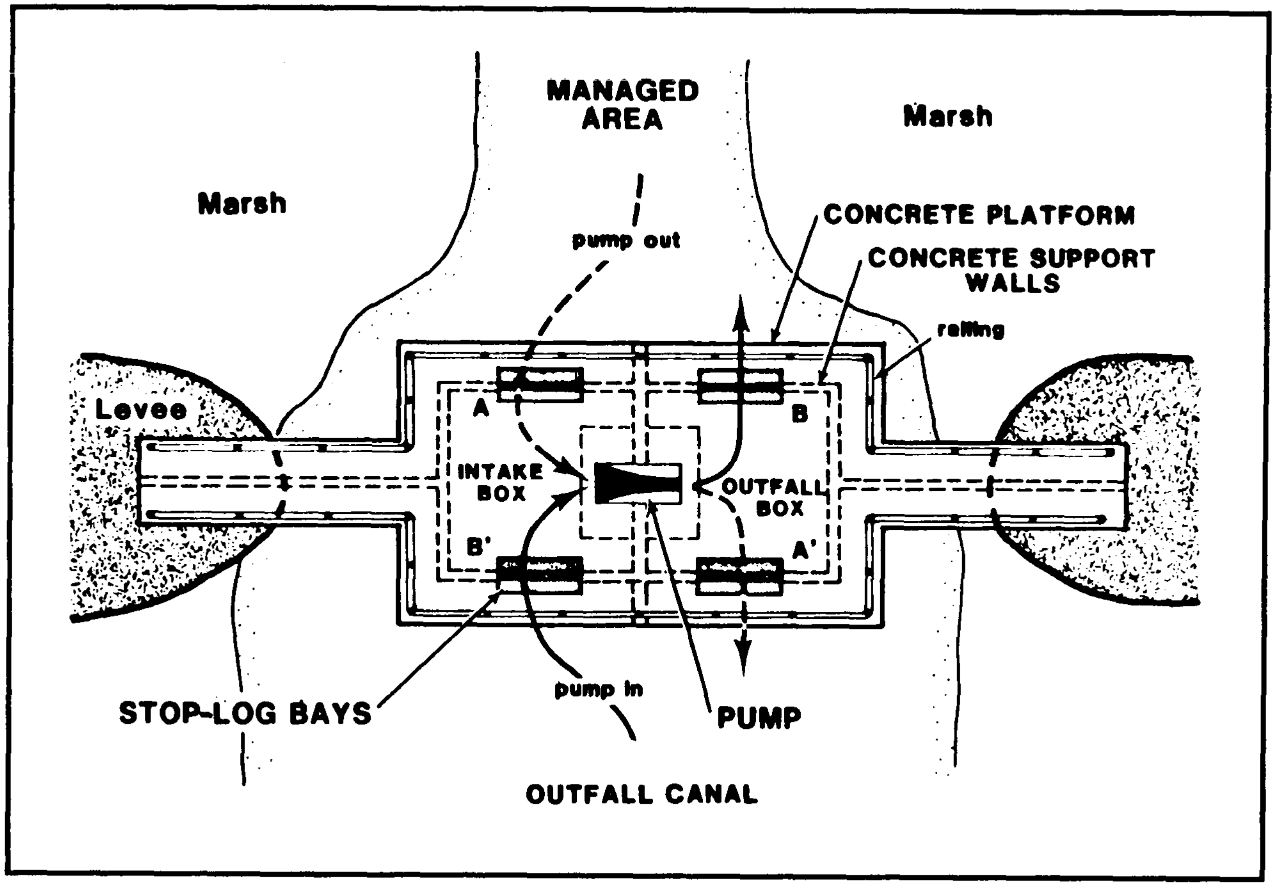


Figure 33. Double divergent pumping unit: top view. To pump out, remove stop logs from A and A'. To pump in, remove stop logs from B and B' (Wicker et al. 1983).

adjustable structures are not total impoundment situations.

The effects of impoundments on the management of saltwater intrusion, vegetation composition, land loss, and wildlife habitat have been widely debated. Day et al. (1986) provided an extensive review of literature concerning the effects of impoundments world-wide on the environment. Rather than repeat all his findings in depth, they have been summarized in table 5 along with other selected references. Only the effects of impoundments on those variables of primary concern to Louisiana landowners and government agencies are presented in table 5. These variables include the effectiveness of impoundments for agricultural purposes, the effects of impoundments on slowing saltwater intrusion and land loss, and the use of impoundments to manage areas for wildlife and fisheries.

Although there are numerous environmental effects, the findings in the literature may be contradictory (e.g., numbers 26 and 50 in table 5), and their meaning is often interpreted differently. For example, turbidity is decreased in impounded marshes (number 25 in table 5). This effect is viewed favorably by people concerned about improving waterfowl habitat, because decreased turbidity usually will encourage the growth of aquatic vegetation, an important waterfowl food source. On the other hand, decreased turbidity may indicate a lack of sedimentation. If so, this effect of management could contribute to diminishing marsh health and wetland loss in the rapidly subsiding coast of Louisiana. Because of the contradictory nature and differing interpretations of some of the findings, determining the beneficial and detrimental effects of marsh impoundments requires that all possible effects be considered, many of which have yet to be clearly understood (i.e., fully investigated).

General Operation

In Louisiana all manipulated impoundment water control structures operate according to three basic schemes, which are termed phases:

1.) Phase I--principally a drawdown or water level lowering phase.
2.) Phase II--a maintenance phase.
3.) Phase III--a flow through phase (Clark 1989; Broussard 1988).

Phase I is usually employed on the average of once every three years, with Phase II being used for the years in between. Phase I may also be used during each of the first three years of management to stimulate revegetation, with Phase II being used after Phase I has been determined successful (Broussard 1988). Phase III is employed intermittently during one of the other two phases. It is still in an experimental stage with not much field observation or actual field use by marsh managers (Clark 1989b; Paille 1989).

In all of these scenarios, there are usually safety provisions built into the management plans which provide for the closing of gates or manipulation of stop logs in situations when the salinity and or target water levels are exceeded.

Table 5. Environmental effects of impoundments as reported in published literature.

Environmental effects
1. Impede water flow and decrease basin discharge and tidal exchange (Day et al. 1986).
2. Leads to dessication, desalination and increased aeration of the soil (Beeftink 1979).
3. Increases the rate of organic matter mineralization (Beeftink 1979).
4. Causes the replacement of the halophytic community by glycophytic communities (Day et al. 1986).
5. May hold water on the marsh surface (Day et al. 1986).
6. Decreases current velocities and interstitial water movements, thereby decreasing circulation (Swenson and Turner 1985).
7. Impedes subsurface drainage of water from marsh areas surrounded by levees (Mendelssohn et al. 1983).
8. Prevents sheet flow of water onto the marsh, decreasing sedimentation (Mendelssohn et al. 1983).
9. Decreased flushing of a wetland leads to decreased primary productivity (Conner et al. 1981; Howes et al. 1981).
10. Changes water depths and water residence times (Day et al. 1986).
11. Heightened water levels in impounded high elevation marshes may lead to loss of the original community or a regression of the original community to one characteristic of the lower marsh, which may be detrimental to wildlife in the area (Beeftink 1979).
12. Increases fresh water input and decreases tidal effects (Day et al. 1986).
13. May cause communities to change from brackish to fresh or fresh to brackish (Day et al. 1986; Mendelssohn et al. 1983).
14. Leads to lower dissolved oxygen concentrations due to flooding of dry soils, increased salinity and decreased circulation (Turner and Patrick 1968; Day et al. 1986).
15. Decreases phosphorus and nitrogen contents in surface waters (Day et al. 1986).

Table 5. Environmental effects of impoundments as reported in published literature (continued).

Environmental effects
16. Decreases the export of ammonium and orthophosphate from marshes (McKellar et al. 1986), both of which are nutrients important to the estuary.
17. Increases water temperature as compared to nearby, natural marshes, if the impoundment is shallow (Rose et al. 1975; Gunnison et al. 1985).
18. May result in colder temperatures during winter, enhancing the possibilities of ice formation and periodic erosion of impoundment shorelines (Day et al. 1986).
19. Water toxicity increases due to poor aeration and low pH (Redman and Patrick 1985).
20. Humic substances such as manganese and hydrogen sulfide, potential plant toxins, increase after submergence (Day et al. 1986). Hydrogen sulfide inhibits nutrient uptake and causes marsh die-back (Mendelssohn et al. 1981). Dilution and water circulation are decreased and higher temperatures accelerate responses of organisms to toxic substances (Miglarese and Sandifer 1982).
21. Decreases the supply of sediment and nutrients moving into a marsh, leading to increased subsidence and land loss (Turner and Neill 1983). Increases sedimentation in nearby marsh areas outside impoundments (Day et al. 1986).
22. Drying of impoundments increases subsidence due to oxidation of organic soils and loss of interstitial soil space. The development of cracks when soil dry increases soil permeability, increasing subsidence (Klein 1982).
23. Increase land loss rates (Day et al. 1986).
24. Increase the incidence of unintentional impoundment through the construction of levees (Day et al. 1986).
25. Turbidity is decreased in managed impoundments (Day et al. 1986).
26. Decreases wetland primary productivity (Fritz 1975; Steever et al. 1976; Conner and Day 1982; Conner et al. 1981; Howes et al. 1981).

Table 5. Environmental effects of impoundments as reported in published literature (continued).

Environmental effects
27. Increases productivity if managed for duck food due to the growth of submerged aquatics (Day et al. 1986).
28. Decreases tree growth if flooding occurs during periods of high metabolism (McAlpine 1961; Broadfood 1967). Increases tree growth if impoundment flooded during dormant season and water levels decrease prior to the growing season (McAlpine 1961; Broadfood 1967).
29. Detrimentally affects swamp forests (Green 1947), decreasing recruitment, tree numbers and tree basal areas (Conner et al. 1981).
30. Decreases production of fishery organisms (Drijver 1982; Herke et al. 1987).
31. Inhibits fishery organisms from leaving an area, thus increasing mortality during periods of poor water quality (Montague et al. 1987).
32. Increases the average weight of an organism as compared to the same species in natural marshes, due to reduced competition, accelerated growth rates and favorable survival rates (Anderson 1976; Manzi et al. 1977b).
33. Decreases the diversity of both flora and fauna within the impoundment (Sklar and Conner 1979; Harrington and Harrington 1981; Gilmore et al. 1982; Davidson and Chabreck 1983).
34. Alters the successional patterns of marshes (Day et al. 1986).
35. Alters zooplankton communities within impoundments (Sklar and Conner 1979; Mahajan et al. 1982; Bakker and DeVries 1984; Day et al. 1986).
36. Alters benthic communities within impoundments (Sklar and Conner 1979) with some important species dissappearing completely (deJong and Roelofs 1984).
37. Allows for the maintenance of water levels ideal for waterfowl feeding (Day et al. 1986).
38. Impoundments may be managed to encourage the growth of vegetation beneficial to waterfowl (Fredrickson and Taylor 1982; Perry 1987; Prevost 1987).

Table 5. Environmental effects of impoundments as reported in published literature (continued).

Environmental effects	
39.	Provides resting and feeding sites for wintering waterfowl by holding water on the marsh (Wilkinson 1987).
40.	Provides favorable conditions for many bird species (deJong and Wiggins 1982; Miglarese and Sandifer 1982) while displacing others (deJong and Wiggins 1982).
41.	Provides greater waterfowl hunting opportunities in many marshes by concentrating ducks in one area.
42.	Increases resident and fresh water fish species (Clark 1989; Pittman and Piehler 1989) decreases marine species (deJong and Roelofs 1984; Harrington and Harrington 1961).
43.	Provides habitat beneficial to deer (Chabreck and Hoffpauir 1962; Miglarese and Sandifer 1982), alligators (Bara 1971; Davidson and Chabreck 1983) and nutria (Davidson and Chabreck 1983).
44.	Decreases salinity over that found in natural control areas (Montague et al. 1987; Montague et al. 1985; Bidlingmayer 1982).
45.	Impoundments may encourage the growth of emergent species of vegetation (Voights 1976; and Rey et al. 1984).
46.	Increased fisheries production (Schooley 1980).
47.	Tidal exchange is less in impoundments compared to natural marshes (Montague et al. 1987).
48.	Impoundments may cause an increase in water levels which may cause vegetation death and stress (Provost 1973; McCoy 1979; Montague et al. 1987).
49.	May decrease land loss rates by stimulating emergent vegetation growth (Wicker et al. 1983; Clark 1989; Soil Conservation Service 1989a; Soil Conservation Service 1989b; Soil Conservation Service 1988).
50.	Increased productivity (Montague et al. 1987; Zedler et al. 1980; Anderson 1976; Mansi et al 1977; McKeller and Marshall 1985; Kelly et al 1985; Day et al. 1986).
51.	Increases estuarine fisheries production over that of fixed-crest weirs (Paille et al. 1989).

Table 5. Environmental effects of impoundments as reported in published literature (continued).

Environmental effects
52. May increase mean weights (biomass) of some fisheries organisms (Rogers and Herke 1987; Clark et al. 1989).
53. May cause a vegetation shift from emergent to submergent vegetation (LaSalle and Knight 1974; Wicker et al. 1983).
54. May increase salinities in certain instances (Montague et al. 1987).
55. May increase submerged vegetation (Day et al. 1986).

Phase I

Phase I is employed for two purposes: 1) the lowering of water levels to below marsh levels in the spring and early summer to stimulate revegetation; 2) the raising of water levels in the fall and winter for winter waterfowl habitat. Operationally, Phase I consists of three parts: 1) drawdown in early spring to summer; 2) water level rise from summer to fall; 3) increased water levels for waterfowl and trapping during late fall and winter. Part one is accomplished by lowering or removing stop logs and opening the outside gates on culverts. In part two, tidal flow is allowed to return estuarine organisms to the marsh by opening the outside gates, closing the inside gates, and raising the stop logs to a level of -6" marsh level. In part three, both gates may be opened and the stop logs either kept at -6" or raised to marsh level for optimal waterfowl winter habitat and, in some cases, for furbearer trapping access. There are usually safety target levels for salinity and water levels built into management plans.

Table 6 presents the three parts of Phase I, or drawdown. Within each part all adjustable control structures are operated similarly.

Phase II

Phase II has three parts (table 7) and roughly parallels Phase I with less emphasis on the drawdown portion. Phase II is termed the maintenance phase, because water levels are maintained at or near fixed-crest weir levels throughout the year. In fact, during Phase II the adjustable structures are operated much the same as fixed-crest weirs except for a small drawdown in the spring and the raising of water levels to marsh level in the winter (Broussard 1988; Spicer et al. 1986). Gates are usually kept open as much as possible throughout the year unless the target levels for salinity and water levels are exceeded.

Phase III

During Phase III, the flow through phase, fresh water, sediment, and nutrients are encouraged to enter the plan area from one side through an intake control structure. In order to accomplish this, water is drawn into the managed area during springtime periods of high tides, low salinity, and high turbidity. The freshwater and nutrients are then allowed to flow over the marsh surface from the intake to the outflow structures on the opposite side. Gated structures, as well as the existence of a higher fresh water head on the intake compared to the outfall side, are needed to make this scenario work. The inflow structures have their logs lowered or removed, their outside gates opened, and their inside gates closed. The outflow structures also have their logs removed or lowered, but their inside gates are opened, and their outside gates are closed to prevent the water from re-entering the marsh. Phase III is primarily employed during Phase I and Phase II, when sufficient head differential and fresh water are present. This is a relatively new and untested operational scheme, but landowners are urged by resource agencies to employ the flow-through water control structure scenario as much as possible to bring freshwater nutrients and sediment into their managed marsh (Department of Natural Resources 1988). Marsh managers need to fine-tune the management plan (table 8), especially when winds, tides, and water levels are favorable. Phase III holds the promise of increasing

Table 6. The three parts of operational Phase I of adjustable water control structures.

Part	Stoplog Position	Inner flap gate	Outer gate	Pump direction	Purpose
1. Drawdown: spring to early summer	1-2′ below marsh level	open	closed	out	water level drawdown for revegetation
2. Water level rise: summer to early fall	6" below marsh level	open	open	could be in	water level rise for waterfowl season
3. Increased water level rise: winter to early spring	marsh level to 6" below	open	open (or closed because of high salinities)	in	water level increase for waterfowl and trapping access

Table 7. The three parts of operational Phase II of adjustable water control structures.

Part	Stoplog position	Inner flap gate	Outer gate	Pump	Purpose
1. Slight draw-down early spring	removed, 1-2' below marsh level	open	closed	out	to lower water to set stage for estuarine organism movement
2. Spring to fall	6" below marsh level	open	open	none	increased water flow for estuarine organism access
3. Late fall to winter	marsh level, or 6" below in some acres	open	open	perhaps (sometimes in, closed if salinities are high, i.e., if target reached)	water level increase for waterfowl wintering habitat and trapping access

fresh water, sediment, and nutrients into managed marshes (Clark 1989; Paille 1989).

Operations in Other States

Control structures are often operated in other states quite differently than in the Louisiana coastal zone, because the overall purposes or goals differ. For instance, in Florida the basic mode of operation is to keep the impoundments flooded almost continually to prevent salt marsh mosquitos from laying their eggs. Eggs are laid on moist but not flooded marsh surfaces and mud flats. However, adverse impacts to estuarine fisheries and vegetation have been caused by these mosquito impoundments. Because of these impacts, the Florida Mosquito Abatement Districts are trying to employ control structures which can be operated to allow tidal flow and regular marsh hydrologic mechanisms, while at the same time controlling mosquitos, their primary goal (Schooley 1980; Provost 1977; Rey et al. 1984).

In South Carolina, old rice field impoundments are being reclaimed and managed for waterfowl impoundments (Baughman and DeVoe 1988). The management scheme employed is similar to the Phase I scenario mentioned above. In the spring to summer, there may be one to many drawdown and reflooding events. In the winter, water levels are allowed to rise to provide for wintering waterfowl habitat. This water level management is accomplished by use of the South Carolina Trunk water control structure. It consists of a double flap-gated culvert with a variable-crest weir or riser on the marsh side (figure 16). The drawdown periods are aimed at increasing the production of widgeon grass (*Ruppia maritima*). To augment the control structure operation, the surface of the marsh may be disturbed, or augmented, from one to many times a year using burning and plowing techniques (Baughman and DeVoe 1988).

Environmental Factors Affecting Feasibility

Environmental factors such as marsh type, soil composition, shoreline erosion, buoyancy, and corrosion can influence the need for management as well as the ability of structures to achieve management objectives.

The need for structural management may vary with marsh type. For example, organic marsh soils are usually more susceptible to the erosive action of hydrologic forces (e.g., tidal scour) than mineral marsh soils. Therefore the need to restrict tidal exchange may be greater in marshes with organic soil types. An exception to this would be the organic soils in non-tidal fresh marshes and swamps because they are not exposed to tidal exchange. In another example, management for saltwater intrusion should not be necessary in saline marshes.

The feasibility of structural management also may vary with marsh type. Increased hydroperiod (i.e., prolonged flooding) caused by canals and spoil banks can reduce plant growth of saline vegetation (Mendelssohn and McKee 1988). However, the ability of structural management to lower water levels in a salt marsh with an artificially enhanced hydroperiod is limited because this marsh type occurs in the lowest part of the tidal range. Very little hydraulic head exists in a submerging salt marsh for gravity drainage to occur. Pumps would likely be required to manage a salt marsh experiencing higher than normal water levels. In addition, the effectiveness of manipulated impoundments in a salt

Table 8. Operational Phase III, or flow through, of adjustable water control structures. Time: usually spring when water levels on outside of plan are high and turbid and contain fresh water.

Structures	Stoplog Position	Inner flap gate	Outer gate	Purpose
Inflow water control structures	removed	closed	open	bring fresh water and nutrients into plan area
Outflow water control structures	removed	open	closed	

marsh is limited by a need to accommodate the access of estuarine organisms into the managed area and by their remote location in the coast. Consequently, active management with adjustable water control structures in this environment can be logistically more difficult than in other environments.

The construction of control structures in very organic soils, those with a high percentage of organic material or subsidence potential, is more difficult to perform than in more mineral soils. Soils with a very high percentage of organic material in coastal Louisiana frequently will have a subsidence potential of 51" or more. This is the potential to shrink and compact upon dewatering. Some coastal soil types have as much as 51" of the top soil profile, which consists of a high percentage of organic material that is more susceptible to compaction and shrinking than are mineral soils. Pole and sheet pilings have to be longer and driven deeper into the refusal layer (clay layer) located beneath the unconsolidated organic or peat layer near the surface. This increases the expense and may make the structures more susceptible to erosion. It therefore becomes more difficult and expensive, but not impossible, to install control structures in these highly organic soils. Heavy structures made of concrete (such as those on Rockefeller Refuge and Sabine Refuge) must be properly reinforced, braced, and set on stronger foundations when installed in wetland areas. These structures may sink or turn over if not properly installed. Concrete structures are especially subject to circular moments of force which tend to make them rotate and fall over (Broussard 1988).

All control structures should be installed away from the shoreline, especially a shoreline undergoing active erosion caused by wave energy or boat waves or both. Many structures, primarily fixed-crest weirs, are now hundreds of feet out in open water. All structures should be set back away from eroding shorelines with sufficient wing wall protection extending into the marsh on both sides (Broussard 1988; Spicer et al. 1986; Coastal Management Division-Soil Conservation Service 1988).

In many areas, culverted control structures, because they are horizontal or parallel to the marsh, are subject to buoyant forces. If not properly tied down or anchored by pole pilings and braces, the culvert may float to the surface. One end of the structure may bend upward while the other end remains in place. This causes problems with water movement through the culverts. Highly organic soils, having more water content than mineral soils, contribute more to buoyancy problems. Concrete placed in the bottom of a structure to counteract buoyant forces may cause the structure to sink (Broussard 1988).

Culverts, because they are made of metal, are also susceptible to corrosive forces. These forces tend to ionize metal atoms in the structures so that the structures literally dissolve into the soil or water. These corrosive forces are greatest in areas where the soil or water conductivity is the greatest, such as in saline marshes. Metal control structures can be protected from these corrosive forces by the addition of sacrificial cathodes, coatings, and by simply making them thicker. These methods of corrosion protection add to the costs of installing structures in saline areas (Broussard 1988).

A final note on corrosion: during construction and installation you should try to avoid or prevent the following (Broussard 1988):

1) the connection of different metals,
2) metal flaws or inclusions,
3) structural strains,

4) new metal connected to old,
5) scratches or abrasions which expose clean metal, and
6) mill scale.

Also, avoid the following conditions at the construction site (Broussard 1988):

1) variations in soil moisture and type,
2) variation in soil aeration,
3) variation in soil acidity or other chemical properties, and
4) parts of metal in two different media (i.e., part of metal in soil and part in air or part in soil and part in concrete).

Construction and Engineering

Introduction

The following discussion of structures is organized by general structure type: 1) variable-crest weirs, 2) gated culverts with and without weirs, and 3) pumps. In all groups the structures are ordered from the relatively simple to the more complex. Emphasis is given to those structures not only in wide use in Louisiana, but also to those structures that hold promise for the future, such as the two-way aluminum flapgate with hoist (gated culvert group). The discussion will include construction comments on each general structure type, prototypical operational schemes, some specific construction methods, and construction or maintenance problems encountered. A separate section on cost will immediately follow this discussion of individual structures.

Variable-Crest Weirs

Variable-crest weirs are similar in nature to fixed-crest structures, but the variable-crest weir has a greater ability to vary the water levels in a marsh or wetland (figure 13). With fixed-crest weirs, the water levels stay at a constant level of usually 6" below marsh. However, meteorological events such as high rainfall may increase water levels behind fixed-crest weirs. Variable-crest weirs differ from fixed-crest weirs in that they have a notch in the center which sometimes extends to the bottom of the water way. Stop logs with dimensions 2"-by- 6" are placed in the notch, held by 2"-by- 4" guides. This is done so that logs can be added or removed and in so doing, the manager can vary the water depths within the marsh or wetland. These water depths are usually varied between 1-2' below to 4" above marsh level. In certain cases, all of the stop logs may be removed so that the water column is open to the bottom, or sill, of the weir.

Variable-crest weirs may be part of other types of gated control structures. They are usually installed on the marsh side of gated culverted structures so that water levels in the marsh can be maintained at certain levels (figures 23 to 32) (Broussard 1988; Wicker et al. 1983; Spicer et al. 1986). The gate prevents water from re-entering the marsh with the high tide. During Phase II, the maintenance phase, variable structures are usually operated to produce similar water levels to fixed-crest weirs for most of the year. Some variable-crest weirs, such as the ones in the Cameron-Creole watershed, have hurricane gates which are able to close or in effect raise the variable crest to 3' above marsh level.

The construction of variable-crest structures is identical to fixed-crest weirs with the exception of the notch and stop logs mentioned above. This notch is the same in width as the fixed-crest weir crest. One rule of thumb is that the weir crest should be at least 30% of the width of the waterway with one foot of variable-crest weir being necessary for every 70 acres of marsh managed (Spicer et al. 1986; Coastal Management Division-Soil Conservation Service 1988). Variable-crest weirs are constructed of wood, metal, or concrete sheet pilings usually with interlocking grooves. Metal is used when long pilings are needed. Heavy equipment is needed to install concrete structures unless the concrete is to be poured in place. The most popular material used in weir construction is wood. The sheet pilings may be single tongue and groove, double lapped, or of a three wall (or layer) construction. The latter three wall method--which is also the most successful method--is called the Wakefield weir type. The wood is either creosote pressure treated to a 12 lb retention or wolmanized with chromated copper arsenate to 0.6 lb per cubic foot (pcf). The length of pilings are usually at least three times the channel depth. The pilings should be driven to the clay or refusal layer, with the center sheet pilings driven so that the weir sill is near the depth of the water body or about 2+' below marsh level.

Pole pilings are a minimum of 12" in diameter, creosoted and placed no more than 6' apart to brace the sheet pilings. Pole pilings are either placed on the downstream (or non-marsh) side of the weir or on both sides. The downstream side is the side that receives the most force during the falling tide and therefore must be supported more than the upstream or marsh side. Batter pole pilings or diagonal bracings are used on channels greater than 30' wide and are placed on the downstream side to brace every other pole piling or at least one for every 12' of weir. Batter pilings can be placed on both sides of the weir just like pole pilings. The stop logs are held in place in the notch by either 2"-by- 4" wood or by metal angle irons. With proper installation and the use of wood that has been properly treated, variable-crest weirs, like fixed-crest weirs, can last 30 or more years in the Louisiana coastal marshes (Broussard 1988).

<u>Wooden box weirs</u>. Wooden box weirs (figure 14) have been used for many years in the marsh, but they are more expensive and more difficult to install than culverted or Wakefield weirs, and they are no more efficient or long lasting (Broussard).

<u>Cameron-Creole concrete variable-crest weirs with hurricane gates</u>. These large structures are so expensive that, only the government can afford to install them (figures 15 and 15a). The U.S. Department of Agriculture Soil Conservation Service was responsible for installing the five Cameron-Creole structures at a cost of nearly $2 million (1990 dollars) (Melancon 1990).

<u>Gated Culverts</u>

These structures can be separated into two categories: 1) gated culverts without weirs or risers, and 2) gated culverts with some type of variable-crest weir or fixed or adjustable riser. These structures are usually made of aluminum and less often of corrugated metal, iron, polyvinyl chloride (pvc), and pressure-treated wood. Anti-seep collars and toe-plates may be added to culverted structures to prevent lateral seepage around the structure (Broussard 1988).

Gated culverts are generally 30' long and 24-48" or greater in diameter. On some of the culvert designs are attached flapgates, screw gates, stop logs and or fixed or adjustable risers. Gated culverts with adjustable risers are the most versatile in manipulating water levels.

Sufficient culvert capacity is that culvert diameter needed to maintain proper hydrologic flow in a managed marsh. One rule of thumb for culverts offered by this author is that 1 foot of culvert diameter may be sufficient for 250 acres of marsh. The rule of thumb for a fixed or variable-crest weir is one foot of weir crest for every 70 acres of marsh managed within the drainage watershed. Another formula (based on the Cypress Creek formula) is: one foot of weir crest = 13M 5/6; where M is equal to the drainage area in square miles. The Cypress Creek Drainage Formula is expressed as follows:

$Q = CM^{5/6}$ (where M=drainage area in square miles),
C = a co-efficient based primarily on the level of protection needed, and
Q = rate of flow or capacity in cubic feet per second).

The co-efficient "C" normally used for marshlands is 10 and for coastal cultivated crops is 45. The procedures for determining values for "C" can be found in the Soil Conservation Service National Engineering Handbook, Section 4, Hydrology. This general formula is used to compute a removal rate (cfs) and does not represent peak flow requirements of a drainage area (Broussard 1988; Melancon 1987).

For example, let us assume that we wish to calculate the runoff for a 2,000-acre (3.1 mi^2) marsh area. The formula is $Q = CM^{5/6}$; this becomes Q = (10)(3.1 mi^2) (0.83); therefore, Q = 25.7 ft^3 per second. This means that a structure which provides this capacity should be sufficient to drain this 2,000-acre area. Since one 48" diameter culvert has an area of 12.5 ft^2, two 48" culverts may be needed for this particular drainage area of 2,000 acres. Thus a drainage rule of thumb based on the Cypress Creek Formula for culverts translates to one inch of culvert diameter for every 20 acres of marsh or wetland within the drainage watershed for that culvert. Therefore, one foot of culvert may be sufficient to provide drainage for 250 acres of marsh. This is calculated from the above which states that two 48" diameter culverts are sufficient to drain 2,000 acres of marsh.

If one calculates the area of a 4-ft-diameter culvert and compares this to the cross section of a fixed-crest weir with water levels at marsh level, a 4-ft-diameter culvert would have the same cross-sectional area for water flow as a 25-ft fixed-crest weir. If we apply the rule of thumb of 70 acres per each foot of weir, the amount served by the 25-ft weir or the 4-ft-diameter culvert becomes 1,750 acres. However, in practice, the culverted control structures are combined with variable-crest weirs. A 4-ft-diameter culvert is frequently fitted with a 15-ft-wide variable-crest weir on the marsh side. Since a 15-ft weir using the weir rule of thumb may drain 1,050 acres, a more reasonable figure to use for 4-ft-diameter culverts with variable-crest weirs would be this figure. The weirs fitted for 3-ft-diameter culverts are usually 10 ft wide while those for 2-ft-diameter culverts are usually 5 ft wide. Thus the drainage area affected by 3- and 2-ft-diameter culverts in these cases would be 700 and 350 acres, respectively.

Therefore, in two methods of calculating the drainage area for a 4-ft-diameter culvert, the figure 1,000 acres is derived. Similar values were derived from a calculation of the drainage area (or M) by computing Q/ C (5/6). If you assume a water velocity of 1 ft/sec, M=12.56 ft^3/10 (.83); M=1.51 $miles^2$ (968 acres).

Culverts cannot be directly compared to weirs because they are lower in the water column and thus are better able to allow water movement in or out of the plan area when water levels fall below fixed-crest weir levels of 6" below marsh. Culverts are thus better able to take advantage of head differences between inside and outside water levels and thus they are more efficient than weirs in general.

These calculations were made by the author and represent interpretations of the Cypress Creek Formula for culverts and from observations of the marsh area served by existing culverts in coastal Louisiana. It must also be noted that these calculations are only based on the culvert sizes needed to drain a particular area of marsh within two weeks or so. These sizes may have to be greater to also accommodate fisheries, nutrients, and sediment movement, into or out of the management area. Caution must be used with these calculations, and it should be kept in mind that they are rules of thumb only and not exact formulas for use in all areas of the marsh in coastal Louisiana. Landowners contemplating structure installation should contact a consulting engineer or the U.S. Department of Agriculture, Soil Conservation Service, for assistance in calculating culvert capacities needed for specific areas.

Gated Culverts Without Weirs or Adjustable Risers

Single flap-gated culvert. These aluminum culverted structures have openings from 24-48" with a flapgate or screwgate on one end. Drainage Districts especially in western Louisiana near the Mermentau River (i.e., Cameron Parish) use these structures for drainage purposes on areas considered fastlands, or totally leveed lands. If these one-way flap-gated culverts are set at a shallow depth (i.e., 11-12" below marsh level), they may act to lower water levels in the marsh without drastically causing marsh drainage. In effect, such an installation acts as a culverted fixed-crest weir (figure 16). A variation of the single flap-gated culvert exists where the flap is on the marsh side; these structures allow fresh water and nutrients to enter an area, but they do not allow the water to leave.

Double flap-gated culvert. This versatile structure with flapgates on each end has the ability to flood, drain, and maintain water levels for varying lengths of time (figure 16). A floodgate is located on the outside and a drain gate, or drawdown gate, is positioned on the inside (or marsh side) of the culvert. The double flap-gated culvert is completely adjustable; the manager can control water levels up to the limitations of culvert capacity and elevation. The manager lifts or opens the outside gate (floodgate) to flood the marsh with outside water. Both gates are opened for normal tidal flow. Both gates are closed to stop all water movement (Broussard 1988). Often the limiting factor is culvert elevation. If a double flap-gated culvert is set with its invert at one foot below marsh level, then water will only be able to be lowered to this level, that is, if conditions such as head differential are optimal. All three operational phases (drawdown, maintenance, and freshwater and sediment diversion or flow through) are possible with these types of structures; however, they do not operate as automatically as flap-gated culverts with variable-crest weirs attached on the marsh side.

Single screw gate (or other) culvert. This structure is similar to single flap-gated culvert structures but the difference is in the positioning of the adjustable screw gate (figure 17). Whether this screw gate is on one end or the middle, it allows water to move either into or out of the plan area depending on the hydrologic head differential caused by winds, tides, or other differences in water levels. With the gates down, water movement is completely stopped (Broussard 1988).

Two-way aluminum flapgate with hoist. This structure, also called the compressed culvert, consists of a wooden sheet-pile dam constructed similar to a fixed-crest Wakefield weir with the crest set above marsh level (figure 18). In the center of this dam is a round hole with flapgates fixed to both sides. It operates similarly to the double flap-gated culvert discussed above and differs only in the mechanism of lifting the flaps. This structure is more expensive than a normal 30' long aluminum flap-gated culvert and shares that structure's problems with buoyancy and corrosion (Broussard 1988). Like fixed- and variable-crest weirs, it is probably better suited for installation in existing channels and canals. It may allow more estuarine fisheries organisms access to the marsh than do fixed-crest structures.

Culvert with L-shaped riser. These types of structures with fixed risers are seldom used in wetland management areas in coastal Louisiana (figure 19).

Rockefeller Refuge concrete radial arm lift gate. Only the government can afford these types of structures with large concrete gates (figure 20) (Wicker et al. 1983). Rockefeller State Wildlife Refuge has several of these structures across Big and Little Constance Bayous.

Sabine Refuge cement (concrete taintergate water control structure. This expensive structure (figures 21a and 21b) and the 2-way aluminum flapgate with hoist (see figure 18) are both relatively new structures designed by the U.S. Department of Agriculture Soil Conservation Service. Sabine Wildlife Refuge has two large Taintergate water control structures, 90' and 110' long respectively, and the cost is approximately $1850 per foot, or approximately $185,000 for each structure (Walther 1990).

Gated Culverts with Variable-Crest Weirs/Adjustable Risers

This basic design involves a wooden box or metal (mostly aluminum) culvert or conduit. These structures may have a gate on the non-marsh and a variable-crest weir or variable riser and a gate on the marsh side (figures 23 to 32) (Broussard 1988). With this type of arrangement, these structures are able to manipulate water levels within a management area. Managed water levels may range from 1-2' feet below to approximately 0.5' above marsh level depending on the location along the Louisiana coast. The outside gates are closed and the risers or stop logs are lowered during the spring for water level lowering to occur. The outside gates are opened for the rest of the year unless the salinity or water level target levels are exceeded. During the summer and early fall, the risers and stoplogs are slowly raised to that of 0.5' below marsh level or at the level set for fixed-crest weirs. In the fall and winter, the outside gates are left open and the stop logs are set at marsh level or slightly lower for waterfowl wintering habitat.

Two-way semi-automatic gate structure. This is a wooden box weir structure approximately 6' wide by 30' long and 4' high (figure 22). The flapgate bay opening is generally 6' high by 6' wide with the bottom, or sill, set at approximately 4' below marsh level. Flapgates are located on both sides of this box culvert, but the inside flap consists of a partial gate. It is open at the top and allows water to flow over it after it reaches a certain level. This level is usually set at fixed-crest weir level or 6" below marsh (Broussard 1988). Thus when the inner flap is down or closed and the outer flap is open, the structure operates as sort of a fixed-crest weir. The exception is that water coming in from outside the plan is able to come in continuously because of the automatic nature of the inner flapgate. The structure can be operated as an open culvert when the flaps are open or in the up position. This structure, primarily an embankment control structure, is not in common use in the Louisiana coastal area (figure 22). While not as versatile as gated culverted variable-crest weirs, it is capable of lowering water levels for revegetation purposes. However, the structure can hold water levels in the marsh at only two levels, either 6" below marsh or the sill (bottom) level of the structure itself. This structure may also be more expensive to install compared to the aluminum culverted control structures. It is found in Vermilion Parish near Pecan Island on Vermilion Corporation's property.

Single flap-gated culvert with variable-crest weir. These structures are characterized by having an outside flapgate and a variable-crest weir on the inside or marsh side (figure 23). Other structures that operate in almost the same manner as this water control structure, but which are constructed with slight variations, include: 1) culvert with screwgate and variable-crest weir (figure 24); 2) flap-gated culvert with a variable-crest weir and vertical slot (figure 25); 3) wooden box flap-gated culvert with variable-crest weir on marsh side (figure 26); 4) variable-crest weir with 2-way aluminum flapgate with hoist (figure 27); 5) double flap-gated culvert with variable-crest weir (figure 28); 6) culvert with a floodgate and riser inlet (figure 30); and 7) the Amoco West Black Lake flap-gated culvert with variable-crest weir with 18" ingress gates (figure 32).

The structure operation is similar to the 2-way semi-automatic gated structure, but instead of a partial flap on the inside or marsh side, it has a variable-crest weir. The water control structure is operating with the outside flap up or open during all times except drawdowns. The stop logs on the inside variable-crest weir are set at 6" below marsh level. During drawdowns, the stop logs are removed and the outside flap lowered to reduce water levels and prevent water from coming in from outside and flooding the area.

The single flap-gated culvert with variable-crest weir and the above structures all have the ability to fully manipulate water levels within a managed marsh from 1-2' below marsh level to basically marsh level or slightly above. Why go to the extra expense of installing a double flap-gated water control structure when a single flapgate may do the same job? The double flap-gated structure allows water to be brought into the management area and for interior levels to be maintained, such as in the winter, during both phases when water levels are kept at marsh level but outside gates are open and inside gates are flapping, which allows water to move into the plan at this time. Excess water simply flows over the variable-crest weir. With the single flap-gated water control structure, water only flows into the plan when the level exceeds marsh level, because the outside gate is open and logs are set at marsh level. Therefore the basic difference between these water control structures is in estuarine organism ingress, and the movement of water, sediments, and nutrients from outside the plan to inside. This difference exists because the interior flap of the double flapgated structure is operating (down but able to swing open with water pressure), while the single flapgated culvert must operate with consideration for the weir. These water control structures may be superior to those described above because of the greater adjustments which can be made and because of the ingress feature mentioned above. But the increased cost of these more complicated water control structures may preclude their use in some areas.

Flap-gated culvert with variable-crest weir with vertical slot. A relatively new control structure has been introduced recently for the Hog Bayou Management Plan in Cameron Parish. Because of the plan's proximity to the Mermentau River and the Gulf of Mexico, it was recommended that additional provisions be made in the structure design to include more estuarine organism access to the brackish marshes in the plan area. This led to the design on the structure diagrammed in figure 25. The structure is a regular flap-gated culvert with a variable-crest weir on the marsh side with provisions for a 2.5' vertical slot in the center of an 8' wide weir. Stop logs, each 2.75' wide, are fitted on each side of the vertical slot. This control structure has not been installed or even permitted at this time, but it shows promise of providing increased estuarine organism movement compared to other adjustable structures in use today. It is hoped that the vertical slot will allow some fisheries access to the marsh during times of the year when the variable-crest weir is normally in the raised position, such as during the waterfowl wintering season.

Wooden box flap-gated culvert with variable-crest weir. The wooden box flap-gated culvert with variable-crest weir (figure 26) operates exactly like the above single-gated culvert with a variable-crest weir. It differs only in that it is made of wood and is box, or rectangular, shaped. It has minimum dimensions of 4'-by- 4'-by- 30'(Broussard 1988). The Fina Laterre Falgout Canal management area's southeastern structure consists of two 10'-by-6'-by- 30' box weirs set side by side to share a common wall and to increase strength. This side by side construction of two or more bays gives more strength to the structure (Clark 1989).

This wooden water control structure shares some of the disadvantages of other wooden water control structures. The installation and materials are more expensive than with metal culverted structures. Also, Fina had to replace wooden flaps with aluminum ones because of deterioration and difficulty in lifting them.

Variable-crest weir with 2-way aluminum flapgates with hoist. Broussard (1988) calls this structure a "variable-crest gated structure." This structure is similar to the previously described two-way aluminum flapgate with hoist (see figure 18) with the exception that it also contains one or more variable-crest weirs imbedded in the bulkhead in addition to the culvert opening (figure 27). It is basically a variable-crest weir bulkhead type of structure with one or more circular holes with double flapgates in the bulkhead. It has an aluminum hoist and cable mechanism to open the culvert flapgates. The variable-crest weir stoplogs are arranged similar to those of a variable-crest weir.

Instead of cutting a round hole in the bulkhead, an aluminum plate with a hole is installed in a notched section of the bulkhead similar to the notch in a variable-crest weir where stop logs are placed (figure 27). This structure provides an alternative to the double flap-gated culverted variable-crest weir described above and is operated the same way. It is easier to install, especially in large channels, requires less maintenance, has no buoyancy problems and fewer corrosion problems than does the culverted embankment structure. However, it is more expensive and there is less room (tolerance) for construction errors compared to the regular flap-gated culverted variable-crest structures and weirs (Broussard 1988).

Double flap-gated culvert with variable-crest weir: South Carolina trunks. The South Carolina trunk water control structure is basically a double flap-gated culvert with a variable-crest weir (figure 28) set on marsh side (interior) between the two flapgates (figure 29). The main difference between the trunks and the double flap-gated culvert with variable-crest weir is that the trunks have a different flapgate attachment arrangement. The flapgates in addition to being able to swing outward, are able to be raised and lowered along a vertical axis along horizontal pegs. These pegs are fastened horizontally to vertical posts set above the culvert (figure 29). In this way, the flaps are able to be pulled up to cover partially the culvert opening. The flaps and posts are usually wooden but may be made of aluminum. To our knowledge, the South Carolina trunks have not been used in Louisiana.

Culvert (conduit) with floodgate and fixed riser. This culverted water control structure has a flapgate (floodgate) on the outside and a fixed riser inlet and screw gate on the marsh side (figure 30). The structure is not as versatile as gated culvert with variable-crest weir because of fixed riser.

Rockefeller Refuge concrete variable-crest reversible flapgate control structure. Rockefeller State Wildlife Refuge has a large four bay concrete variable-crest reversible flap-gated control structure located at the southwestern corner of Unit 4 (figure 31). It can be thought of as a double flap-gated culvert with a variable-crest weir without the culvert. This structure is able to manipulate water levels completely as long as gravity flow and head differential allow water movement.

Amoco West Black Lake flap-gated culvert with variable-crest weir with ingress gate. The Amoco West Black Lake type of culverted variable-crest weir is very similar to the flap-gated culvert with variable-crest weir with one exception (figure 32). There is an 18" wide opening (usually a screw gate) in the variable-crest weir on the marsh side for the ingress, or inward movement, of estuarine organisms during times such as winter or fall when the stop logs are set at marsh level or above in order to increase water levels in the marsh for waterfowl and furbearers.

Pumps

Pumping systems in the Louisiana coastal zone are only permitted in areas of total impoundment (fastlands) or to assist a gravity drainage system primarily dominated by adjustable types of water control structures (Louisiana Coastal Restoration Program 1980; Department of Natural Resources 1988). The low tides and relatively flat terrain of the coastal zone make it difficult without wind assistance to lower water levels below mean sea level. This level is in many cases the same as marsh level.

Pumps are used mostly for crawfish and catfish pond aquacultural operations in the Louisiana coastal zone (Clark et al. 1988), but they can lower water levels in the spring for revegetation in management of total impoundments for waterfowl habitat. Pumps are not a significant component of marsh management plans in coastal Louisiana (Spicer et al. 1986; Clark et al. 1988; Department of Natural Resources 1988). The disadvantages are that the fuel consumption may make pumping out large areas costly. However, they can be used to assist the manager in accomplishing all phases of water level control within his marsh

(Wicker et al. 1983).

There are many engineering formulas and tables concerning pump and pipe sizes, costs, and efficiencies. The Louisiana State University Cooperative Extension Service (Baker and Bankston 1987) provides many of these formulas, tables, and definitions in their Agent Training Notebook. In addition, pump manufacturers such as Gorman-Rupp provide various types of pump information to their customers. It is beyond the scope of this report to go into a detailed discussion of all of the various engineering terms and relationships concerning pumps. Wetland managers who are interested in using a pump should contact the U.S. Department of Agriculture, Soil Conservation Service, Louisiana State University Cooperative Extension Service, or a consultant.

Pumping systems are usually of two basic types: a simple one-way pump and a double divergent pump. Both pump systems are able to pump water out of or into the management area.

One-way pumps. These pumps pump in one direction only, usually from the management plan area outward. They may, however, be reversed to also pump inward. They may be permanently fixed in the field or they may be portable. They can be powered by a tractor or other vehicle or by their own motor fueled by electricity, natural gas, gasoline, liquified petroleum gas, or diesel.

Double divergent pumping unit. The Louisiana Department of Wildlife and Fisheries at Rockefeller Refuge employs a double divergent pumping unit on a few of its total freshwater impoundments (Wicker et al. 1983). This double divergent pump consists of two separate concrete boxes (figure 33) (Wicker et al. 1983) joined to the levee system. The intake pipe of a diesel pump is placed in one box and the discharge in the other box. Each box has two stop logs bays, one on the marsh side (interior) and the other open to the exterior. To pump into the management unit, the exterior stop log bays on the intake side are removed (or the exterior opening opened) and the interior stop log bays on the discharge side are lowered. The exterior discharge and interior intake logs remain in place. To pump out of the management area, this process is reversed with the interior intake side logs removed and the exterior discharge logs removed with the others closed.

Archimedes' screw type pump. These are devices for raising water by means of a broad-threaded screw or a spirally bent tube which turns in a cylinder (Parker 1984). These types of pumps, or water lifts, have been recommended by National Marine Fisheries Service in the past for use as pumps in fastland areas, because fisheries organisms are more likely to survive the pumping process with this type of pump compared to other mechanical pumps mentioned above.

Water Control Structure Cost Comparisons

Tables 9, 10, 11 and figures 34 and 35 show the relative costs for various water control structures with costs of installation included. An attempt was made to convert the costs of water control structures to costs per foot of weir or diameter-foot of culvert to facilitate comparison (figures 34 and 35). For culverts with weirs and for weirs the total width of structures including wing walls was determined by multiplying three times the weir crest (three times the box width for box weirs). For actual costs for specific structures in today's price index you are asked to check with Soil Conservation Service or consulting engineers.

Weir and Culverted Control Structure Costs

The cost of weir and culvert control structures ranges from a relatively inexpensive $105 per foot for a shell covered earthen plug to $1850 per foot for the Sabine concrete taintergate water control structures. The cost range for normal weirs is from $285 per foot for Wakefield fixed-crest weirs to $753 per foot for wooden box weirs, because they are more complicated and more difficult to install. Vertical slotted fixed-crest weirs cost slightly more than the common Wakefield weir. The large concrete water control structures, such as those on Sabine and Rockefeller Refuges, are mentioned here for comparison purposes only. Only federal and state governments may have sufficient resources to expend in some cases almost $800,000 (Sabine Grand Bayou Structure) on one water control structure (Melancon 1990). The implementation of an entire marsh management plan does not usually cost that much, including levee work and maintenance. Therefore the average marsh management plan with an average sized structure (or opening) of 20-30' would probably cost from $285-$753 per foot for a wooden weir structure, with a total cost from $5700-$15,060 for a 20' structure (Broussard 1986).

The costs for culverted water control structures follow the general trends mentioned above for weirs in that the more complicated structures with optional flapgates and variable-crest weirs, built with more expensive materials (i.e. concrete vs. wood), make the structure more expensive overall. Culverted water control structures range from $1044 per foot of culvert diameter (single flap-gated culvert) to $16,958 per foot culvert diameter (Sabine Taintergate) (table 9). Discounting the large concrete structures on the refuges, the costs of culverted water control structures range from $1044 per foot culvert diameter (single flap- gated culvert) to $5100 per foot culvert diameter (variable-crest gated aluminum structure; see figure 35). This translates to from $4176-$20,400 for a 48" diameter culvert, depending on the type of structure. Therefore, a marsh manager would probably have to pay from $4000-$20,000 each to purchase and install various types of weirs and culverted water control structures. Multiplying these figures by a 50% increase which may have occurred in some areas due to the higher costs involved in installation, the range may be from $6000-$30,000 per structure.

The most common structures in use today are the $285 per linear foot and $295 per linear foot variable-crest weirs, simple culverted water control structures ($1044-$1249 per diameter foot), and the flap-gated culvert with variable-crest weir structure ($1906 per diameter foot). The total costs for 20' weirs and 3' diameter culverts range from $5700 (20' variable-crest weir; see figure 13) to $5178 (flap-gated culvert variable-crest weir; see figure 23). Therefore, for a cost of from $5000-$10,000, a marsh or wildlife manager may install an adjustable structure such as a double flap-gated culvert to flap-gated culvert with variable-crest weir, which would enable him to totally manipulate water levels in his marsh, not including the cost of levee construction. A 20' weir (10' crest) would be able to control 700 acres of marsh at a cost per management acre of $8.14. For a 36" culvert controlling 1100 acres, the cost per management acre would be $5.72 ($5718 per 1000 acres). The cost for a 36" double flap-gated culvert would be $3.73 per acre ($3732 per 1000 acres) (Broussard 1986).

Pump Costs

Pumps, because of their fuel expense, maintenance, the need for constant supervision, and because of the large size of most marsh management plans, are not commonly used in the Louisiana coastal zone for wetland management purposes. However, table 13 is included here for fuel cost comparisons.

Diesel fuel at $.91/gallon for a total cost of $6.50/hr may be the most efficient fuel for pumps at this time (January 1990). Electricity is also lower in cost than either natural gas, LPG, or gasoline (Lam 1990). You can calculate and compare these costs easily by using table 13 above and by substituting your specific brake horsepower and fuel cost. The cost formula becomes:

cost/hr = (bhp) (fuel constant or fuel use in gal/hp-hr) (fuel cost/gallon).

Example: a bhp pump with a capacity of 200 hp diesel at $1.10 gal would cost $15.73. (That is, cost/hr = (200 hp)(0.0715 gal/hp-hr) ($1.10 gal diesel cost) = $15.73/hr. (Baker and Bankston 1987; Lam 1990).

The Louisiana State University Cooperative Extension Service "Agent Training Notebook" (Baker and Bankston, 1987) contains information concerning primarily crawfish pond pumping costs and efficiencies. They discuss the fundamentals of piping and pumping and have even prepared a computer program for easy calculation of these needs for specific pond sizes and locations (Baker and Bankston 1987).

Table 9. Cost comparison for fixed water control structures used in marsh management[1] (Broussard 1986; Coastal Management Division-Soil Conservation Service 1988; Soil Conservation Service 1988).

Structure	Total cost (based on various average lengths)
fixed-crest weir (wood)[2]	
with single wing wall;	$14,250 (50')
with double wing wall	$17,250 (50')
plug with sheet piling core	$31,000 (100')
shell armored plug	$10,500 (100')
levee construction (3'high)	
without support fabric;	$190 (100')
with support fabric	$1325 (100')

[1]Costs include materials, installation, and earth work; are based on a 1986 statewide average and could vary greatly.
[2]All wood is creosoted or CCA treated lumber.

Table 10. Cost comparison of less complicated variable-crest structures used in marsh management[1] (Broussard 1986; Coastal Management Division-Soil Conservation Service 1988; Soil Conservation Service 1988).

Structure	Weir box opening	Total cost (based on various weir lengths[2])
Variable-crest weir with single wall	none	$5,310 (18')
Wooden box weir[3]	6'	$16,000 (18')
	8'	$18,000 (24')
	10'	$20,250 (30')
Two-way semi-automatic gate structure	6'	$13,000 (18')
	8'	$15,000 (24')
	10'	$17,250 (30')
Wooden box flap-gated culvert with variable-crest weir	6'	$13,000 (18')
	8'	$15,000 (24')
	10'	$17,250 (30')

[1]Costs include materials, installation, and earth work; are based on a 1986 statewide average and could vary greatly.
[2]When a weir includes a box opening, the average length = three times weir box opening.
[3]All wood is creosoted or CCA treated lumber.

Table 11. Cost comparison of culverted structures, with and without weirs, used in marsh management[1] (Broussard 1986; Coastal Management Division-Soil Conservation Service 1988; Soil Conservation Service 1988).

Structure	Culvert opening[2]	Cost of culvert	Cost of sheet piling[3]	Total Cost
Single flap-gated culvert	24"	$1,650	none	$1,650
	36"	$2,850	none	$2,850
	48"	$6,100	none	$6,100
Double flap-gated culvert	24"	$1,850	none	$1,850
	36"	$3,050	none	$3,050
	48"	$6,300	none	$6,300
Two-way aluminum flapgate with hoist	24"(with 4' weir)	$4,000[4]	$9,000	$13,000
	36"(with 6' weir)	$5,500[4]	$9,000	$14,500
	48"(with 8' weir)	$8,500[4]	$9,000	$17,500
Single flap-gate with variable-crest weir	24"(with 4' weir)	$3,850[4]	none	$3,850
	36"(with 6' weir)	$4,850[4]	none	$4,850
	48"(with 8' weir)	$8,450[4]	none	$8,450

Table 11. Cost comparison of culverted structures, with and without weirs, used in marsh management[1] (Broussard 1986; Coastal Management Division-Soil Conservation Service 1988; Soil Conservation Service 1988) (continued).

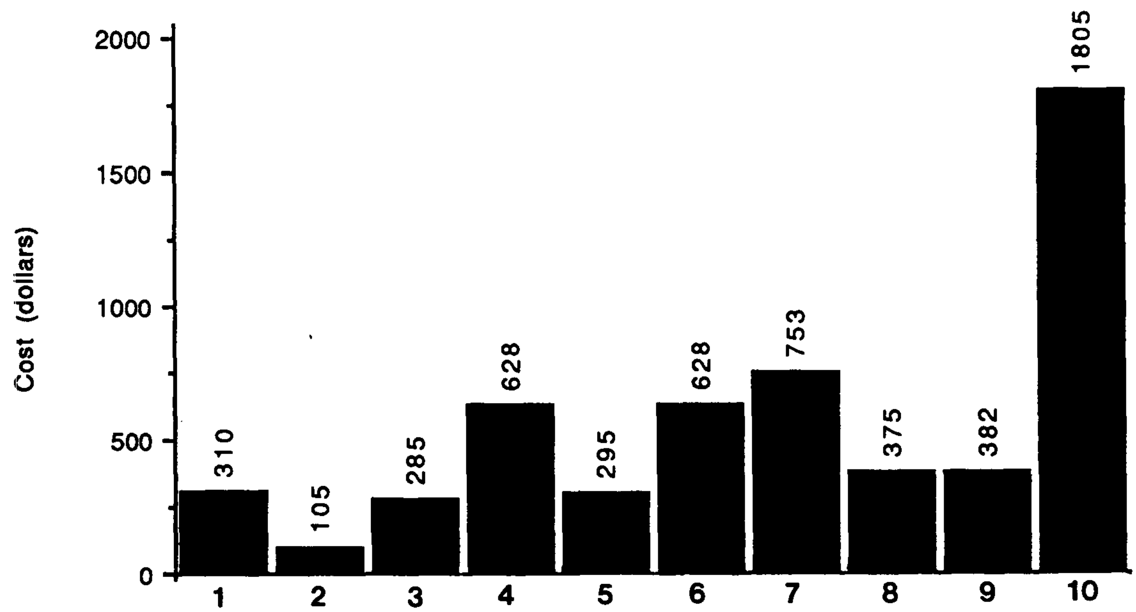
Structure	Culvert opening[2]	Cost of culvert	Cost of sheet piling[3]	Total Cost
Double flap-gated culvert with variable-crest weir	24" (with 4' weir)	$1,850[4]	$6,200[5]	$8,050
	36" (with 6' weir)	$3,050[4]	$6,200	$9,250
	48" (with 8' weir)	$6,300[4]	$6,200	$12,250
Culvert with flood-gate and fixed riser	24"	$3,550	none	$3,550
	36"	$5,700	none	$5,700
	48"	$10,950	none	$10,950
Variable-crest weir with two-way aluminum flapgate with hoist	24" (with 4' weir)	$4,000[4]	$9,300	$13,300
	26" (with 6' weir)	$5,500[4]	$9,300	$14,800
	48" (with 8' weir)	$8,500[4]	$9,300	$17,800

[1]Costs include materials, installation, and earth work; are based on a 1986 statewide average and could vary greatly.
[2]Culverts are 30' long, polymer coated steel or alcad protected aluminum.
[3]Cost of sheet piling based on 30' length (except for double flap-gated culvert with variable-crest weir).
[4]When culverts include weirs, the weirs compose 25-50% of culvert costs.
[5]This structure differs in that the culvert runs perpendicular to the weir and sheet piling; therefore, the cost figures for sheet piling are based on a 20' length, which would be a maximum for this structure.

Table 12. Cost comparison of large water control structures used in marsh management[1] (Melancon 1990; Hardeman 1990; Richard 1990; Walther 1990).

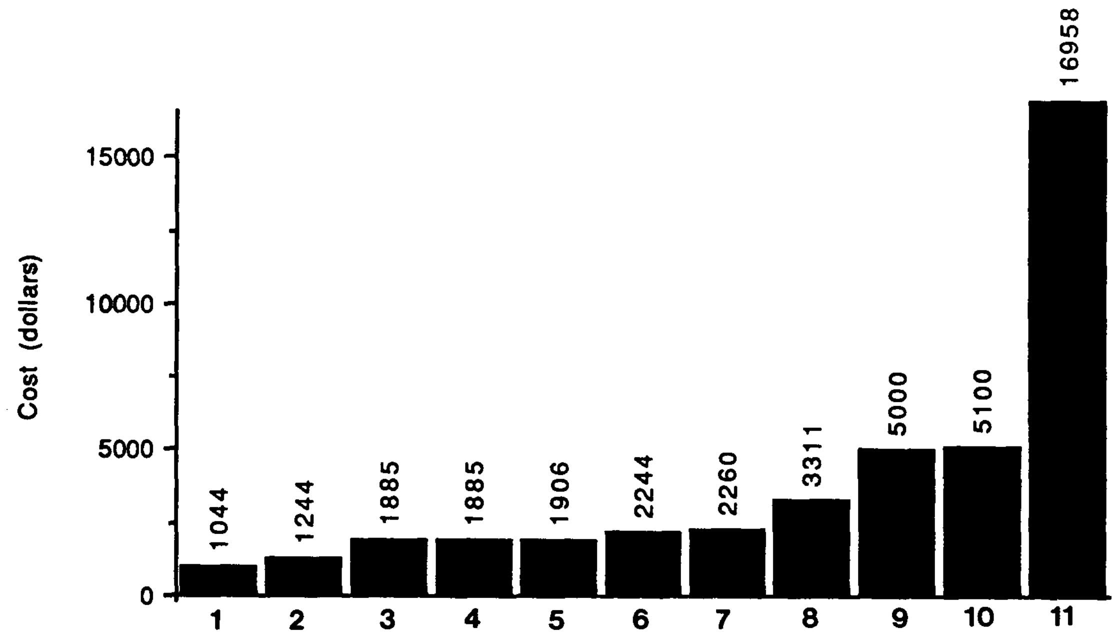
Structure	Culvert opening[2]	Weir length	Total cost
Amoco West Black Lake flap-gated culvert with variable-crest weir with ingress gate	48"	15'	$15,000-$20,000
Sabine Refuge concrete taintergates	8'-by-8'	90'	$166,500
	12'-by-8'	110'	$203,500
Rockefeller Refuge concrete stainless steel radial arm lift gates	8'-by-8'(3)	100'	$400,000

[1]Costs include materials, installation, and earth work, and are for specific one-of-a kind structures; costs of erecting similar structures at different sites may be greater.
[2]Culverts are 30' long, polymer coated steel or alcad protected aluminum.
[3]Structure is essentially a multiple single flap-gated culvert with variable-crest weir, in use at Rockefeller Refuge.



1. Plug with sheet piling core.
2. Plug with shell layer.
3. Fixed-crest weir.
4. Two-way semi-automatic gated structure.
5. Variable-crest weir.
6. Wooden box flap-gated culvert with variable-crest weir.
7. Wooden box weir.
8. Two-way aluminum flapgate with hoist.
9. Variable-crest weir with two-way aluminum flapgates with hoist.
10. Sabine tainter-gate structure.

Figure 34. Cost comparison of selected water control structures by linear foot of weir. Cost assumptions: figures based on 1986 dollars; all wood is CCA treated or creosoted; culverts are all 30' long, polymer coated steel or alclad protected aluminum; sheet and batter pole pilings included in costs; costs include materials, installation, and earthwork; costs could vary greatly depending on location of structure (Chabreck 1968; Melancon 1990; Richard 1990; Hardeman 1990; Walther 1990; Louisiana Department of Natural Resources, Soil Conservation Service 1988; Soil Conservation Service 1988; and Broussard 1986).



1. Single flap-gated culvert.
2. Double flap-gated culvert.
3. Two-way semi-automatic gate structure.
4. Wooden box flap-gated culvert with variable-crest weir.
5. Single flap-gated variable-crest weir.
6. Culvert with floodgate and fixed riser.
7. Wooden box weir.
8. Double flap-gated culvert with variable-crest weir.
9. Two-way aluminum flapgate with hoist.
10. Variable-crest weir with two-way aluminum flapgates with hoist.
11. Sabine tainter-gate structure.

Figure 35. Cost comparison of selected water control structures by foot diameter of culvert. Cost assumptions: figures based on 1986 dollars; all wood is CCA treated or creosoted; culverts are all 30' long, polymer coated steel or alclad protected aluminum; sheet and batter pole pilings included in costs; costs include materials, installation, and earthwork; costs could vary greatly depending on location of structure (Chabreck 1968; Melancon 1990; Richard 1990; Hardeman 1990; Walther 1990; Louisiana Department of Natural Resources, Soil Conservation Service 1988; Soil Conservation Service 1988; and Broussard 1986).

Table 13. Pump cost comparisons based on different fuels[1] (Baker and Bankston 1987; Lam 1990).

Fuel type	Fuel consumption per hour	Fuel cost[2]	Fuel cost per hour
Diesel	7.15 gallons	$.91/gal.	$6.50
Electricity	.866 kilowatt-hour (kwh)	$7.90/kwh	$6.84
Natural gas	1.26 thousand cubic feet (mcf)	$5.80/mcf	$7.31
Gasoline	10 gallons	$1.05/gal.	$10.50
Liquid petroleum gas	12.4 gallons	$.89/gal.	$11.04

[1]Assume pump is 100 horsepower.
[2]1989 prices.

PART IV

ENVIRONMENTAL CHARACTERIZATION
OF
LOUISIANA'S COASTAL ZONE

Chapter 6

ENVIRONMENTAL CHARACTERISTICS AND HABITAT CHANGE FOR THE LOUISIANA COASTAL ZONE

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INTRODUCTION

This chapter describes the environmental setting in which marsh management occurs in coastal Louisiana. A regional overview is presented of the geology, soils, hydrology, water quality, and natural and human-induced changes in the Louisiana coastal zone. A description of habitats and habitat changes, including a discussion of the extent of saltwater intrusion, is provided for each major hydrologic basin of the coast.

A supplemental report also has been prepared, which describes hydrologic and geologic conditions of each basin and the database and approach used to evaluate them, the distribution of threatened and endangered species in coastal Louisiana, and the composition of the 15 most common habitat types located in the coastal zone. This detailed report appears as appendix L.

Study Area

The study area is the Louisiana coastal zone. The northern limit of the study area was set at the Louisiana coastal zone boundary (La. Rev. Stat. Ann. 49§214.24) (West 1989). The Louisiana coastal zone boundary crosses and includes sections of the late Pleistocene Prairie terraces and alluvium of active and abandoned rivers and distributary channels. This boundary is shown in figure 36. Detailed information concerning the location of this boundary is available at the Coastal Management Division, Louisiana Department of Natural Resources. The hydrologic baseline boundaries are also shown in figure 36.

REGIONAL PHYSICAL ENVIRONMENT

The coastal marsh of Louisiana is a broad, flat plain of low relief along the southern part of the state (figure 37). It extends from the Sabine River on the west to the Pearl River on the east and is bounded by the Gulf of Mexico on the south. The inland extent from the Gulf varies across the state from 20 mi in Cameron and Vermilion parishes, to 10 mi in Iberia and St. Mary parishes, 30 mi in Terrebonne, Lafourche, and Jefferson parishes, and 50 to 60 mi in the recently and presently active Mississippi River delta areas of Plaquemines and St. Bernard parishes. The northern limit of the Louisiana coastal marshes lies at about 30°N latitude along the boundary with the late Pleistocene Prairie terraces or the alluvium of active and abandoned distributaries of the Mississippi River.

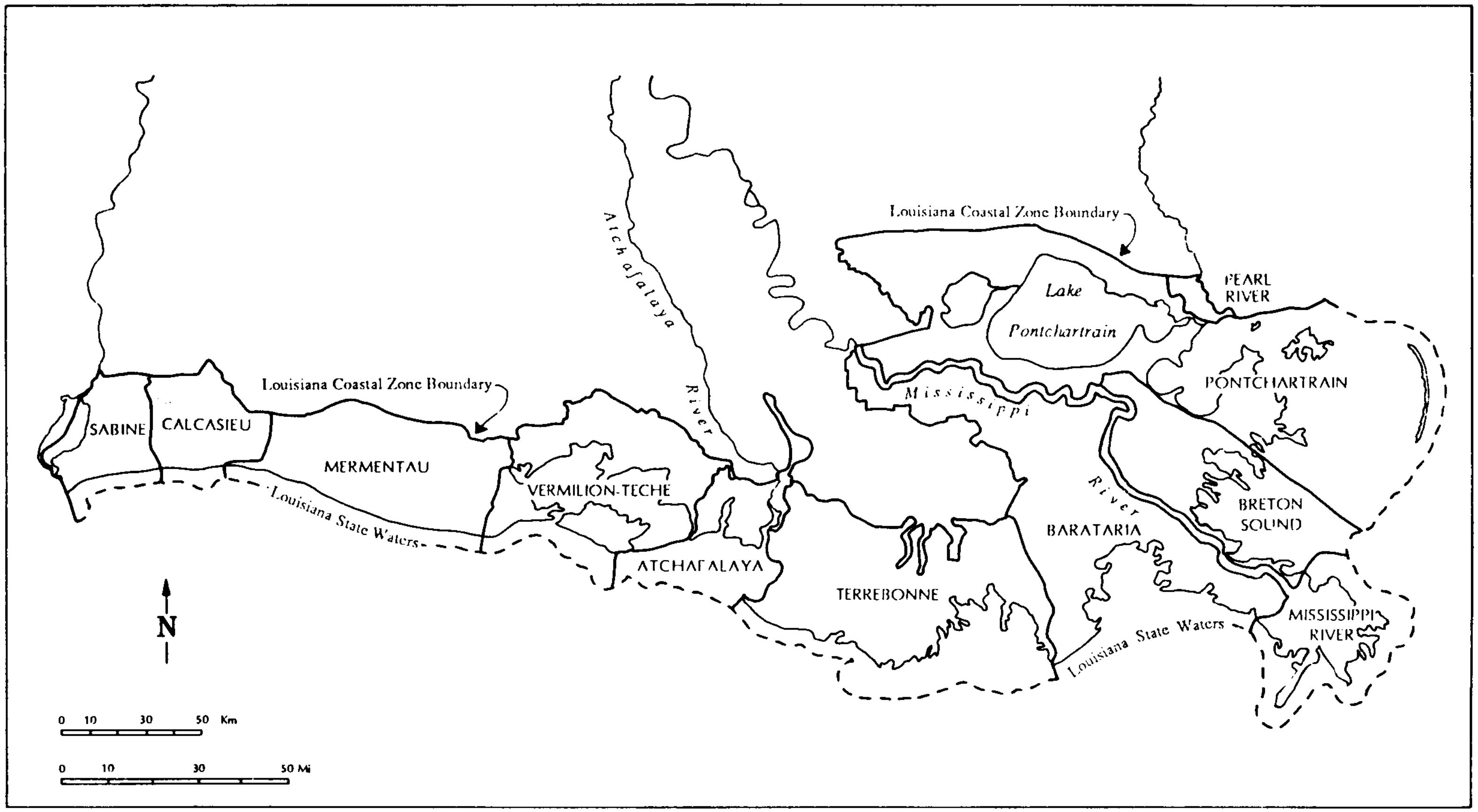
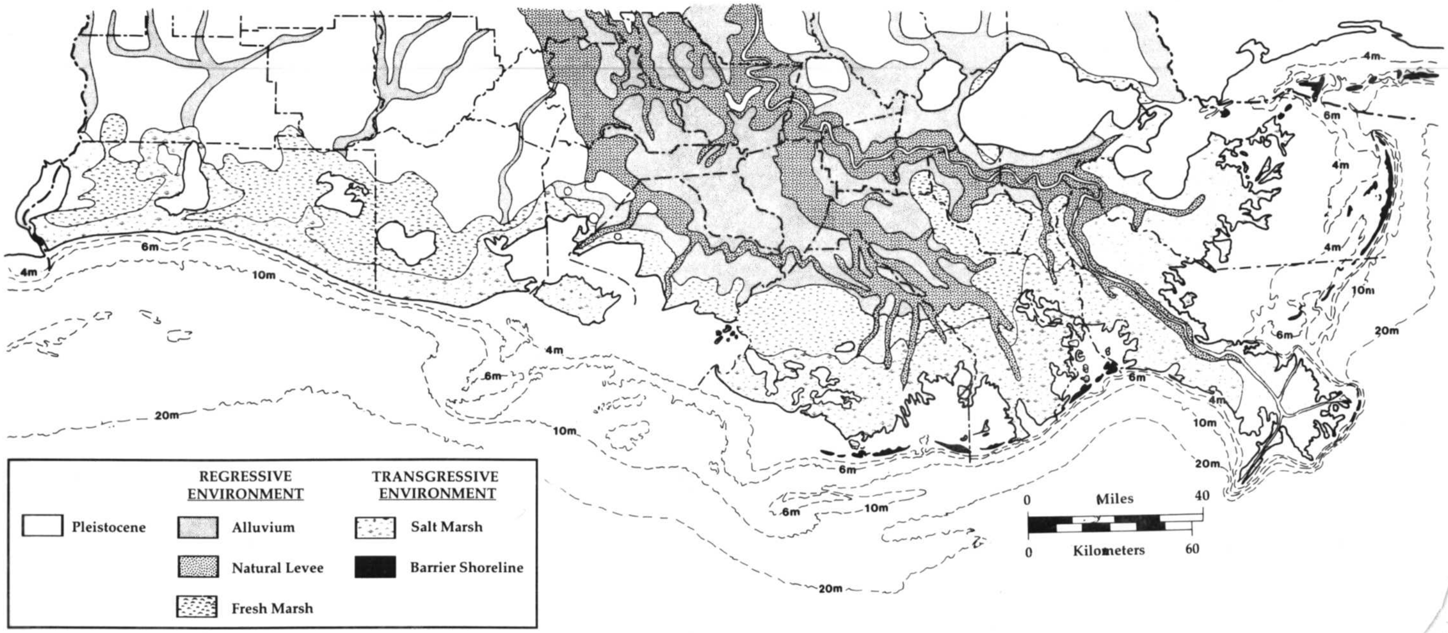


Figure 36. Coastal zone boundary of Louisiana.



redrawn and adapted from Snead and McCulloh, 1984.

Figure 37. Coastal marsh of Louisiana (Snead and McCulloh 1984).

Geology

The coastal zone of Louisiana can be divided into two major physiographic areas: the delta plain of southeastern Louisiana, and the chenier plain in southwestern Louisiana. The Mississippi River delta plain consists of deposits of abandoned and active deltas and channels of the Mississippi River. It contains distinctive delta complexes and lobes that are the product of shifting of the Mississippi River during the Holocene. In the delta plain, distributary ridges are surrounded by fresh to saline marsh. During the Holocene, the Mississippi River meander belt and delta have shifted at least five times (figure 38). The succession and configuration of these meander belts have been described in detail by Saucier (1974), and the effects of these shifts on the development of the delta plain and the Pontchartrain basin have been examined in several studies (Saucier 1963; Frazier 1967; Otvos 1978; Penland and Boyd 1985). Conceptual ideas of depositional episodes and characterizations of transgressive and regressive events on the delta plain are described by Frazier (1974), Penland et al. (1981), and Boyd and Penland (1988). The chenier plain reflects alternating periods of outbuilding and erosional reworking, partly related to the position of the Mississippi delta (Gould and McFarlan 1959; Beall 1968). Cheniers are shore-parallel ridges of sand and shell and are surrounded by fresh to saline marsh and mudflats.

Structural and neotectonic influences on the landscape of south Louisiana include diapirism (piercing or rupturing of domed or uplifted rocks, locally pertaining to salt domes and mudlumps), growth faulting (faulting in sedimentary rock that forms contemporaneously and continuously with deposition), and regional structural features (those produced by deformation or displacement of rocks, such as a fault or fold) that are subsiding or being uplifted. Salt domes with surface expressions include the Five Islands in south-central Louisiana. Of these, Belle Isle, Cote Blanche, Weeks, and Avery islands (figure 38) are veneered with Pleistocene sediments, including loess, and are surrounded by Holocene marsh deposits, and Jefferson Island is surrounded and covered by Pleistocene sediments with loess (Snead and McCulloh 1984). The maximum relief of the domes approaches 160' (50 m). Except for Jefferson Island, all of these are in the Louisiana coastal zone. Growth faults that have surface expression in southeastern Louisiana include the Baton Rouge and Denham Springs fault systems in the coastal Pontchartrain basin (Durham and Peeples 1956; Durham 1982), and possibly others that have not been well documented either stratigraphically or regionally (Murray 1961; Saucier 1963; Durham et al. 1967).

Human activities have had a pronounced influence on landscape development in south Louisiana, particularly since the onset of European settlement. Engineering structures, urbanization, resource utilization, and landscape modification in river basins and in the coastal zone have affected the geomorphic and hydrologic processes. Structures outside the coastal areas of Louisiana's hydrologic basins, such as diversions and dams, influence hydrology and sediment transport and load; structures inside coastal Louisiana, including locks and structures associated with marsh management, also affect hydrology and sediment movement. Construction by humans has even modified basin boundaries. Examples include the construction of artificial levees on the Mississippi and Atchafalaya rivers, basins, and associated floodways; and the dredging of major waterways with large spoil banks, such as the Mississippi River Gulf Outlet.

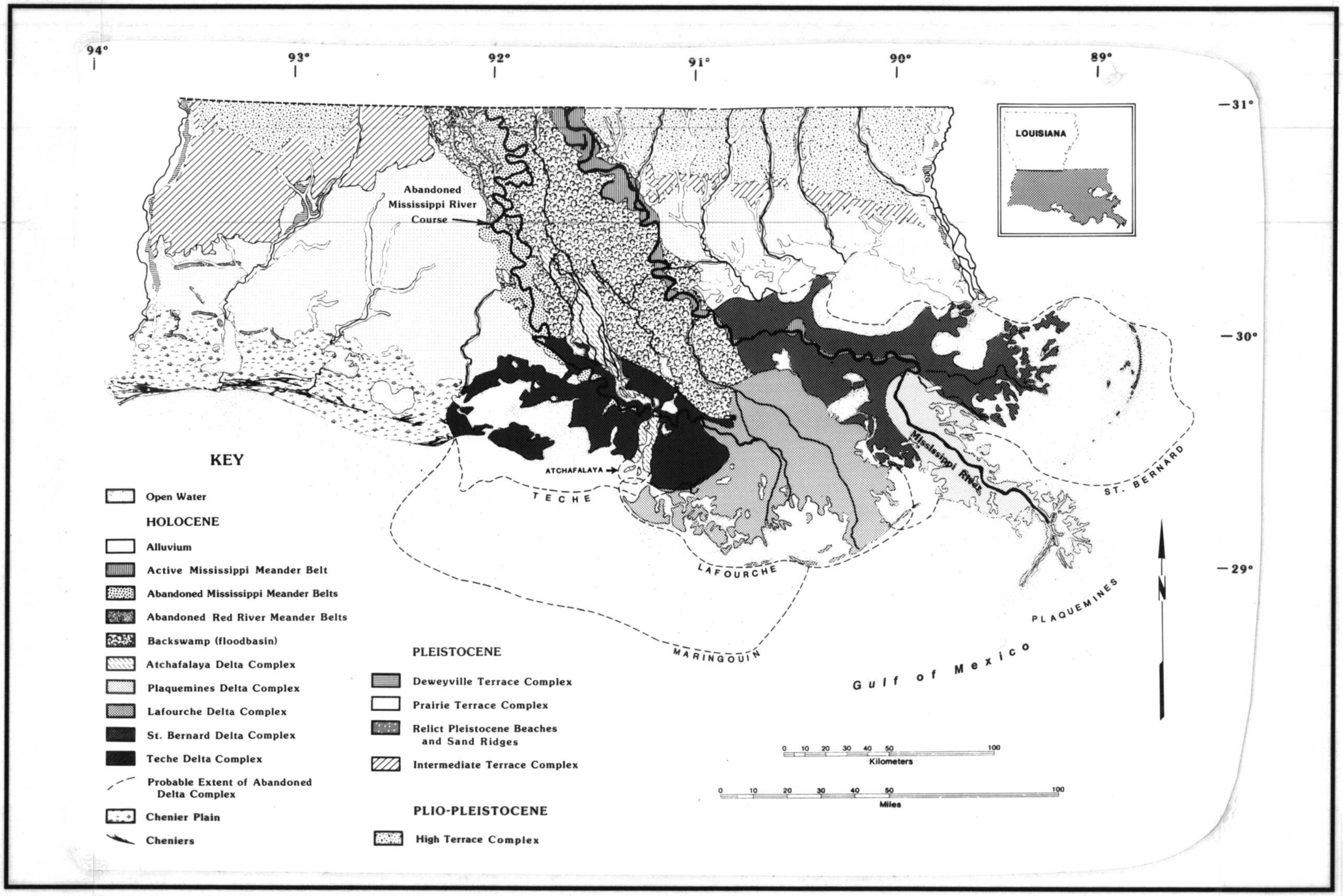


Figure 38. Geomorphology of south Louisiana (Saucier and Snead 1989).

Delta Plain Landforms and Deposits

Approximately 15,000 to 20,000 yr B.P., sea level was some 300 to 360' (90 to 120 m) lower than it is today and the shoreline was several hundred miles seaward of its present position on the outer continental shelf (Fisk and McFarlan 1955). During this low sea level stand, rivers flowed across the shelf into the Gulf of Mexico and entrenched themselves into the late Pleistocene Prairie Terraces. The Mississippi River incised the largest trench, about 10 to 30 mi (15 to 50 km) wide and 400' (135 m) deep, in the vicinity of Houma and Terrebonne Bay. Sea level began to rise after this lowstand, and Gulf Coast rivers of various sizes began to fill their entrenched valleys. However, because the rate of sea level rise was 3 to 10' (1 to 3 m) per 100 yr, the rate of alluvial and deltaic deposition was overwhelmed by the sea, and alluvial environments were transformed into estuarine and marine environments.

The delta plain consists primarily of deposits of abandoned and active channels and distributaries of the Mississippi River and interdistributary backswamp and marsh deposits. Mississippi River delta deposition in the Holocene originated approximately 8,000 years ago when the rate of sea level rise began to slow after the latest Pleistocene (Wisconsinan) deglaciation. As channel became overextended, the river shifted its position several times to channels with steeper gradients. Each major course or belt of the Mississippi River during the Holocene is associated with a delta complex. The individual lobes within each complex are the products of distributary networks (Frazier 1967).

The delta plain chronology described by Frazier (1967) includes the Maringouin, Teche, St. Bernard, Lafourche, and Plaquemines-Modern complexes and older lobes that are buried by younger sediments (figure 38). A delta that has been emergent for the past two decades is being deposited by the Atchafalaya River, a human-modified distributary of the Mississippi River (Fisk 1952; Shlemon 1972). Each major Holocene delta complex first experiences a constructive phase and then undergoes a destructive phase. Four of these complexes, the Maringouin, Teche, St. Bernard, and Lafourche, are in various stages of deterioration, while two, the Modern and Atchafalaya, are actively prograding or outbuilding (figure 38). The Balize lobe of the modern Mississippi delta is the only delta with a birdfoot shape, which reflects its progradation into deep water. The presently forming Atchafalaya and most abandoned deltas that were deposited in shallow water, in contrast, have a lobate morphology.

Transgressive shoreline development along abandoned deltas is a product of relative sea level rise and erosional shoreface retreat (Penland and Boyd 1981). After delta abandonment, compactional subsidence results in a sea level that rises in relationship to the land surface; during this stage, marine processes transform a once-active delta into an erosional headland with flanking barrier islands, which is followed by the development of a barrier island arc system, and eventually an inner shelf shoal (figure 39). The relative age of the abandoned delta complexes can thus be assessed by the dominant processes and geomorphic criteria. The record of these transgressive and regressive events in the delta plain is well preserved due to the high rates of subsidence and sedimentation in south Louisiana.

The Mississippi River alluviated its valley and prograded to form the Maringouin delta complex in the western section of the Mississippi River delta plain as sea level rise slowed around 8,000 years ago. Sea level at that time

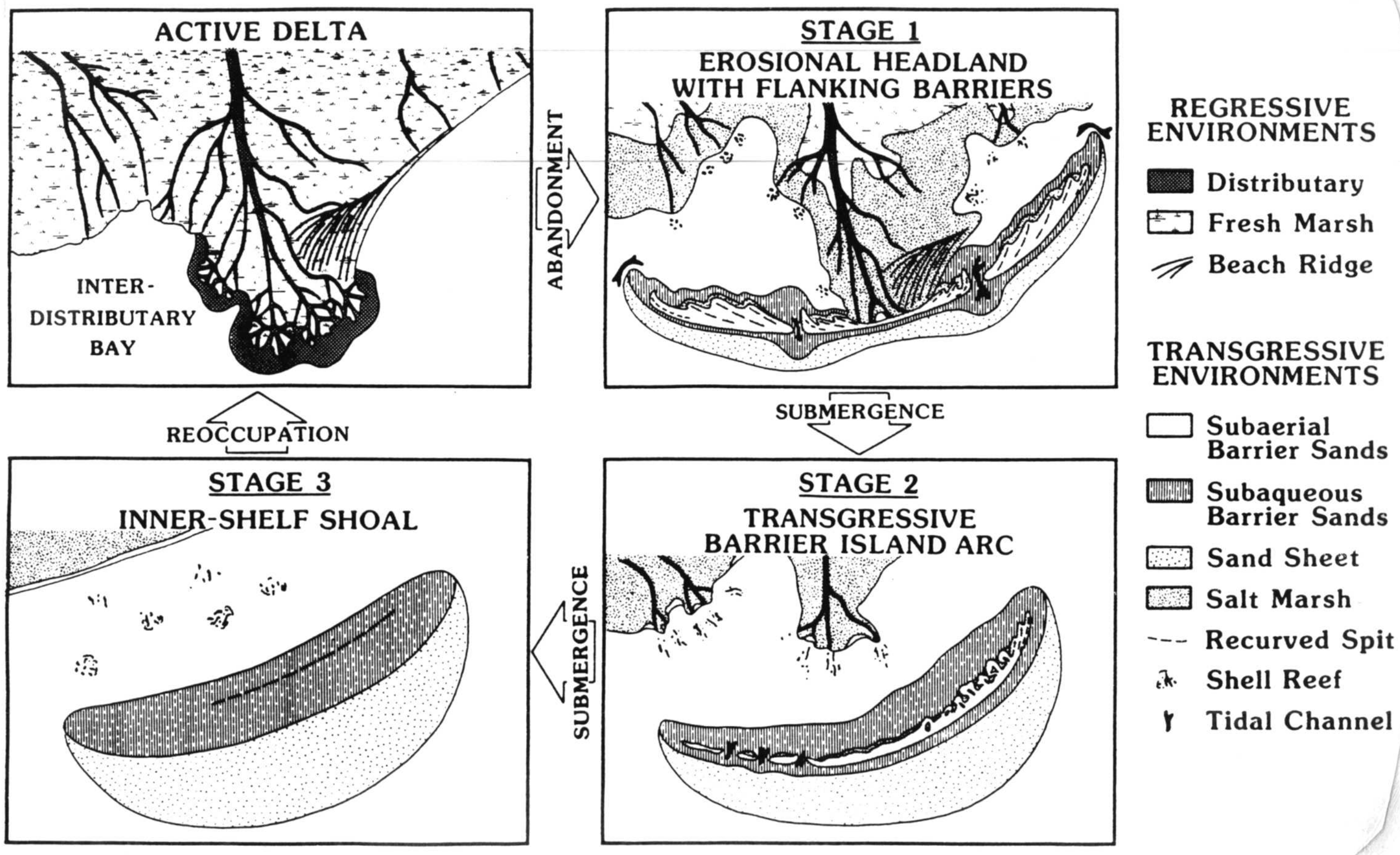


Figure 39. Geomorphic model of delta plain development (Penland and Boyd 1981).

was approximately 15 to 25' (5 to 8 m) lower than at present. After the Mississippi River shifted, the delta was abandoned and reworked by marine processes. The Maringouin delta complex has since been buried by a sequence of younger deltaic sediments, so that its distributaries and delta lobes are now subsurface or offshore features. Ship Shoal, a subaqueous sand shoal in offshore Louisiana, is a remnant of the submerged barrier shoreline of the Maringouin delta complex.

The Mississippi River shifted into the Bayou Teche course approximately 5,700 years ago and was actively depositing sediment until about 3,900 years ago. When the delta was regressive, sea level stood about 6 to 15' (2 to 4 m) below its present level. The delta complex consisted of three delta lobes with distributaries (Bayou Teche, Bayou Sale, and Bayou Cypremort) in the western portion of the Mississippi River delta plain. These distributaries have surface expression in coastal Louisiana, but the seaward sections of the abandoned deltas are offshore. Trinity and Tiger shoals are remnants of the submerged barrier shoreline of the Teche delta complex.

Distributaries of the St. Bernard delta complex, located in the easternmost and northernmost portions of the Mississippi River delta plain, were established by 4,050 yr B.P. Sea level was probably about 2 m below its present level (Frazier 1974). Major distributaries of this complex include Bayou Terre aux Boeufs, Bayou La Loutre, Bayou des Families, Bayou Sauvage, and several unnamed distributaries. The Mississippi River and Bayou La Loutre were active in building the St. Bernard delta complex. The Chandeleur Islands are transgressively reworked from the St. Bernard delta complex, and are the oldest of the subaerial barrier features on the Louisiana coast. Older barrier shorelines associated with the St. Bernard delta complex are now buried by younger deltaic deposits. Although deposition was occurring in other delta lobes contemporaneously with that in this delta complex, active sedimentation was occurring until 650 years ago.

Major progradations of the Lafourche delta complex, which lies in the central portion of the Mississippi River delta plain, began about 3,500 yr B.P. and continued until about 400 yr B.P. Major distributaries include Bayou Terrebonne, Bayou Black, Bayou Blue, Bayous Grand and Petit Caillou, and Bayou Lafourche. Since abandonment, the delta lobes associated with these distributaries have been reworked by marine processes. In some areas, notably Cheniere Caminada, there is extensive beach ridge development. The Isles Dernieres, Timbalier and East Timbalier islands, the Bayou Lafourche headland, and Grand Isle have been reworked since abandonment of delta lobes associated with the Lafourche delta complex.

The Modern delta complex has been active since about 950 yr B.P. and is still active today. It includes the Plaquemines and modern Mississippi or Balize delta lobes and distributaries. The Plaquemines delta lobe includes distributaries Bayou Grand Cheniere, Grand Bayou, Robinson Bayou, Bayou Grand, Bayou Long, Dry Cypress Bayou, and Bayou Fontanelle. Beach ridge development has occurred on the Plaquemines headland, particularly in the vicinity of Cheniere Ronquille. The Grand Terre Islands and Shell Island have developed since abandonment and subsequent transgression.

The Balize delta lobe is the only deepwater delta lobe of the Mississippi River. Historical documentation shows that it is composed of several subdeltas, which undergo cycles similar to those of larger lobes, including subaqueous growth and rapid subaerial development, followed by deterioration. The time required for completion of the cycle is much shorter for subdeltas, which have switched several times during the past few centuries, than for delta lobes. As with the larger delta lobes, once these subdeltas become inactive, transgressive processes dominate and barrier shoreline development takes place on a localized scale.

The Atchafalaya River formed in the 16th century when a westward-migrating meander of the Mississippi River intercepted the course of the Red River and captured its drainage. For years it remained an insignificant distributary of the Mississippi River because it was choked on its upstream end by a log jam on the outer end of Turnbull's bend, where the Red River flowed into the Mississippi. In 1839, the State of Louisiana began to burn, blast, and dredge the log jam on the Atchafalaya. After that, the flow through the connecting link was no longer subject to reversals in direction depending upon whether the water level was higher in the Mississippi or in the Red River. Instead, the Atchafalaya continued to enlarge as it received progressively larger volumes of flow from the Mississippi River. In a letter to the Mississippi River Commission dated 1882, Eads recognized the possibility of potential diversion of the entire Mississippi into the Atchafalaya (Salisbury 1935), and several others since then have suggested that the potential for diversion exists (Salisbury 1935; Latimer and Schweizer 1951; Odom 1951; Fisk 1952; Kazmann and Johnson 1980; Kolb 1980; Martinez 1986). The lower Atchafalaya River delta and Wax Lake delta began a subaqueous phase in about 1952 and have been prograding across Atchafalaya Bay since the early to mid 1970s (Cratsley 1975; Shlemon 1975; Rouse et al. 1978; Roberts et al. 1980).

Chenier Plain Landforms and Deposits

The term "chenier" was introduced by Russell and Howe (1935) to describe linear ridges of sand and/or shell upon which a substantial oak tree population has developed; "chene" is French for oak, and the term chenier has since been applied in other parts of the world. The chenier plain consists of late Holocene alternating or coalescing transgressive chenier ridges and regressive mudflat and marsh deposits (Price 1955) (figure 40). Most of these shore-parallel ridges were formed by coastal reworking and thus are genetically quite similar to beach ridges. The relict beaches or cheniers are lenticular and biconvex in cross section and are characterized by a smooth, generally arcuate seaward front and an irregular landward margin (Byrne et al. 1959). They extend as uninterrupted coastal ridges up to 30 mi (50 km) long, average 600′ (200 m) across and about 7′ (2 m) thick.

The wedge of sediments constituting the chenier plain was deposited during the recent sea level rise. Radiocarbon dates suggest that deposition occurred since 5,600 yr B.P. (Gould and McFarlan 1959), although such inferences are based principally on dates of shell material which may produce suspect results. The basal section of the sequence, which overlies a late Pleistocene surface, consists of transgressive brackish-water and marine deposits laid down as sea level rose from about -5 m to the present level (Gould and McFarlan 1959). Shortly before or coincident with upbuilding, the longshore influx of sediment, largely from the shifting Mississippi River deltas, brought about outbuilding of the coast. Nearshore coastal deposits rest upon the seaward-thickening wedge of Gulf-bottom sediments that form the upper part of the sedimentary wedge. The cheniers, which are coastal deposits and decrease in age toward the Gulf from

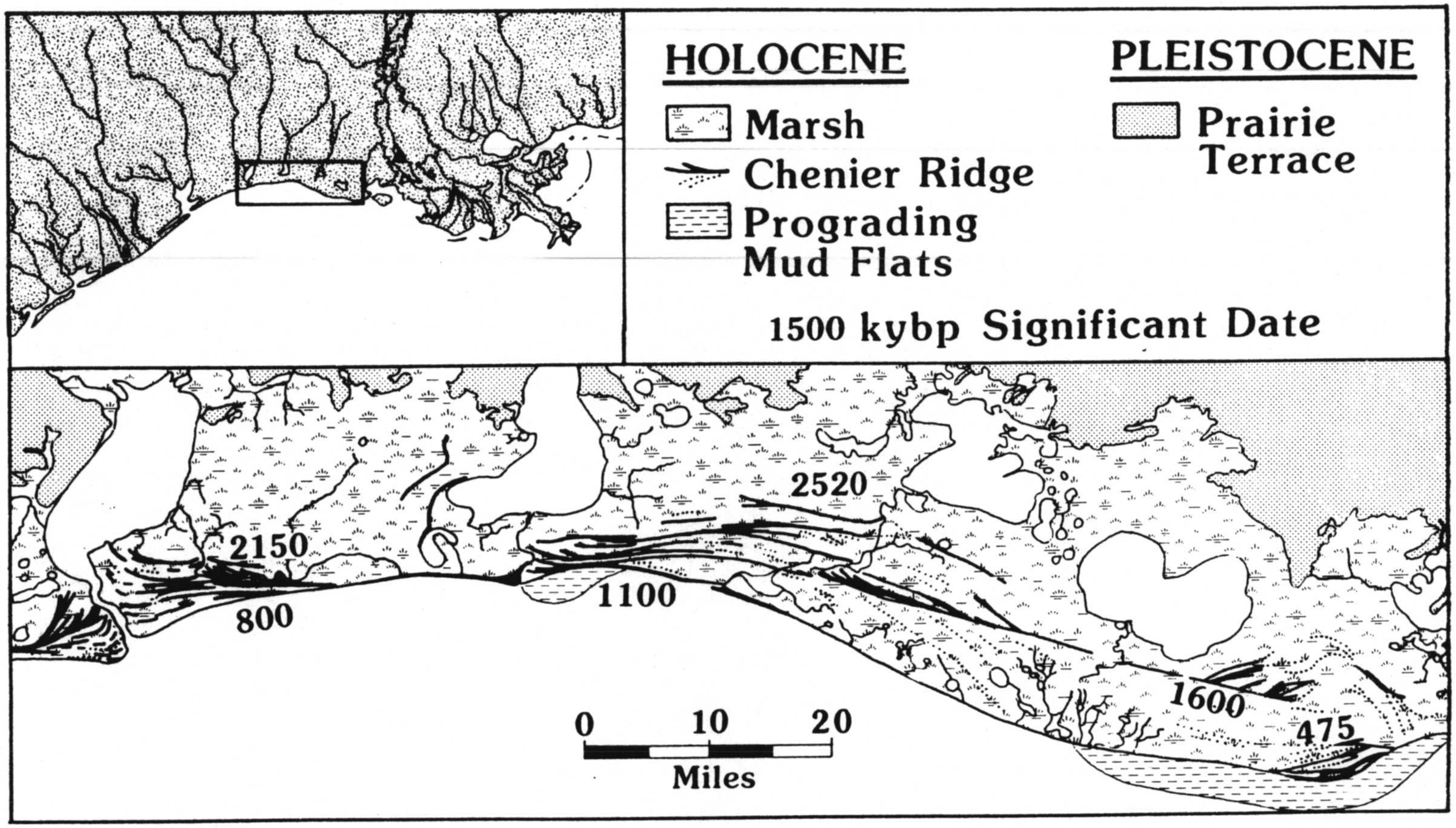


Figure 40. Geologic setting and ages of the chenier plain (redrawn from Gould and McFarlan 1959).

about 2,800 to 300 years old, show the seaward advance of about 10 mi (15 km) of the coastline in western Louisiana (figure 40).

The conceptual model that has been suggested and is generally accepted to explain the form-process relationships and the development of the chenier plain provides that the strandline consists of either sandy chenier ridges or mudflats, considered to have been the major source of sediment supply (figure 41). Mudflat progradation occurred when the ancestral river was closest to western Louisiana, and reworking of sand and shell bodies into ridges was a result of marine processes dominating when the Mississippi was farthest from this area. This general relationship was advocated and partly substantiated by Gould and McFarlan (1959) and Beall (1968), but Kaczorowski (1980) believes that modern conditions, radiocarbon dates, and growth rate curves do not fully support this model. It is likely that local river influx and the influence of other physical processes during the late Holocene also have been quite important in chenier plain development.

Geomorphic features of the chenier plain include the long, narrow, low-relief cheniers, perched beaches, and overwash deposits. Rivers generally cut across or are somewhat diverted by the ridges, and both the ridges and rivers are surrounded by mudflats, marshes, and wetland lakes. The lakes are often round and some may be relics of unfilled estuaries that were isolated from the sea when mudflats and beach ridges were built up across their mouths (Gould and McFarlan 1959). Marsh compaction and wave erosion have been considered important in the genesis and enlargement of the lakes (Russell and Howe 1935; Fisk 1948).

Soils

Organic soils or Histosols are the most common soil order in the Louisiana coastal marsh, and they sometimes also occur in coastal swamps. Mineral soils of various soil orders are developed in swamps, alluvium, and mudflats; these generally have clayey textures. Mineral soils of various soil orders are developed on natural levees, barrier shorelines, and cheniers; they usually have fine-silty, coarse-silty, sandy, or composite textures. Mineral soils developed on Pleistocene deposits may have clayey, silty, sandy, or composite textures, depending on the environment of deposition.

Properties used to differentiate these soils include mineral content, organic content, consistence as related to water content, and the development, thickness, and sequence of soil horizons. Throughout much of coastal Louisiana, soil properties have been altered through artificial drainage and other human activities. Subsidence due to oxidation of organic materials and cracking of montmorillonitic (shrink-swell) clays are two common responses of the soil to drainage.

Climate, Hydrology and Water Quality

Climate

Louisiana has a humid subtropical climate because it is bordered by most of the North American continent to the north and by the Gulf of Mexico to the south. Summers are long and hot, winters are short and mild, and precipitation

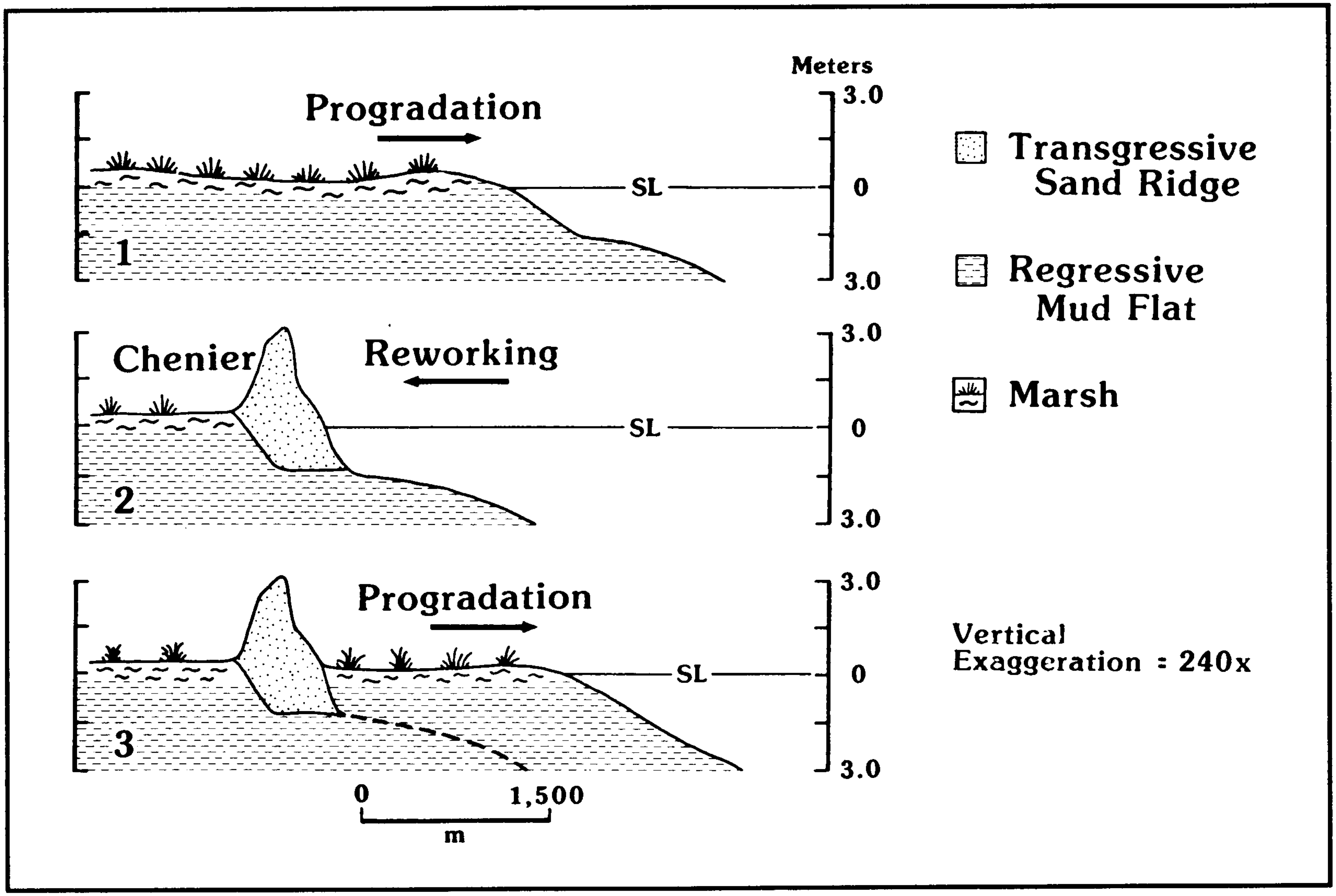


Figure 41. Geomorphic model of chenier plain development (redrawn from Hoyt 1969).

is abundant throughout the year. Summer heat and humidity and winds from the south and southeast cause frequent thunderstorms during the warmer months; in the winter, storm centers developing over the Gulf cause extended rainfall. Sudden changes in temperature and precipitation are not uncommon in the winter, because of the alternating influence of cold air from the north and warm air from the Gulf. Annual precipitation in the region averages approximately 60" (150 cm), but ranges from under 30 to over 90"/yr (100 to 200 cm/yr). Flood-producing rains may occur during any month of the year and large, long-lasting storms are common. Variability in precipitation across the area causes much of the variability in flood response. During a two-to-three-day storm with a stationary cold front, 10" (25 cm) of rainfall or more may be produced within 24 hours. During the winter and spring, the lack of storage potential in the soil may cause flooding to be more pronounced.

Tropical storms and hurricanes, often accompanied by strong winds and heavy rainfall and occasionally by tornados, are common in the summer and early fall. Between December and April, fog often occurs along the Mississippi and Atchafalaya rivers, and around the many lakes and marshes in south Louisiana; this occurs when the temperature of the air falls below the dew point, or when the air temperatures are higher than the colder water temperatures beneath. Arctic outbreaks are one of the climatic hazards and can be devastating to crops, plants, and water pipes in coastal Louisiana (Muller and Fielding 1987).

Average annual temperatures range from about 65°F in the northeastern portion of the state to 70.5°F in the southernmost portions (Louisiana Department of Transportation and Development 1984). Winter temperatures usually range between 40°F and 50°F in the mornings and between 55°F and 65°F in the afternoons. Summer temperatures average from the mid-60s and 70s around dawn, to the mid-80s and 90s in the afternoon. The average annual rainfall ranges from 54.4" in northwest Louisiana to 66" in the southeastern portion. Limited rainfall data near the coast suggests that annual totals may be as much as 5 to 10% less than in the zone of maximum rainfall (Muller and Fielding 1987). Average annual runoff ranges from 10" in the southwestern portion of the state to 20" in the extreme southeast.

Coastal Hydrology

The hydrology of the coastal marsh is complex because of the interconnected rivers, bayous, lakes, ponds, and canals, and the natural and artificial levees, spoil banks, roads, cheniers, locks, weirs, gates, and plugs that form hydrologic barriers. Hydrology differs markedly between the coastal basins with large rivers and those without them. In basins with large rivers, the flow is controlled principally by runoff and is generally directed toward the Gulf; in basins without large rivers, tidal influence is the principal hydrologic control.

Because they are largely dependent on wind and astronomical conditions, tides and water levels vary temporally and spatially. The influence of tides generally increases downstream in the coastal basins and influences the direction of flow. The environmental conditions that control flow rates and patterns in wetland water bodies, such as bayous, lakes, and canals, include wind direction, speed, duration, and fetch, and barometric pressure. Northerly winds cause water levels to fall; southerly winds blow water in from the Gulf, causing levels to rise. Low water extremes in the coastal marshes of Louisiana have a narrow range, from marsh level (1.5′ NGVD) to about 2′ below marsh level (-0.5′ NGVD).

High water extremes are more variable. The typical monthly high is generally a few feet above marsh level. High water levels caused by extremely strong southerly winds, of which the highest are generated by hurricanes, cause water levels over 5' NGVD in the marsh.

The reach of tidal influence in a basin varies from day to day and year to year. During extreme events, including both storms and low water, tidal influence may extend inland of the basin boundaries described in this report. Although the reach of tidal influence can be defined in various ways, the best definition available is that of the boundary between fresh and intermediate marsh. The tide gage stations are sparsely scattered throughout the coastal area, and thus could not be used extensively to determine water level variations. Neither are topographic criteria ideal for determining tidal influence because spoil bank elevations are not well documented, and the pathways of tidal flux have not been closely examined.

The boundary between fresh and intermediate marsh is a conservative estimate of the reach of tidal influence. Tides can and do influence water levels in fresh marshes. However, the line between fresh and intermediate marshes approximates the northern extent of salt water.

The rivers and streams with the largest drainage areas and consequently the largest discharges of water and sediment in south Louisiana include the lower Mississippi and the Atchafalaya rivers. The Pearl, Sabine, and Calcasieu rivers are sizeable in drainage area and carry large amounts of fresh water during floods, but minor amounts during most of the year. Other rivers, namely the Mermentau and the Vermilion and streams in the Pontchartrain basin, carry appreciably less water than these large rivers, but nonetheless constitute an important source of fresh water and sediment for the adjoining coastal swamps and marshes. Flow discharge in the largest basins, specifically the Mississippi and Atchafalaya, is influenced by regional climatic patterns throughout the drainage basin, which includes much of the continental interior. Discharges in the smaller basins are influenced by the local climate in Louisiana, Mississippi, and Texas.

The state's natural lakes include coastal lagoons, oxbow lakes, and naturally and artificially dammed lakes. The largest natural lake is Lake Pontchartrain, with a surface area of about 621 mi^2. The state's second largest-lake is the human-made Toledo Bend Reservoir, covering 289 mi^2. There are several other artificial reservoirs in addition to a large network of constructed waterways including the Gulf Intracoastal Waterway, the Mississippi River Gulf Outlet, and numerous drainage canals and access canals.

Coastal Water Quality

Water quality is an important aspect of the condition and productivity of coastal marshes. Dissolved oxygen is necessary for fish and aquatic organisms. About 3 to 5 ppm is accepted as the lowest limit for support of fish life over a long period of time (Swenson and Baldwin 1965). According to conventional indices, most lakes in Louisiana fall into the eutrophic category, having high primary productivity due to their shallow depths and high nutrient levels. However, these lakes support diverse, productive fisheries and provide various recreational opportunities. High water tables in the coastal marshes hinder the safe subsurface disposal of hazardous wastes and sewage. Discharge of brine or highly saline water into the coastal marshes can kill the vegetation and accelerate the erosion of marsh soils.

Among the major water pollutants in Louisiana are fecal coliform bacteria, oxygen-demanding substances, nutrients, oil, and inorganics, specifically chlorides and brine. Oyster harvesting areas are often closed because of high bacterial counts. The most commonly cited causes of pollutants include runoff from unsewered communities, inadequately treated sewage discharges from municipalities, discharges and spills from petroleum industry activities, agricultural runoff, and urban runoff. Nonpoint sources appear to be the predominant contributors to the state's water quality problems.

Coastal water bodies severely affected by toxic pollutants include the Calcasieu River and Ship Canal, Prien Lake, and Bayou D'Inde in the Calcasieu basin, and Bayou Trepagnier in the Lake Pontchartrain basin near Norco in St. Charles Parish (O'Hara and Capello 1988). Pollutants in the Calcasieu basin include halogenated aliphatic and aromatic priority pollutant organic chemicals, and those in Bayou Trepagnier include petroleum hydrocarbons, phenol, chromium, lead, and zinc. These pollutants all have industrial point sources. Swimming and fishing advisories in coastal areas are in effect for these water bodies and for two streams in the Lake Pontchartrain basin. Bayou Bonfouca has organics pollutants from surface runoff at an abandoned creosote facility, and the Tangipahoa River contains fecal coliforms from municipal point sources, farm runoff, and septic tank drainage. Similar pollutants occur in other rivers in the coastal zone, but not at such high levels.

Natural and Human-induced Changes

The coastal marshes of Louisiana are changing. Spatial changes in the Mississippi River delta plain have been mapped by Wicker (1980), and May and Britsch (1987). Many areas are losing wetlands at a rapid rate, while in others wetland area is expanding. Land loss is a widespread and serious problem in coastal Louisiana because of the high rates of relative sea level rise, which is a result of the combined effects of eustatic change, subsidence, the lack of sediment supply, frequent storms, and human impacts. Conversion rates of land to open water in 1980 were about 50 mi^2 per year (130 km^2) in all of south Louisiana (Turner and Cahoon 1988). These rates are the highest in the nation and threaten coastal communities, fisheries resources, and wildlife habitat. In localized areas the land area is increasing, particularly in the vicinity of the Atchafalaya delta and downdrift areas and where water bodies have been drained for urban, industrial, and agricultural development.

Another change taking place in coastal Louisiana is the alteration of vegetative communities from fresher to more salt-tolerant species; this ultimately has an effect on fishery and wildlife production. The changes in habitat type have been attributed to saltwater intrusion (Van Sickle et al. 1976), although this is not substantiated by readings from salinity stations in water bodies across coastal Louisiana (Wiseman and Swenson 1987).

Relative Sea Level Rise

Relative sea level rise refers to the long-term, absolute vertical relationship between the land and water surfaces, excluding the short-term effects of wind and astronomical tides. Relative sea level rise is controlled by seven major factors (Kolb and van Lopik 1958; Adams et al. 1976): 1) eustacy, 2) geosyncline downwarping, 3) compaction of Tertiary and Pleistocene deposits, 4) compaction of Holocene deposits, 5) localized consolidation, 6) tectonic activity, and 7) subsurface fluid withdrawal.

Eustacy refers to the global sea level regime and its fluctuations; it is primarily controlled by the changing volumes of the planet's glaciers and ice caps, as well as by worldwide tectonic activity and density-temperature relationships. A recent study based on analysis of 190 tide gage records worldwide concluded that mean eustatic sea level is rising at a rate of 0.05"/yr (0.12 cm/yr) (Gornitz et al. 1982). For the Gulf of Mexico, the regional rate of sea level rise was 0.09"/yr (0.23 cm/yr) (Gornitz et al. 1982).

Geosynclinal downwarping is a minor factor in the observed sea level rise in coastal Louisiana. A sequence of shallow-water sediments about 40,000' (12,000 m) thick has accumulated in the geosyncline, downwarping the Mesozoic basement and creating a gradually subsiding trough. An estimated average rate of downwarping over the past 60 million years is 0.01"/yr (0.02 cm/yr); because downwarping is a function of loading it is more pronounced during periods of heavy sedimentation. By examining the Pleistocene subsurface geometry, Fisk and McFarlan (1955) analyzed the consolidation of Tertiary and Pleistocene deposits. They observed subsidence rates as high as 0.09" yr (0.23 cm/yr) along the axis of the infilled alluvial valley south of Houma. These rates are fairly high compared to many other causes of relative sea level rise.

Compaction of Holocene deposits is considered to be the primary cause of relative sea level rise occurring in coastal Louisiana. Kolb (1958) believed that consolidation of the Holocene prodelta clays, which have a high water content, is perhaps the most important factor affecting subsidence. Holocene compaction consists of three major components: 1) primary consolidation, 2) secondary consolidation, and 3) oxidation of organic materials (Terzaghi 1943; Roberts 1985). Primary consolidation occurs when dewatering reduces the volume of the soil. Secondary consolidation takes place when soil volume is reduced because of the rearrangement of internal structure. Oxidation of organic matter causes further losses in soil volume. When deposits with high organic content are reclaimed from marshes and lake bottoms for suburban development, the organic material dries and the soil subsides as a portion of the material is released as CO_2 gas.

Localized consolidation, caused by landforms with relatively high specific gravity or by the presence of engineering structures on the surface, is locally important but geographically highly variable. Landforms, such as natural levees and cheniers, subside faster than surrounding organics, silts, and clays (Kolb and van Lopik 1958; Morgan 1973). Several structures built in the 1700s lie a meter or more below sea level now, far deeper than would be expected from all the other causes of relative sea level rise combined.

Tectonic activity and subsurface fluid withdrawal of water and hydrocarbons can contribute to dramatic sea level changes in localized areas. The most pronounced changes take place at the downthrown end of growth faults. Although little documentation exists on the effects of fluid withdrawal in coastal

Louisiana, the removal of subsurface fluids has resulted in significant subsidence in the vicinity of Galveston, Texas (Kreitler 1977). An attempt to estimate subsidence potential over several shallow oil fields has been made by Suhayda (1987).

Subsidence-induced sea level rise caused by compaction of sediments generally decreases with time (Morgan and Larimore 1957). Soon after abandonment, interstitial water losses are high, causing rapid rates of subsidence. Once much of the water is removed, the rates of subsidence decrease. Some recent estimates of relative sea level rise and/or subsidence follow. Kolb and van Lopik (1958) estimated a rate of 0.8'/century or 0.096"/yr (0.24 cm/yr), including sea level rise; Saucier (1963) estimated subsidence at 0.4'/century or 0.048"/yr (0.12 cm/yr) for the Pontchartrain basin; Gagliano and van Beek (1970) suggested a rate of 0.4'/century or 0.048"/yr (0.12 cm/yr); Watson (1982) estimated, using geodetic benchmark data, a value of 1.3'/century or 0.156"/yr (0.40 cm/yr); and Ramsey and Moslow (1987) estimated that relative sea level rise averages about 0.33"/yr (0.85 cm/yr) from 1942 to 1982, 0.18"/yr (0.45 cm/yr) during 1941-1962, and 0.44"/yr (1.12 cm/yr) from 1962 to 1982. The highest rates of rise were observed along the coast at 0.39 to 0.47"/yr (1.0 to 1.2 cm/yr) and in the southwestern portion of the delta plain at 0.71 to 0.75"/yr (1.8 to 1.9 cm/yr). Ramsey and Moslow (1987) also concluded that compactional subsidence accounts for about 80% of the observed sea level rise in Louisiana; this figure was based on an analysis of tide gage records and a eustatic correction factor for the Gulf of Mexico.

<u>Sediment Supply</u>

Sediment supply to wetland areas has diminished due to the construction of artificial levees along the Mississippi River. Sediment load to the Gulf has decreased in the Mississippi River because of increased diversion of flow into the Atchafalaya River, and the construction of reservoirs and increased use of soil conservation practices upstream (Keown et al. 1986; Kesel 1988). After upstream diversion associated with distributary switching, the major source of sediment in many areas is the reworking of local sediment bodies. Along the shoreline, the major source of sediments are reworked distributary sand bodies and beach-ridge plains, principally from erosional headlands. Despite the abundance of sediment, the predominant trend along the Louisiana coast is shoreline erosion, at rates up to 50'/yr (Penland and Boyd 1981). In the coastal wetlands, sediments may come from eroded marshes, from the Gulf during storms, and from resuspension in bayous during occasional flooding.

<u>Storm Impacts</u>

The maximum storm intensity, relative intensity at the coast, and dates of influence on the southwestern, south-central, and southeastern areas of the Louisiana coast of major tropical storms and hurricanes from 1900 to 1986 are described by Muller and Fielding (1987). Major floods in the Mississippi and Atchafalaya basins in recent history occurred in 1927, 1937, 1945, 1950, 1973, 1975, 1979, and 1983. Major floods in the coastal basins of southwestern Louisiana took place in 1940, 1953, and 1983, and in the coastal basins of southeastern Louisiana in 1977, 1979, and 1983. Major annual floods are described at individual measurement stations along with the basin descriptions, below.

Human Impacts

The influence of human activity on the coastal landscape, and vice versa, is an important aspect of the dynamic changes of south Louisiana. The area's geologic problems and hazards are numerous and recurrent. An extensive artificial levee system has been built along the major rivers in south Louisiana to reduce the risk of flooding. Numerous engineering structures have been built to improve drainage, reduce coastal or riverbank erosion, and assist navigation. Canals constructed for oil and gas recovery, navigation, and drainage contribute to land loss because of the changes in hydrology and sedimentation that they cause, and because of saltwater intrusion, which can damage vegetation.

Although the Old River Project was designed and built to prevent the Mississippi River from changing its course to flow into the Atchafalaya basin, it is still possible that it may do so (Kolb 1980). This would mean the demise of significant ports and the deterioration of New Orleans' and other communities' water supplies because of saltwater intrusion of the lower Mississippi River.

Modifications such as the Old River control structure in turn have aggravated existing problems or created additional ones. Keeping the Mississippi on its present course has led to the reduction of sediment supply to the coastal zone (Gagliano and van Beek 1976) because the riverborne sediment, that formerly spread laterally over the wetlands and shallow bays adjacent to the river is now channeled by the levee system out to deep water in the Gulf. This aggravates land loss because the delta sediments compact and subside below sea level without the addition of new sediment to fill in the subsiding areas.

One of the major human modifications of the coastal area was the construction, extension, and enlargement of the Gulf Intracoastal Waterway. It is interconnected with the Mississippi River system and several other important inland waterways, and enables small craft and commercial tows to reach many eastern and southern seaboards and towns in the continental interior. The Gulf Intracoastal Waterway within Louisiana extends along the coast of the Gulf of Mexico from Lake Borgne Light No. 29 on the eastern boundary to the Sabine River on the western boundary, a distance of 302 mi. It also extends inland from Morgan City to Port Allen (64 mi), from Plaquemines to Indian Village (7.4 mi), and to Franklin via the Franklin Canal (5.1 mi). There are nine locks in operation on the waterway routes, many of which are described in detail in the basin descriptions below. The Gulf Intracoastal Waterway is 12' deep, 150' wide from the Lake Borgne Light No. 29 to the Industrial Canal, and 125' wide from the Mississippi River to the Sabine River, including the routes through both Algiers and Harvey locks.

Another major modification of the coastal area is the removal of aquatic growth that clogs waterways and makes them impassable. This is a statewide project maintained by the Corps of Engineers in navigable waterways. The Gulf Intracoastal Waterway connects many water bodies and has aggravated this problem. The control of unwanted growth can be achieved by 1) building control structures to keep the vegetation from drifting from infested areas into main waterways; 2) destroying the vegetation by moving it to saline water bodies; 3) mechanical destruction by shredding with multiple semi-submerged saws; 4) chemical treatment; and 5) biologic control.

A more detailed report (appendix L) describes specific conditions in each of 11 hydrologic basins in the Louisiana coastal zone and the data base and approach used to evaluate the conditions. Sources of data on soils, hydrology, water quality, salinity, and relative sea level rise used in this and the detailed report are described. Research methods employed in previous studies and in this report are also briefly discussed. Regional soils data, stage and discharge stations, marsh types, water quality data, salinities, relative sea level rise assessments, and major structures are presented by hydrologic basin.

Saltwater Intrusion

The inland spread of salt water into coastal marshes is reflected in the salt concentrations in coastal waters or changes in the composition of coastal vegetation. Wiseman and Swenson (1987) examined historical water salinity data sets of the Louisiana Department of Wildlife and Fisheries and of the Corps of Engineers collected during the past 30 to 40 years. The data revealed statistically significant trends in mean surface salinity, salinity variance, and maximum salinity in some locations. In some areas of the coast salinity increased while in other areas it decreased but there was no discernible spatial pattern to the trends. In most cases, the change was too small to affect coastal vegetation. In two areas, however, significant alterations in salinity levels were associated with major changes in vegetation: Lower Bayou Lafourche changed from brackish to saline marsh, and a region between the Mississippi River delta and Lake Pontchartrain changed from saline to brackish marsh. Comparison of vegetative type maps reveals that substantial changes in vegetative type occurred between 1948 and 1978 (see section on habitat types and changes). In general, the saline and brackish marsh area increased while intermediate and fresh marsh area decreased. Trends of increasing salinity may be a function of sea level rise, decreased river discharges, or the presence of canals that allow salt water to move farther inland.

METHODS

Habitat Characterization

The habitat characterization consists of a description of vegetative habitats and associated vegetation and wildlife for 15 habitat classifications. Areal extent or land cover of each habitat in 1956, 1978, and 1984 was calculated using the data base, and then portrayed on computer-generated maps (see procedure described below). A literature search was conducted for the habitat description and species composition. Lists of species found in the major habitats accompany the narrative.

Development of Habitat Data Base

The data base used to produce maps of the major habitats was produced by aggregating habitats described in the U.S. Fish and Wildlife Service coding system (see appendix I, table 1) (Cowardin et al. 1979) into simplified classifications for 1956 and 1978. Fifteen habitat classes were chosen because most coastal projects do not require the level of detail used in the Fish and Wildlife Service system. The aggregated habitats are natural water bodies, artificial water, aquatic vegetation, fresh marsh, intermediate marsh, brackish marsh, saline marsh, swamp, forest, shrub/scrub, shrub/scrub (spoil), agricultural/pasture, developed, unvegetated (called "inert" in the Fish and Wildlife Service system), and beach. For 1956, the marsh types were generalized into two categories: fresh and non-fresh. Table 1 in appendix I lists these major habitat types with their Fish and Wildlife Service codes. For 1984, habitat types were based on a modified level 1 land cover classification system (Braud and Streiffer 1987).

The 1956 and 1978 digital habitat data bases are based on approximately 540 1:24,000 maps which are referenced to the existing 7.5' U.S. Geological Survey topographic quadrangle base of coastal Louisiana. These maps were developed by photointerpretation of 1978 false-color infrared and 1951-1958 black-and-white aerial photographic coverage (scale 1:20,000-1:24,000) of coastal Louisiana. The photointerpreted habitat maps were then digitized by the U.S. Fish and Wildlife Service to serve as a digital data base for an environmental geographic information system. The coding system used to develop the habitat maps was adapted from Cowardin et al. (1979) and consists of a hierarchical structure used to identify wetland and nonwetland vegetative types, unvegetated habitat (such as spoil or beach), developed areas, oil- or natural gas-related habitats, and water habitat types (Wicker et al. 1980).

The Louisiana Department of Natural Resources, Coastal Management Division incorporated the habitat data into its vector-based geographic information system (the Map Overlay and Statistical System, or MOSS) to help analyze permit impacts, produce a variety of special projects, and conduct land change analysis. A modified Fish and Wildlife Service coding scheme used in the original habitat maps (Wicker et al. 1980) was aggregated to a simplified land cover classification system that was developed by consultants to and personnel of the Coastal Management Division for projects that did not require the level of detail inherent in the system used by Cowardin et al. (1979).

The Coastal Management Division also operates a satellite image processing system, the Earth Resources Data Analysis System, to obtain recent thematic coverage of coastal Louisiana. In 1986, the Coastal Management Division began developing a land cover data base from Landsat thematic mapper data for Louisiana's coastal zone. Raw satellite imagery of coastal Louisiana taken in December 1984 and January 1985 was used to develop the classified data base, which was completed in early 1987. The classification scheme was designed to adhere as closely as possible to that developed for the 1956 and 1978 habitat data so that the two data sets could be compared.

Because vector habitat data become more complex as the size of the area under study increases, comparing areas of more than a few thousand acres is best done with raster-based data. Therefore, the aggregated habitat data for 1956 and 1978 were converted to the raster-based system before they were compared with the classified 1984 data. In general, the comparisons were limited to areas ranging from several thousand to tens of thousands of acres.

Habitat Change

Habitat change statistics were generated from the data base by comparing the three years. The habitat loss analysis by hydrologic basin required that the 1978 habitat data and the 1984 data be compared by hydrologic unit in order to evaluate recent trends within the units. Several problems are inherent to any comparison of the 1978 and 1984 data: 1) misregistration between the data sets, 2) differences in the actual area covered by each data set, 3) differences in the classification method used to develop each data set, and 4) differences in weather and tidal conditions at the time each data set was obtained.

The misregistration between the 1978 and the 1984 data sets is a result of the photorectification process used to develop the habitat maps. Although the habitat maps are registered to each other, they do not register well with other digital maps. The 1984 data is registered to control points taken from 7.5' U.S. Geological Survey maps and does not register exactly with the habitat data. The comparison between the 1956 and 1978 (tables 14 and 15 and plates 1 and 2) data is more logical than the 1978-to-1984 comparison because the two earlier data sets were developed by the same method (photointerpretation), whereas the 1984 data were derived from satellite imagery (table 16 and plate 3).

Other problems also exist. The total area covered in all three years varies because the area interpreted was sometimes different. The areas covered for 1956 and 1978 are similar and both are smaller than that covered in 1984, because the legal description of the coastal zone boundary was altered between 1978 and 1987, the date of completion for the 1984 TMC data base. The present boundary encompasses a larger area than in 1978 (figure 42); this causes mismatches with some hydrologic units. The hydrologic units with the most missing 1956 and 1978 data are the Barataria, Ponchartrain, and Pearl basins. Habitat areas are also missing in the Atchafalaya, Sabine, Mississippi, Terrebonne, and Vermilion-Teche units. Some of the northern portions of the coastal zone were not interpreted, and some quads were not available for 1956 and 1978.

In addition to the boundary problem, some hydrologic units for which 1956 coverage exists are not covered for 1978. For example, the Mermentau unit has complete 1956 coverage for the Intracoastal City area but the same location is only partly covered in 1978. The 1956 aerial photography for the entire Intracoastal City 7.5' quadrangle was photointerpreted and digitized, but for some reason only the eastern half of the quad's 1978 photography was photointerpreted, causing a discrepancy of some 20,000 acres between the 1956 and 1978 data for that area.

Comparisons between years are further complicated because data from all three years contain different habitat classifications. For example, the 1956 data delineated marshes into fresh and non-fresh only, whereas in the 1978 data marshes were identified as fresh, intermediate, brackish, and saline. Water is a single category in 1984 rather than two (natural and artificial). Marsh is delineated into two categories in 1984: marsh, which includes saline, brackish, and inter-mediate; and broken marsh, which is an indication of stress. Shrub/scrub is one habitat type in 1984 rather than two (naturally occurring and spoil). In 1984 floating vegetation is a separate category. Mixed vegetation, a category specific to the 1984 data, refers to areas in which a single habitat could not be identified.

Because of classification differences between years, habitats were aggregated into water, marsh, and land for between-year comparisons. For the

Table 14. Areal extent of habitat types on the chenier plain, delta plain, and coastal zone of Louisiana in 1956, in acres (percentages in parentheses).

	Sabine	Calca	Mermen	Vermil	Chenier Plain Total	Atchaf	Terre	Baratar	Miss. R	Pont.	Breton	Pearl	Delta Plain Total	Coastal Zone Total
Inland water (natural)	34,664 (13)	70,271 (24)	129,703 (19)	310,156 (41)	544,795 (27)	183,100 (58)	442,220 (37)	304,683 (31)	144,374 (38)	1,358,196 (65)	397,968 (56)	1,618 (5)	2,832,159 (50)	3,376,954 (44)
Water (artificial)	1,368 (1)	3,507 (1)	8,358 (1)	6,039 (1)	19,273 (1)	3,026 (1)	8,586 (1)	21,401 (2)	5,967 (2)	13,411 (1)	5,324 (1)	54 (<1)	57,769 (1)	77,042 (1)
Fresh marsh	51,054 (20)	44,481 (15)	357,942 (54)	31,220 (4)	484,697 (24)	26,188 (8)	340,560 (28)	260,840 (27)	145,033 (39)	33,661 (2)	40,168 (6)	8,303 (25)	854,753 (15)	1,339,450 (17)
Non-fresh marsh	150,146 (58)	130,940 (45)	127,279 (19)	242,498 (32)	650,863 (33)	40,018 (13)	336,122 (28)	273,212 (28)	3,648 (1)	232,136 (11)	213,120 (30)	3,556 (11)	1,101,812 (19)	1,752,675 (23)
Forest	1,032 (<1)	341 (<1)	7,361 (1)	14,832 (2)	23,565 (1)	1,003 (<1)	15,525 (1)	32,246 (3)	5,611 (1)	105,079 (5)	15,262 (2)	4,890 (15)	179,617 (3)	203,183 (3)
Swamp	0 (0)	0 (0)	203 (<1)	40,013 (5)	40,217 (2)	49,732 (16)	46,840 (4)	33,131 (3)	13,658 (4)	195,005 (9)	14,090 (2)	8,668 (26)	361,123 (6)	401,340 (5)
Shrub/scrub	976 (<1)	435 (<1)	929 (<1)	10,233 (1)	12,572 (1)	392 (<1)	441 (<1)	2,254 (<1)	3,940 (1)	3,547 (<1)	839 (<1)	0 (0)	11,415 (<1)	23,986 (<1)
Shrub/scrub (spoil)	840 (<1)	1,864 (1)	3,710 (1)	2,023 (<1)	8,437 (<1)	2,629 (1)	4,842 (<1)	3,002 (<1)	598 (<1)	62 (<1)	295 (<1)	0 (0)	11,429 (<1)	19,866 (<1)
Agric/pasture	17,905 (7)	35,099 (12)	26,992 (4)	97,122 (13)	177,118 (9)	4,670 (1)	7,781 (1)	25,557 (3)	19,686 (5)	81,626 (4)	11,400 (2)	5,588 (17)	156,308 (3)	333,426 (4)
Developed	816 (<1)	2,809 (1)	3,036 (<1)	5,392 (1)	12,053 (1)	1,382 (<1)	1,365 (<1)	14,162 (1)	25,954 (7)	55,819 (3)	5,644 (1)	543 (2)	104,869 (2)	116,922 (2)
Aquatic vegetation	0 (0)	0 (0)	2 (<1)	10 (<1)	12 (<1)	0 (0)	312 (<1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	312 (<1)	324 (<1)
Unvegetated	712 (<1)	3,861 (1)	1,618 (<1)	2,713 (<1)	8,904 (<1)	2,660 (1)	2,706 (<1)	3,897 (<1)	7,575 (2)	3,053 (<1)	1,114 (<1)	44 (<1)	21,049 (<1)	29,954 (<1)
Beach	731 (<1)	299 (<1)	1,212 (<1)	701 (<1)	2,943 (<1)	0 (0)	2,163 (<1)	2,438 (<1)	292 (<1)	3,927 (<1)	491 (<1)	0 (0)	9,310 (<1)	12,253 (<1)
TOTAL AREA	260,244	293,908	668,345	762,950	1,985,447	314,801	1,209,463	976,823	376,336	2,085,524	705,714	33,264	5,701,927	7,687,374

Figures do not include 1,179,471 acres of offshore state waters within the coastal zone.

Table 15. Areal extent of habitat types on the chenier plain, delta plain, and coastal zone of Louisiana in 1978, in acres (percentages in parentheses).

	Sabine	Calca	Mermen	Vermil	Chenier Plain Total	Atchaf	Terre	Baratar	Miss. R	Pont.	Breton	Pearl	Delta Plain Total	Coastal Zone Total
Inland water (natural)	58,249 (22)	121,328 (41)	161,821 (24)	323,604 (42)	665,002 (33)	179,259 (57)	544,210 (45)	348,640 (37)	206,999 (55)	1,107,874 (61)	427,596 (61)	1,808 (5)	2,816,387 (52)	3,481,388 (47)
Water (artificial)	9,427 (4)	9,369 (3)	13,458 (2)	11,642 (2)	43,897 (2)	5,232 (2)	20,956 (2)	36,477 (4)	8,520 (2)	14,658 (1)	15,138 (2)	198 (1)	101,179 (2)	145,075 (2)
Fresh marsh	16,779 (6)	4,939 (2)	236,801 (35)	48,512 (6)	307,031 (15)	54,983 (17)	165,857 (14)	51,063 (5)	39,872 (11)	29,685 (2)	2,542 (<1)	2,603 (8)	346,605 (6)	653,636 (9)
Intermediate marsh	65,324 (25)	41,901 (14)	75,781 (11)	42,397 (6)	225,403 (11)	0 (0)	66,680 (6)	76,421 (8)	25,025 (7)	15,902 (1)	8,701 (1)	8,254 (25)	200,983 (4)	426,386 (6)
Brackish marsh	70,939 (27)	60,990 (21)	99,098 (15)	148,984 (19)	380,010 (19)	0 (0)	140,172 (12)	107,472 (12)	5,052 (1)	128,056 (7)	148,129 (21)	591 (2)	529,471 (10)	909,481 (12)
Saline marsh	4,498 (2)	4,706 (2)	15,287 (2)	6,389 (1)	30,881 (2)	0 (0)	152,402 (13)	156,927 (17)	2,147 (1)	62,494 (3)	50,194 (7)	0 (0)	424,164 (8)	455,044 (6)
Forest	813 (<1)	784 (<1)	6,614 (1)	17,651 (2)	25,862 (1)	2,089 (1)	16,788 (1)	28,483 (3)	7,444 (2)	101,263 (6)	12,399 (2)	5,248 (16)	173,715 (3)	199,577 (3)
Swamp	0 (0)	0 (0)	169 (<1)	37,032 (5)	37,201 (2)	53,387 (17)	34,237 (3)	23,698 (3)	12,000 (3)	171,637 (10)	1,751 (<1)	8,515 (26)	305,225 (6)	342,425 (5)
Shrub/scrub	1,935 (1)	816 (<1)	3,527 (<1)	10,193 (1)	16,471 (1)	2,012 (1)	12,176 (1)	5,703 (1)	2,330 (1)	8,277 (<1)	1,454 (<1)	73 (<1)	32,026 (1)	48,497 (1)
Shrub/scrub (spoil)	3,200 (1)	7,017 (2)	11,030 (2)	4,453 (1)	25,701 (1)	5,138 (2)	19,244 (2)	17,454 (2)	5,836 (2)	3,475 (<1)	17,124 (2)	0 (0)	68,272 (1)	93,973 (1)
Agric/pasture	14,370 (6)	32,990 (11)	43,053 (6)	98,985 (13)	189,398 (9)	5,506 (2)	10,940 (1)	29,767 (3)	12,942 (3)	46,758 (3)	6,229 (1)	1,662 (5)	113,804 (2)	303,202 (4)
Developed	1,962 (1)	4,486 (2)	4,912 (1)	10,665 (1)	22,025 (1)	2,143 (1)	4,416 (<1)	38,416 (4)	32,411 (9)	106,579 (6)	11,717 (2)	4,269 (13)	199,951 (4)	221,976 (3)
Aquatic vegetation	3,575 (1)	420 (<1)	1,694 (<1)	2,217 (<1)	7,905 (<1)	2,520 (1)	18,810 (2)	8,236 (1)	3,844 (1)	3,881 (<1)	366 (<1)	17 (0)	37,674 (1)	45,580 (1)
Unvegetated	8,465 (3)	3,849 (1)	6,186 (1)	1,511 (<1)	20,012 (1)	2,463 (1)	1,167 (<1)	3,603 (<1)	11,741 (3)	1,773 (<1)	2,292 (<1)	27 (<1)	23,066 (<1)	43,078 (1)
Beach	675 (<1)	292 (<1)	994 (<1)	578 (<1)	2,539 (<1)	37 (<1)	1,398 (<1)	1,098 (<1)	124 (<1)	1,930 (<1)	173 (<1)	0 (0)	4,761 (<1)	7,299 (<1)
TOTAL AREA:	260,212	293,887	680,425	764,814	1,999,336	314,770	1,209,454	933,458	376,286	1,804,243	705,807	33,265	5,377,282	7,376,619

Figures do not include 1,179,471 acres of offshore state waters within the coastal zone.

Table 16. Areal extent of habitat types on the chenier plain, delta plain, and coastal zone of Louisiana in 1984, in acres (percentages in parentheses).

	Sabine	Calca	Hermen	Vermil	Chenier Plain Total	Atchaf	Terre	Baratar	Miss. R	Pont.	Breton	Pearl	Delta Plain Total	Coastal Zone Total
Inland water	58,470 (22)	110,015 (37)	171,594 (25)	324,932 (42)	665,011 (33)	184,624 (58)	569,111 (47)	455,402 (37)	214,973 (54)	1,474,709 (61)	418,983 (59)	5,276 (12)	3,323,078 (53)	3,988,089 (48)
Broken marsh	64,205 (24)	47,256 (16)	82,254 (12)	31,833 (4)	225,550 (11)	9,302 (3)	166,077 (14)	160,975 (13)	14,135 (4)	36,836 (2)	39,164 (6)	1,149 (3)	427,640 (7)	653,190 (8)
Marsh	105,137 (40)	95,380 (32)	367,423 (54)	238,773 (31)	806,713 (40)	35,951 (11)	381,582 (32)	287,020 (23)	69,766 (17)	223,263 (9)	206,796 (29)	17,418 (40)	1,221,797 (19)	2,028,509 (24)
Forest	788 (<1)	710 (<1)	4,898 (1)	14,744 (2)	21,139 (1)	1,390 (<1)	14,040 (1)	48,792 (4)	14,576 (4)	240,107 (10)	13,042 (2)	5,199 (12)	337,146 (5)	358,285 (4)
Swamp	0 (0)	0 (0)	48 (<1)	33,004 (4)	33,051 (2)	52,573 (17)	22,514 (2)	117,611 (10)	4,237 (1)	201,844 (8)	1,227 (<1)	7,817 (18)	407,824 (6)	440,875 (5)
Shrub/scrub	1,559 (1)	1,915 (1)	4,968 (1)	17,173 (2)	25,615 (1)	10,418 (3)	28,341 (2)	18,656 (2)	2,861 (1)	8,728 (<1)	6,380 (1)	134 (<1)	75,517 (1)	101,132 (1)
Agric/pasture	16,327 (6)	25,713 (9)	34,641 (5)	102,397 (13)	179,077 (9)	6,621 (2)	12,250 (1)	92,379 (7)	30,192 (8)	77,909 (3)	6,409 (1)	1,169 (3)	226,928 (4)	406,005 (5)
Developed	252 (<1)	1,092 (<1)	657 (<1)	3,257 (<1)	5,258 (<1)	1,854 (1)	1,200 (<1)	32,918 (3)	27,219 (7)	93,863 (4)	10,902 (2)	3,012 (7)	170,969 (3)	176,227 (2)
Unvegetated	1,491 (1)	2,050 (1)	2,356 (<1)	449 (<1)	6,346 (<1)	5,652 (2)	699 (<1)	487 (<1)	21,913 (5)	6,644 (<1)	619 (<1)	86 (1)	36,102 (1)	42,448 (1)
Beach	132 (<1)	64 (<1)	931 (<1)	159 (<1)	1,285 (<1)	22 (<1)	862 (<1)	833 (<1)	46 (<1)	1,594 (<1)	160 (<1)	13 (<1)	3,530 (<1)	4,816 (<1)
Obscured by clouds	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5,671 (<1)	10,909 (1)	0 (0)	3,340 (<1)	210 (<1)	0 (0)	20,129 (<1)	20,129 (<1)
Floating vegetation	15,208 (6)	8,708 (3)	10,399 (2)	1 (<1)	34,315 (2)	1,198 (<1)	2,107 (<1)	349 (<1)	0 (0)	37 (<1)	0 (0)	0 (0)	3,690 (<1)	38,005 (<1)
Mixed vegetation	0 (0)	927 (<1)	415 (<1)	384 (<1)	1,726 (<1)	6,092 (2)	5,722 (<1)	6,725 (1)	1,239 (<1)	30,476 (1)	1,783 (<1)	1,846 (4)	53,882 (1)	55,608 (1)
Unclassified	0 (0)	0 (0)	4 (0)	140 (<1)	145 (<1)	68 (<1)	0 (0)	862 (<1)	0 (0)	0 (0)	0 (0)	0 (0)	930 (<1)	1,074 (<1)
TOTAL AREA:	263,569	293,830	680,587	767,247	2,005,232	315,765	1,210,176	1,233,916	401,157	2,399,352	705,676	43,120	6,309,162	8,314,394

Figures do not include 1,179,471 acres of offshore state waters within the coastal zone.

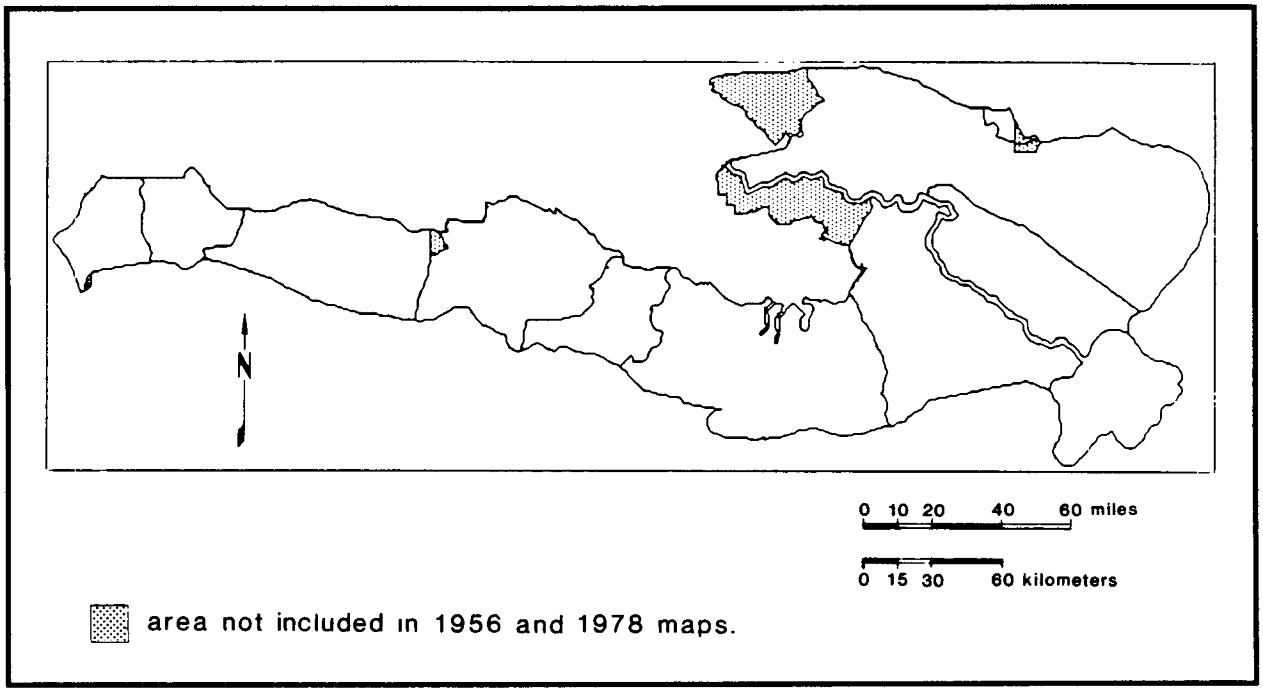


Figure 42. Louisiana coastal zone boundary for 1984.

1956-1978 change statistics, the water class includes water (natural), water (artificial), and aquatic vegetation; the marsh class includes fresh, non-fresh, intermediate, brackish, and saline marsh, and swamp; the land class includes forest, shrub/scrub, shrub/scrub (spoil), agriculture/pasture, unvegetated, and beach. For the 1978-1984 habitat change maps the classes are similar. The water class includes water and aquatic vegetation (primarily floating vegetation). The marsh class includes marsh and swamp. The land class includes forest, shrub/scrub, agriculture/pasture, developed, unvegetated, beach, and mixed vegetation. The broken marsh class is used only for the 1984 data and is described below. Areas obscured by clouds and those that could not be classified were deleted from the change analysis. Detailed description of these habitats are presented in the detailed report in appendix L.

Broken marsh represents wetlands, which are "wetter" than surrounding areas. The spectral signature of this class falls between those of water and marsh. Much of the broken marsh is believed to be stressed wetland, an area that is in the process of deteriorating. However, some broken marsh areas could be healthy if affected by winter dieback, or be in the early stages of colonization of mud flats. Time-series analysis of areas containing broken marsh has identified the development of new water bodies occurring within this class. This suggests that broken marsh can be used to identify areas of potential wetland loss. The broken marsh class is composed primarily of land but does contain some water; this is a result of the resolution of the satellite imagery and the presence of mixed spectral classes. Most of these broken marsh areas would have been coded as marsh (land) in the 1956 and 1978 data.

The resolution of the unclassified satellite imagery is 30 m. This presents problems when trying to classify canals, pipelines, and small ponds that are near the minimum resolution of the thematic mapper sensor. These mixed spectral classes represent boundary zones between the distinct classes, such as marsh and water, and may be included with a true broken marsh class (land class) because the spectral signatures are similar. Canals and small ponds are sometimes included with the broken marsh class rather than with the water. Because of these problems and the lack of an equivalent land cover class in the 1978 habitat data, broken marsh was considered a separate class on the 1978 and 1984 hydrologic unit change maps.

Variations in weather and tidal conditions at the time imagery is taken (either film or satellite) can cause variation in water levels which, in turn, can influence comparisons that are based on the data sets derived from the imagery.

Although there are several problems with using these different data sets for localized areas, they do provide a regional view of wetland change not available from any other source. The advantage of using a geographic information system to analyze land loss is that it will not only calculate wetland loss or gain but also show where the change is occurring. This facilitates making decisions about wetland management.

The MATRIX routine was used to create a nine-class change map by hydrologic unit for 1956 to 1978. This was done by comparing water, marsh, and land classes for each date. This technique was used again to create a 12-class change map for each hydrologic unit by comparing 1978 water, marsh, and land classes to 1984 water, broken marsh, marsh, and land classes. The recoded classes used to create each change map were aggregated to produce the most informative depiction. The broken marsh class was isolated because it is specific to the 1984 data. The change matrix was restricted to nine and twelve classes because a larger one would have generated a confusing number of classes and required excessive storage space on the computer system. In most cases, an analyst familiar with Louisiana's wetlands can, by examining the maps, determine the types of habitat changes taking place.

Salinity Trends

Trends of salinity change presented in the basin descriptions below are based on analyses from Wiseman and Swenson (1987). The methods used to analyze the data and a summary of each basin are presented in appendix L. We were not able to incorporate our analysis of vegetation change between 1978 and 1984 into this evaluation of salinity trends because the 1984 habitat data are classified only as marsh or broken marsh and not categorized by marsh type (e.g., saline, brackish, intermediate, fresh).

BASIN DESCRIPTIONS

The main factors influencing the species composition of coastal plant communities are elevation, hydrology, and salinity. Salinity is primarily controlled by hydrology. In Louisiana, higher salinities occur at the southern end of each hydrologic unit because of the proximity of the Gulf and the resultant higher tidal amplitude. The least favorable growing conditions for plants occur in this region of the hydrologic units because of the combined effects of salinity and flooding. Plant species such as *S. alterniflora*, which dominate these areas, are well adapted to the higher salinities and flood conditions. More favorable growing conditions for wetland plants occur at the upper end of the units where salinity is low, elevations are slightly higher, and flooding is less frequent. Consequently, plant diversity increases from the lower limits to the upper limits of each unit. Species composition at the lower end of the units seems to be controlled by physiochemical parameters, such as salinity and frequency of flooding, while the composition in the upper limits (in the swamp, for example) seems to be regulated more by biological competition (Bahr and Hebrard 1976). Plant communities in the upper basin are susceptible to salt stress if saline water encroaches farther inland.

Simple land cover (habitat) change statistics and maps were generated by comparing the 1956 and 1978 data and then the 1978 and 1984 data (tables 17 and 18, plates 4 and 5). For the purpose of simplification, the habitats were aggregated into three classes for 1956 to 1978 and four classes for 1978 to 1984. Detailed changes for each habitat are stored by hydrologic unit in the computer system, but are much too detailed for discussion here. The three habitat classes for 1956 to 1978 were water, land, and marsh; the four classes for 1978 to 1984 were water, land, marsh, and broken marsh.

Habitat Types and Changes in the Coastal Zone

Habitat descriptions for the coastal zone are based on the 1978 data set. Coastal habitat covered an area totaling 7.4 million acres in 1978 (table 15).

Table 17. Land cover change in each basin between 1956 and 1978, in acres (percentages in parentheses).

	Sabine	Calca	Mermen	Vermil	Chenier Plain Total	Atchaf	Terre	Baratar	Miss. R	Pont.	Breton	Pearl	Delta Plain Total	Coastal Zone Total
1956 water to 1978 water	88,050 (28)	104,394 (32)	256,362 (32)	408,086 (47)	856,893 (37)	258,473 (65)	618,829 (44)	481,912 (42)	385,710 (62)	1,510,703 (67)	405,568 (56)	1,304 (4)	3,662,498 (56)	4,519,391 (51)
1956 marsh to 1978 water	36,111 (12)	59,260 (18)	44,482 (6)	23,883 (3)	163,736 (7)	7,647 (2)	143,003 (10)	118,731 (10)	77,096 (12)	43,915 (2)	50,217 (7)	593 (2)	441,202 (7)	604,938 (7)
1956 land to 1978 water	914 (<1)	2,410 (1)	3,382 (<1)	4,270 (1)	10,976 (<1)	2,014 (1)	7,172 (1)	10,956 (1)	6,517 (1)	8,799 (<1)	3,461 (<1)	127 (<1)	39,046 (1)	50,022 (1)
1956 water to 1978 marsh	996 (<1)	1,544 (<1)	6,094 (1)	5,034 (1)	13,667 (1)	5,382 (1)	14,448 (1)	12,930 (1)	10,052 (2)	12,063 (1)	10,163 (1)	339 (1)	65,378 (1)	79,045 (1)
1956 marsh to 1978 marsh	152,787 (49)	106,201 (32)	409,378 (51)	283,128 (33)	951,494 (41)	102,788 (26)	549,894 (39)	397,510 (35)	71,627 (11)	396,210 (18)	197,559 (27)	19,345 (58)	1,734,934 (26)	2,686,428 (30)
1956 land to 1978 marsh	5,691 (2)	5,606 (2)	7,287 (1)	4,116 (<1)	22,701 (1)	2,206 (1)	7,178 (1)	10,789 (1)	4,737 (1)	7,664 (<1)	5,025 (1)	352 (1)	37,950 (1)	60,651 (1)
1956 water to 1978 land	783 (<1)	2,769 (1)	3,414 (<1)	2,033 (<1)	8,999 (<1)	3,386 (1)	2,839 (<1)	6,090 (1)	4,495 (1)	4,555 (<1)	3,798 (1)	29 (<1)	25,191 (<1)	34,190 (<1)
1956 marsh to 1978 land	13,272 (4)	10,392 (3)	32,490 (4)	16,938 (2)	73,092 (3)	5,883 (1)	31,023 (2)	53,176 (5)	17,540 (3)	24,082 (1)	20,414 (3)	591 (2)	152,709 (2)	225,801 (3)
1956 land to 1978 land	15,431 (5)	36,256 (11)	33,259 (4)	114,227 (13)	199,172 (9)	8,107 (2)	20,002 (1)	59,554 (5)	48,453 (8)	233,088 (10)	25,719 (4)	10,587 (32)	405,508 (6)	604,680 (7)
Area compared	314,034	328,833	796,148	861,715	2,300,730	395,886	1,394,387	1,151,648	626,226	2,241,079	721,924	33,266	6,564,416	8,865,147
Percentage change	(18)	(25)	(12)	(7)	(13)	(7)	(15)	(18)	(19)	(5)	(13)	(6)	(12)	(12)

Table 18. Land cover change in each basin between 1978 and 1984, in acres (percentages in parentheses). (Comparisons of the 1978 digitized map data from aerial photographs and the 1984 classified LANDSAT data do not always yield accurate results because of the differences caused by a slight misregistration of digital overlays and the difference in the nature of the data types. See text for detailed explanation.)

	Sabine	Calca	Mermen	Vermil	Chenier Plain Total	Atchaf	Terre	Baratar	Miss. R	Pont.	Breton	Pearl	Delta Plain Total	Coastal Zone Total
1978 water to 1984 water	108,106 (34)	144,233 (44)	279,892 (35)	411,960 (48)	944,190 (41)	255,662 (65)	676,866 (49)	537,157 (47)	428,593 (69)	1,517,106 (68)	416,468 (58)	1,021 (3)	3,832,873 (59)	4,777,063 (54)
1978 marsh to 1984 water	10,720 (3)	7,584 (2)	23,648 (3)	8,435 (1)	50,388 (2)	9,413 (2)	67,862 (5)	50,651 (4)	16,457 (3)	23,467 (1)	17,920 (2)	528 (2)	186,298 (3)	236,686 (3)
1978 land to 1984 water	5,427 (2)	1,763 (2)	5,936 (1)	2,273 (1)	15,399 (1)	1,732 (<1)	1,985 (<1)	3,468 (<1)	8,572 (1)	4,121 (<1)	653 (<1)	85 (<1)	20,615 (<1)	36,015 (<1)
1978 water to 1984 marsh	5,607 (2)	7,577 (2)	13,641 (2)	16,413 (2)	43,238 (2)	6,410 (2)	45,412 (3)	30,672 (2)	15,979 (3)	26,669 (1)	27,834 (4)	827 (2)	153,802 (2)	197,040 (2)
1978 marsh to 1984 marsh	92,304 (29)	75,071 (23)	342,345 (42)	257,555 (30)	767,274 (33)	89,617 (23)	375,183 (27)	249,548 (22)	53,674 (9)	332,686 (15)	179,940 (25)	18,065 (54)	1,298,713 (20)	2,065,987 (23)
1978 land to 1984 marsh	8,749 (3)	14,586 (4)	16,420 (2)	14,802 (2)	54,557 (2)	2,808 (1)	11,516 (1)	20,421 (2)	4,906 (1)	16,981 (1)	6,559 (1)	719 (2)	63,910 (1)	118,467 (1)
1978 water to 1984 broken marsh	11,015 (4)	13,690 (4)	10,245 (1)	6,113 (1)	41,063 (2)	1,389 (<1)	42,916 (3)	38,178 (3)	5,700 (1)	7,720 (<1)	13,052 (2)	111 (<1)	109,066 (2)	150,128 (2)
1978 marsh to 1984 broken marsh	50,128 (16)	29,756 (9)	67,736 (8)	24,320 (3)	171,940 (7)	7,721 (2)	121,458 (9)	115,988 (10)	7,740 (1)	28,218 (1)	25,608 (4)	715 (2)	307,448 (5)	479,388 (5)
1978 land to 1984 broken marsh	3,047 (1)	3,750 (1)	4,230 (1)	1,387 (<1)	12,415 (1)	185 (<1)	1,629 (<1)	2,145 (<1)	671 (<1)	657 (<1)	493 (<1)	10 (<1)	5,789 (<1)	18,204 (<1)
1978 water to 1984 land	392 (<1)	421 (<1)	922 (<1)	1,818 (<1)	3,552 (<1)	4,561 (1)	2,114 (<1)	3,069 (<1)	15,886 (3)	10,550 (<1)	1,643 (<1)	63 (<1)	37,886 (1)	41,439 (<1)
1978 marsh to 1984 land	9,523 (3)	7,847 (2)	7,836 (1)	7,565 (1)	32,771 (1)	8,665 (2)	15,134 (1)	14,670 (1)	14,326 (2)	33,979 (2)	6,286 (1)	723 (2)	93,784 (1)	126,555 (1)
1978 land to 1984 land	9,062 (3)	22,267 (7)	35,121 (4)	110,637 (13)	177,086 (8)	7,457 (2)	17,017 (1)	71,215 (6)	50,191 (8)	236,046 (11)	24,977 (3)	10,386 (31)	417,288 (6)	594,374 (7)
Area compared	314,080	328,545	807,970	863,278	2,313,873	395,619	1,379,092	1,137,182	622,696	2,238,200	721,431	33,253	6,527,473	8,841,346
Percentage change	(33)	(26)	(19)	(10)	(18)	(11)	(22)	(25)	(14)	(7)	(14)	(11)	(15)	(16)

Natural water is the most common habitat, covering 47% (3.5 million acres) of the coastal zone. Brackish marsh is the most common wetland (12% or 909,481 acres), followed by fresh marsh (9% or 653,636 acres), saline marsh (6% or 455,044 acres) and intermediate marsh (6% or 426,386 acres).

About 8.9 million acres of coastal zone were analyzed for land cover changes between 1956 and 1978 (table 17). Overall, there was a 12% change in land cover throughout the coastal zone during this period. The major changes were a 7% (604,938 acres) loss of marsh to water and a 3% (225,801 acres) loss of marsh to land. From 1978 to 1984, 8.8 million acres were analyzed, revealing a 16% land-cover change, half of which falls into the broken marsh class and 3% (236,686 acres) is a loss of marsh to water (see table 18). The most significant changes coastwide appear to be a loss of marsh to water and land. It should be noted that small changes in habitat (e.g., 1% or less) between 1978 and 1984 may not be real because of problems with misregistration and differences in water level when the imagery was taken.

Our database does not lend itself to analysis of changes in vegetative type (e.g., fresh to intermediate marsh) because of data format differences between the three years. However, comparison of vegetative type maps from 1948 (O'Neill 1949), 1968, and 1978 (Chabreck and Linscombe 1982) reveal that substantial changes in vegetative type occurred during that 30-year period. The trend was for saline and brackish marsh to increase in area while intermediate and fresh marsh decreased in area. Analysis of a new vegetative type map being produced from 1988 surveys indicates that the trends are continuing (Windham 1990). Chabreck and Linscombe (1982) reported that there was a net increase to more saline conditions on 5.6% of the total marsh area of the coast between 1968 and 1978. Our analysis of historical habitat change presented in the monitoring section of this report reveals a similar trend. Chabreck and Linscombe (1982) also reported that as the saline marsh zone expanded the brackish and intermediate marsh zones moved farther inland with little alteration in size. Hence, the expansion of the saline vegetative type occurred at the expense of the fresh marsh zone.

The following basin descriptions summarize data on habitat type, wetland loss, change in habitat type, and water salinity trends. Much of these data are from previously published sources except for the new analysis of habitat type and wetland loss.

Habitat Types and Changes on the Chenier Plain

According to 1978 habitat statistics, the chenier plain contains all habitat types and covers an area of 2.0 million acres or 27% of the coastal zone (table 15). Natural water is the most common habitat, and covers 33% of the area or 665,002 acres. Fresh marsh is the most common wetland (15% or 307,031 acres), followed by intermediate marsh (11% or 225,403 acres; see table 15), and agriculture/pasture (9% or 189,398 acres). Habitats that make up 1% or less of the chenier plain are saline marsh, forest, swamp, shrub/scrub (spoil), developed, aquatic vegetation, unvegetated, and beach.

About 13% of the land cover in the chenier plain changed between 1956 and 1978 (see table 17). The most dramatic change was a 7% loss of marsh to water (163,736 acres), followed by a 3% loss of marsh to land (73,092 acres).

The 1978-to-1984 change maps (see table 18) indicate that 18% of the land cover in the chenier plain had changed. The main reason for the apparent increase in habitat changes is the creation of the broken marsh class, in which 10% of the water, land, and marsh have converted to broken marsh. The biggest change during this period was a 7% (171,940-acre) loss of marsh to broken marsh, followed by a 2% (50,388-acre) loss of marsh to water a 2% gain of marsh from water (43,238-acre), and a 2% gain of broken marsh from water (41,063-acre). The class changes from water to marsh or broken marsh are probably a result of the different methods of interpretation between the two years. The 1984 interpretation is a more accurate method for delineating a specific land cover or habitat.

Sabine Basin

According to 1978 habitat data, the Sabine basin covers over 260,212 acres or 3.5% of the coastal zone. About 6% of Louisiana's coastal wetlands lie in this basin. The major difference in the total area between the 1956 and 1978 data and the 1984 data is an area of offshore water which is included only in the 1984 data set (see figure 42).

Natural water covers 28% (58,249 acres) of Sabine basin. The most common wetland habitat is brackish marsh, which covers 27% (70,939 acres) of the basin, followed by intermediate marsh (25%, 65,324 acres) (see table 15). Other habitats occupying 1% or less of the area include forest, shrub/scrub, shrub/scrub (spoil), developed, aquatic vegetation, and beach. There is no swamp in the basin.

Eighteen percent of the land cover in Sabine basin changed from 1956 to 1978. The major habitat change was a loss of marsh to water (12% or 36,111 acres) and a loss of marsh to land (4% or 13,272 acres). From 1978 to 1984 33% of the land cover changed. The major change was a 16% (50,128-acre) conversion of marsh to broken marsh and a 4% (11,015-acre) change from water to broken marsh. Other changes were a 3% loss of marsh to water, marsh to land, and land to marsh. Most of the changes occurred in the fresh marshes and aquatic vegetation of Sabine Refuge and in unvegetated areas west of the refuge. Other marsh loss occurred in intermediate marshes south of this area (plates 4 and 5). There was a net change to more saline vegetative types on 4.2% of the Sabine and Calcasieu River basins between 1968 and 1978 (Chabreck and Linscombe 1982).

There are no salinity stations in the coastal Sabine basin.

Calcasieu Basin

The Calcasieu Basin covered an area approximately of 293,887 acres or 3.9% of the coastal zone in 1978. About 4% of Louisiana's coastal wetlands lie in this basin. There are no major differences in area among the three years.

Natural water bodies cover 41% (121,328 acres) of Calcasieu basin. Brackish (21%; 60,990 acres) and intermediate marshes (14%; 41,901 acres) are the most common habitat types. Agriculture/pasture occupies 11% (32,990 acres) of the basin. There is no swamp; habitats occupying 1% or less of the area are forest, shrub/scrub, aquatic vegetation, unvegetated, and beach.

From 1956 to 1978, about 25% of the land cover of Calcasieu basin changed. The biggest change was an 18% (59,260-acre) loss of marsh to water. This change was the biggest proportional loss of marsh to water of any basin within the coastal zone. Another change was a 3% loss of marsh to land (10,392 acres).

From 1978 to 1984 a 26% land cover change occurred; the biggest change was from marsh to broken marsh (9%; 29,756 acres), followed by a 4% change of land to marsh and a 4% change of water to broken marsh. There is some true land gain in this basin, but some portion of what was measured may be a result of water level differences when the imagery was taken; misregistration, or misclassification of the imagery. There was a net change to more saline vegetative types on 4.2% of the Sabine and Calcasieu River basins between 1968 and 1978 (Chabreck and Linscombe 1982).

The Louisiana Department of Wildlife and Fisheries salinity station in the Calcasieu basin at Cameron shows that salinities have decreased over time, significant at the 95% level; the trend of the mean was -0.446 ppt/yr using the Kendall-Tau test on monthly means over a 17.4-yr period of record (Wiseman and Swenson 1987).

Mermentau Basin

The Mermentau basin covered an area about 680,425 acres or 9.2% of the coastal zone in 1978; this accounted for 15% of Louisiana's coastal wetlands. Differences in the total area are caused by missing data from the Intracoastal City area on the 1956 interpretation.

Water is the most common habitat type in Mermentau basin. The most common wetland habitats are fresh marsh (35%; 236,801 acres) and brackish marsh (15%; 99,098 acres). All habitat types are represented in this basin but seven of them occupy 1% or less of its area.

About 12% of the land cover in Mermentau basin changed from 1956 to 1978. The biggest change was a 6% loss of marsh to water (44,482-acre), followed by a 4% loss of marsh to land (32,490-acre).

During the 1978-1984 period about 19% of the land cover changed; 8% (67,736-acre) of the marsh changed to broken marsh and 3% of the marsh changed to water. Most of the habitat changes occurred in the fresh marshes between White Lake and Grand Lake and in the fresh marshes in the western portion of the basin (plates 4 and 5). There was a net change to more saline vegetative types on 5.6% of Mermentau River basin marshes between 1968 and 1978 (Chabreck and Linscombe 1982).

The Department of Wildlife and Fisheries station at Rockefeller North showed a decrease in salinity of -0.848 ppt/yr over a short (4.7-yr) period using the Kendall-Tau test on the monthly means (Wiseman and Swenson 1987). Results were significant at the 90% level. Rockefeller South did not show any statistically significant trends. Of the three Corps of Engineers stations, the trends in the means were significant at the 95% level at Mermentau River (a trend of -0.010 ppt/yr over a short period (3 yr)), were not significant at Schooner Bay, and were significant at the 95% level at Gulf Intracoastal Waterway at Vermilion Lock West (a trend of -0.024 ppt/yr over 19.6 yr).

Vermilion-Teche Basin

The Vermilion-Teche basin covered 764,814 acres or 10% of the coastal zone in 1978, and accounted for 10% of Louisiana's coastal wetlands. The differences in total area among years are due to a change in the coastal zone boundary in the northern section of the basin.

Water is the most common habitat in the Vermilion-Teche basin (42%; 323,604 acres). The most common wetland habitats are fresh marsh (35%; 236,801 acres) and brackish marsh (19%; 148,984 acres). Agriculture/pasture occupies 13% (98,985 acres), the largest proportion of any basin in the coastal zone. Although all habitats are represented in this basin, seven of them each cover 1% or less of its area.

Vermilion basin had the smallest change in land cover (7%) in the chenier plain between 1956 and 1978. The biggest change was a 3% (23,883-acre) loss of marsh to water and a 2% (16,938-acre) loss of marsh to land.

From 1978 to 1984 a 10% change in land cover occurred. The biggest change was a 3% change of marsh to broken marsh (24,320-acre) and a 2% change of land to marsh (16,413-acre). These changes are concentrated in the brackish marshes west of Vermilion Bay and in the intermediate and brackish marshes northwest of Vermilion Bay (see plates 4 and 5). Some of the changes from land to marsh also occur around impounded areas used for agriculture, especially rice fields that were coded as agriculture/pasture in 1978 and registered as marsh in 1984. There may also be some misclassification and misregistration at spoil banks. The wetland habitats of Vermilion-Teche basin changed to slightly fresher conditions between 1968 and 1978 (Chabreck and Linscombe 1982). The eastern portion of the basin near the Atchafalaya River changed to less saline conditions and the western portion of the basin near Freshwater Bayou Navigation Canal changed to slightly more saline vegetative types.

Neither of the Department of Wildlife and Fisheries salinity stations in the Vermilion-Teche basin (Cypremort Point and Southwest Pass) showed statistically significant trends in monthly means (Wiseman and Swenson, 1987). All three Corps of Engineers stations showed statistically significant trends at the 95% level of monthly means, with two stations decreasing and one increasing in salinity. Salinities showed decreases of -0.008 ppt/yr at Charenton Drainage Canal at Baldwin over 29 years and -0.067 ppt/yr at Cypremort Point over 24.3 years. Mean monthly salinities increased by 0.039 ppt/yr on the Gulf Intracoastal Waterway at Vermilion Lock East over 29.1 years.

Habitat Types and Changes on the Delta Plain

The delta plain covered 5.4 million acres or almost 75% of the land area of the coastal zone in 1978. This number does not include offshore waters that are a part of the coastal zone. Natural inland water is the most common habitat, covering 52% (2,816,387 acres) of the area, followed by brackish marsh at 10% or 529,471 acres, and saline marsh at 8% or 424,164 acres.

Habitat changes from 1956 to 1978 in the delta plain are given in table 17. An area comprising 6.6 million acres was compared for these two years. Twelve percent of the land cover changed between 1956 and 1978. The most significant changes were a 7% loss of marsh to water (441,202-acre) and a 2% (152,709-acre) loss of marsh to land. From 1978 to 1984 about 6.5 million acres were compared and 15% of the land cover changed. The biggest change was from marsh to broken marsh (5%; 307,448 acres) and a 3% loss of marsh to water (186,298-acre).

Atchafalaya Basin

The Atchafalaya basin covered an area of about 314,770 acres or 4.3% of the coastal zone in 1978. This basin contains 15% of Louisiana's coastal wetlands. The main differences in basin area among the years are a change in the coastal zone boundary in the northern part of the basin.

More than one-half (57%; 179,259 acres) of this basin is covered by water. The most common habitats are swamp (17%; 53,387 acres) and fresh marsh (17%; 54,983 acres). There are no intermediate, brackish, or saline marshes in the basin. Six of the habitats cover 1% or less of the basin's area.

The Atchafalaya basin had one of the smallest land cover changes (7%) from 1956 to 1978. The greatest change was a loss of marsh to water (2%; 7,647 acres). All other changes were approximately 1% each.

From 1978 to 1984, 11% of the land cover changed. Trends for this period are fairly evenly distributed: there were 2% losses each of marsh to water, marsh to land, and marsh to broken marsh. There was a 2% gain of marsh from water, and a net loss of marsh in the basin. The greatest marsh-to-water changes occurred in the swamp and fresh marshes in the northeastern portion of the basin --the Bateman Island and Avoca Island area. Water-to-land and water-to-marsh changes occurred in the Atchafalaya and Wax lakes deltas, where mudflats--classified as land--have been accreting. There was no change in vegetative type in the Atchafalaya basin between 1968 and 1978 because of the overwhelming influence of freshwater input from the Atchafalaya River (Chabreck and Linscombe 1982).

Two of three Corps of Engineers stations showed increasing monthly mean salinities and one showed decreasing salinity: 1) at Wax Lake Outlet the salinity was increasing but the trend was negligible (0.000 ppt/yr over a 17-year period of record, significant at the 95% level); Lower Atchafalaya River at Morgan City showed a decreasing trend, also of negligible magnitude (0.000 ppt/yr over an 18-year period, significant at the 95% level); and 3) Atchafalaya Bay at Eugene Island showed an increasing trend of 0.131 ppt/yr over about 9 years (significant at the 90% level) (Wiseman and Swenson 1987).

Terrebonne Basin

Terrebonne basin covered an area of about 1.2 million acres or 16.4% of the coastal zone in 1978. The greatest proportion (20%) of Louisiana wetlands lie in this basin. The differences in basin area among years are accounted for by water along the southern end of the basin that was not included in 1956 and 1978 but was added for the 1984 data base.

Almost half (45%; 544,210 acres) of the basin is natural water habitat. The most common wetland habitats are fresh (14%; 165,857 acres), saline (13%; 152,402 acres), and brackish marsh (12%; 140,172 acres). Eight of the habitats cover 1% or less of the basin's total area.

Terrebonne basin was one of the largest areas (1.4 million acres) compared between 1956 and 1978, and it had a 15% land cover change. The biggest change was a 10% loss (143,003-acre) of marsh to water--the largest marsh-to-water loss in any basin. There was also a 2% (31,032-acre) loss of marsh to land during this period.

From 1978 to 1984, about 22% of the land cover changed. The biggest change was a 9% (121,458-acre) loss of marsh to broken marsh. There was also a 5% loss of marsh to water (67,862-acre). Most of the changes are occurring in brackish and intermediate marshes east of Chauvin and west of Gallaino. Another area where marsh is being lost to water is in the fresh marshes south of Bayou Black. Broken marsh areas are scattered throughout the basin; a concentration of marsh loss to water occurs in the intermediate and brackish marshes south of Bayou Black. There was a net change to more saline vegetative types on 10.1% of the Terrebonne basin between 1968 and 1978 (Chabreck and Linscombe 1982). Most of the change in vegetative type occurred in the eastern and central portions of the basin, particularly in the vicinity of the Houma Navigation Canal. In western Terrebonne basin, however, the net change in vegetative type was to more fresh marsh types.

Neither the Department of Wildlife and Fisheries stations in the Terrebonne basin (Cocodrie and Caillou Lake Camp) nor the Corps of Engineers station (Bayou Grand Cailliou at Dulac) showed statistically significant salinity trends in their monthly means (Wiseman and Swenson 1987). The Corps of Engineers salinity station on the Gulf Intracoastal Waterway at Houma showed an increasing monthly trend in means (0.002 ppt/yr over 30.8 yr, significant at the 95% level).

Barataria Basin

Barataria basin covered an area of about 933,458 acres in 1978 or 12.7% of the coastal zone. Fifteen percent of Louisiana's coastal wetlands lie in this basin. A large difference in the area of this basin in 1984 is due to a major change in the coastal zone boundary. In addition, data for some northern portions of the basin were not interpreted for the 1956 and 1978 maps. Most of the additional area is covered by agriculture/pasture, swamp, and some forest. Other differences, obvious on tables 14, 15, and 16, are the result of a more detailed interpretation of swamp and forest habitat in the New Orleans area in 1984.

Thirty-seven percent of Barataria basin is covered by natural water. The most common habitat types are saline marsh (17%; 156,927 acres) and brackish marsh (12%; 107,472 acres). Shrub/scrub, aquatic vegetation, unvegetated, and beach habitats cover 1% or less of the total area.

A large area (1.2 million acres) was compared for land cover changes between 1956 and 1978 in Barataria basin. During this period 18% of the land area changed. The greatest change was a 10% (118,731-acre) loss of marsh to water and a 5% (53,176-acre) loss of marsh to land.

From 1978 to 1984, 1.1 million acres were compared for land changes. During this period there was a 25% change in land cover, including a 10% (115,988-acre) change of marsh to broken marsh and a 4% (50,651-acre) loss of marsh to water. Between 1968 and 1978, there was a net change to more saline conditions for 17.2% of the total marsh area of Barataria basin (Chabreck and Linscombe 1982).

The Department of Wildlife and Fisheries station at Grand Terre showed salinities decreasing at a rate of -0.228 ppt/yr over 26.3 yr (95% significance level), whereas the station at St. Mary's Point showed no significant trend (Wiseman and Swenson 1987). Two of the four Corps of Engineers stations in Barataria basin, Galliano and Bayou Barataria at Barataria, showed no significant trends. Bayou Lafourche at Leeville showed a positive trend (significant at the 95% level), with salinities increasing at a rate of 0.156 ppt/yr over 21.8 yr. Bayou Lafourche at Larose, in contrast, showed a negative trend of -0.003 ppt/yr over about 30 years (significant at the 90% level).

Mississippi River Basin

The Mississippi River basin covered an area of about 376,286 acres or 5.1% of the coastal zone in 1978. About 3% of Louisiana's coastal wetlands lie in this basin. The differences in total coverage are due to the elimination of the northern part of the river corridor in 1956 and 1978.

About 55% of this basin is covered by natural water. The most common wetland habitat is fresh marsh (11%; 39,872 acres), developed (9%; 32,411 acres), and intermediate marsh (7%; 25,025 acres). Five of the basin's habitats cover 1% or less of its total area.

From 1956 to 1978 about 19% of the land cover changed in the Mississippi River basin. The biggest change, 12% (77,096 acres), was a loss of marsh to water, followed by a 3% (17,540-acre) loss of marsh to land.

From 1978 to 1984, a 14% change in land cover occurred in this basin. The largest changes were a 3% (16,457-acre) loss of marsh to water, a 3% (15,886-acre) gain of land from water, and a 3% (15,979-acre) gain of marsh from water. This is the only unit in which broken marsh is not the predominant land cover change, presumably because of sediment input to the interdistributary bays. Much of the land gain from water occurs along the outer edges of Southwest Pass as spoil. Marsh is being lost in the fresh marshes east of the Mississippi River between North and Main passes and north of Main Pass. True land gain is occurring as mudflats and marsh gain in fresh marshes. However, some of the land gain may be only apparent because of misregistration and differences in water levels.

Neither of the Corps of Engineers stations in the Mississippi River basin, (the Mississippi River at Port Sulphur and The Jump) displayed a significant salinity trend (Wiseman and Swenson 1987).

Pontchartrain Basin

The Pontchartrain basin, the largest basin within the coastal zone, covered an area of almost 2 million acres or 24.5% of the coastal zone in 1978. Fifteen percent of Louisiana's coastal wetlands lie in this basin. The major discrepancies in area coverage in this basin are the result of the elimination of a large area of Livingston Parish in 1956 and 1978; this area was not photointerpreted. Most of the additional land area in the 1984 data consists of bottomland hardwoods, swamp, and upland pines and some agriculture/pasture and developed areas.

Natural water covers 61% of the area of the Pontchartrain Basin. The most common wetland habitats are swamp (10%; 171,637 acres) and brackish marsh (7%; 128,056 acres). Seven habitats cover 1% or less of the total basin area. The Pontchartrain basin has the most developed land area (106,579 acres) of all the basins, although the Pearl River has the largest proportion of its basin developed.

The Pontchartrain basin had the largest area compared (2.2 million acres) between 1956 and 1978, and the least (5%) land cover change. The biggest change was a 2% (43,915-acre) loss of marsh to water.

The smallest (7%) land cover change occurred over the 2.2 million acres of this basin for the 1978-to-1984 period. The largest change was a 2% (33,979-acre) loss of marsh to land with 1% changes each in loss of marsh to water and to broken marsh, and 1% change each in a gain of marsh from water and land. Marsh-to-land changes occurred in shrub/scrub and brackish marshes in the New Orleans East area and in intermediate and fresh marshes and swamp west of New Orleans. Marsh was lost to water in localized areas of swamp and intermediate and fresh marshes throughout the basin, especially around Lake Pontchartrain; however, this may be a result of misregistration in the imagery and differences in water levels. Loss of marsh to water occurs in the same areas as change of marsh to broken marsh (plates 4 and 5). Land-to-marsh changes are probably a result of agricultural fields in 1978 being mistaken for marsh in 1984 because their spectral fields are similar. Both Lake Pontchartrain and Breton Sound basins exhibited a small net change towards less saline conditions between 1968 and 1978 (Chabreck and Linscombe 1982). However, vegetative types reflected increased water salinities in the vicinity of the Mississippi River Gulf Outlet in both basins.

Three salinity stations in the Pontchartrain basin are monitored by the Louisiana Department of Wildlife and Fisheries, but none of them showed a significant trend in monthly means when the Kendall-Tau test was applied (Wiseman and Swenson 1987). Three of six salinity stations in this basin monitored by the Corps of Engineers, including the Gulf Intracoastal Waterway at Paris Road, Chef Menteur Pass near Lake Borgne, and the Mississippi River Gulf Outlet at Navigation Light #101, show no significant trend in monthly means. Three stations do show increasing salinities: 1) Lake Pontchartrain North Shore, with rates of 1.992 ppt/yr over only 3.8 years (significant at the 95% level); 2) Little Woods, with rates of 0.086 ppt/yr over 31.9 years, (significant at the 95% level); and 3) The Rigolets near Lake Pontchartrain, with rates of 0.039 ppt/yr over 24.2 years (significant at the 90% level). Of all the basins in the coastal zone, the Pontchartrain shows the most significant trend of increasing salinity.

<u>Breton Sound Basin</u>

Breton Sound basin covered an area of about 705,807 acres or 9.6% of the coastal zone in 1978. Seven percent (211,856 acres) of Louisiana's coastal wetlands lie in Breton Sound basin. There are no major differences in area among the three years.

Natural water is the most common habitat type, covering 61% (427,596 acres) of the total area. The most common wetland habitat types are brackish (21%; 148,129 acres) and saline marsh (7%; 50,195 acres). Eight habitats cover 1% or less of the total area of the basin.

From 1956 to 1978 about 13% of the land cover in Breton Sound basin changed. The biggest changes were a 7% (50,217-acre) loss of marsh to water and a 3% (20,414-acre) loss of marsh to land.

From 1978 to 1984, a 14% change in land cover occurred. The largest changes were a 4% (27,834-acre) gain of marsh from water and a 4% (25,608-acre) change from marsh to broken marsh. Marsh gain is occurring evenly in the south and central brackish and saline marshes of the basin; the loss of marsh is occurring in the brackish marshes in the northern portion of the basin near Meraux and St. Bernard. Other marsh is being lost in the brackish marshes around Lake Lery. Both Lake Pontchartrain and Breton Sound basins exhibited a small net change towards less saline conditions between 1968 and 1978 (Chabreck and Linscombe

1982). However, vegetative types reflected increased water salinities in the vicinity of the Mississippi River Gulf Outlet in both basins.

Breton Sound basin has four salinity stations monitored by the Louisiana Department of Wildlife and Fisheries, two of which (Long Bay and California Bay) show no significant trend in monthly means (Wiseman and Swenson 1987). Bay Gardene shows a negative trend (significant at the 95% level) with salinities decreasing at a rate of -0.344 ppt/yr over 12.3 years. Sable Island shows increasing salinities of 0.870 ppt/yr over a short (4.8 years) period (significant at the 90% level).

Pearl River Basin

The Pearl River basin covered an area of about 33,000 acres in 1956 and 1978, or less than 1% of the coastal zone. Only 1% of Louisiana's wetlands lie in this basin. In 1984 its area was 43,000 acres. The differences are related to northern and eastern portions which were not included in the 1956 and 1978 data. All of this habitat is either marsh or open water.

The Pearl River basin is the only basin in which natural water is not the most common habitat; it covers only 5% (1,808 acres) of the basin. The most common habitats are swamp (26%; 8,515 acres), intermediate marsh (25%; 8,254 acres), and forest (16%; 5,248 acres). This basin has the largest proportion of land area covered by development (13%). There are no saline marsh, shrub/scrub (spoil), or beach habitats. Four other habitats cover 1% or less of the total area.

Pearl River basin had a 6% change in land cover from 1956 to 1978. The largest change was a 2% (593-acre) loss of marsh to water and a 2% (591-acre) loss of marsh to land.

From 1978 to 1984, an 11% change in land cover occurred. A 6% total loss of marsh to water, broken marsh, and land occurred and a 4% gain of marsh from water and land occurred. Changes from water to marsh and land to marsh are due mostly to misregistration, misclassification of the imagery, and differences in water levels when the imagery was taken.

There are no salinity stations in the coastal Pearl River basin.

Threatened and Endangered Species

Because threatened and endangered species are present in the coastal zone, detailed information on these species are presented in appendix L. Generalized locations of threatened and endangered animals, plants, and waterbird colonies in each hydrologic unit are shown in plate 6. Exact locations of the habitats for these species are available through the Natural Hertiage Program at the Louisiana Department of Wildlife and Fisheries.

Chapter 7

MARSH MANAGEMENT PLAN PROFILE

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INTRODUCTION

Interest in managing and preserving Louisiana's coastal wetlands began in the early part of this century with the establishment of state and federal wildlife refuges. Today, there are 17 wildlife refuges and management areas located wholly or partially in Louisiana's coastal zone, all but one of which is government owned and operated (table 1, appendix J). These government-owned and operated refuges encompass approximately 850,000 acres of coastal habitat (10% of all coastal habitat in 1984; see table 16). Wetlands in state and federal refuges may be managed by structural and/or nonstructural means or the refuge may function simply as a preserve for wetland habitat. Fourteen of the 17 refuges use structural management on at least some portions of their property.

Management of privately owned wetland habitat (90% of all coastal wetland habitat) has become increasingly popular during the past several decades. In the 1940s, private landowners began testing methods to improve their wetland habitats and resources. From the 1940s until 1980, the Soil Conservation Service helped private landowners develop plans to manage nearly 350,000 acres of wetland habitat (approximately 4% of all privately owned wetland habitat). The majority of these plans have not been implemented.

In 1980, the State of Louisiana implemented a coastal wetlands regulatory program through the creation of the Coastal Management Division in the Department of Natural Resources. Activities in wetlands, such as structural marsh management, must now be permitted by the state and the federal government (see chapter 3 for a description of the permit process). Since 1980, the Coastal Management Division has received 165 applications to manage 503,000 acres of coastal wetland habitat (approximately 6% of privately owned habitat). The Soil Conservation Service continues to advise and assist private landowners in preparing applications; hence that agency plays an influential role in the development of marsh management plans in Louisiana.

The locations of state and federal refuges, plans developed by the Soil Conservation Service before 1980, and 161 applications to the state and federal government for new management plans are presented in plate 7. A description of each of these data sets is provided in appendix J.

As part of the description of environmental conditions of the coastal zone, this chapter analyzes private marsh management projects permitted by the state since 1980. The analysis is based on permit application data on file at the Coastal Management Division, the Department of Natural Resources, in Baton Rouge, Louisiana. This evaluation will provide an overview of marsh management in coastal Louisiana: where it is occurring (geographic province, basin, and marsh type), for what purpose (e.g., land loss, waterfowl, wildlife), and how it is being accomplished (e.g., structures). Information concerning the influence of the regulatory procedures described in chapter 3 on the design of the final management plan can be gleaned from this analysis, but this is not the primary purpose of this section of the report. Hence, quantification of the Corps of Engineers' regulatory procedures, quantitative comparison of the Corps of Engineers and state regulatory procedures, and a complete quanitification of state regulatory procedures are not presented. Although this information is worthy of investigation, it is beyond the scope of this report.

METHODS

The Coastal Management Division file data base was the source of all plans included in the data base and it also supplied much of the descriptive information used to compile this management plan profile. The Coastal Management Division has kept files (computer and paper) since 1980 on all activities performed in the coastal zone that have required permits.

One variable in the computer file identifies the type of activity permitted. Because agriculture (i.e., pasture) or aquaculture in the coastal zone may require some form of structural management and may be one purpose of a marsh management plan, all permits relating to agriculture, aquaculture, or marsh management were selected to provide the data base from which an informational profile of marsh management projects could be developed.

Variable Descriptions

After permits related to marsh management were identified, sixteen variables relating to each permit were drawn directly from the computer data base:

Corps of Engineers no.
applicant name
parish
7.5' quad no.
section
township
range
latitude
longitude
permit status
issue date
commencement date
cross-reference number(s)
cubic yards of dredge and fill
size of directly impacted area.

These variables were extracted in the form shown in table 19 and provide basic data pertaining to each permit. Many of these variables are understandable without explanation, but some basic information should be presented about a few. The Corps of Engineers number is the number assigned by the U.S. Army Corps of Engineers to that permit application. (The Corps of Engineers and

Table 19. Page 1 of the database codesheet used for the marsh management profile. These variables were extracted directly from the Coastal Management Division computer data base.

---

a. CUP#/______________/

b. Corps of Engineers#/____/

c. Permittee Name/____/

d. Parish/____/

e. Quad#/________/

f. Sec.-Twn.-Rng./_____-_____-_____/

g. Lat.;Long./___-___-___/;/___-___-___/

h. Permit Status and Date/___/ /___-___-___/

i. Commencement Date/___-___-___/

j. See Also (other CUP#'s associated with this Plan or Plan Area)

/________/, /________/, /________/, /________/

k. Cubic Yards of Dredge and Fill/____,____,____/

l. Size of Directly Impacted Area/____,____/(acres)

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the Coastal Management Division do not use the same numbering system). Not all Corps of Engineers/Coastal Management Division permits are Joint Notices, and not all activities permitted by Coastal Management Division are under Corps of Engineers jurisdiction; therefore the Coastal Managementl Division's coastal use permit numbers (CUP#) do not always have corresponding Corps of Engineers numbers. Permit status refers to whether the permit is under review, issued with no conditions, issued with special conditions, withdrawn, denied, etc. The permit status is accurate as of May 15, 1989. The cross-reference variable refers to other permit numbers to which a permit may be somehow related.

Twenty other variables were identified for inclusion in the management plan data base (table 20). Most of these have been divided into subclasses. They were selected because they describe the management plan habitat, the activities and goals for which the plan was designed, or the structures used to manage the marsh. Information about most of these variables came from the permit application, maps of the management area drawn by the Coastal Management Division field personnel, descriptions of the area made by the Coastal Management Division field personnel, vegetative maps, or after consulting with the Coastal Management Division personnel. Data pertinent to these 83 subclasses of variables were coded onto a data sheet and entered into the management plan data base in the Coastal Management Division's computer in the form shown in table 20. These data are current as of May 15, 1989.

Each variable is described below in the order of its appearance in the data set.

1. **Map ID.** This variable is a number assigned by the Coastal Management Division when the management area is digitized into its computer. It allows the management plan to be identified on the maps produced by the Coastal Management Division, which show parish boundaries, major hydrographic features, and boundaries of each management plan for which application has been made.

2. **CUP.** This character variable is the same as the Coastal Management Division's coastal use permit number. The first two digits of this number refer to the year the application was received.

3. **Size.** Numeric variable identifying the area, to the nearest acre, of the plan. In most cases this was taken directly from digitized plan boundaries in the Coastal Management Division's computer data base used to create the map described above. If a permit clearly concerned a fraction of the digitized plan, if there was an obvious error in digitizing, or if the plan had not been digitized, the acreage was estimated by dividing the area into rectangles and triangles and using the appropriate formula for area calculations. The estimated values are considered to be accurate to within 5%; this is based on checking done on five areas of known acreage. These figures should be replaced by digitized acreage as they are available.

4. **SCS plan.** Character variable referring to the Soil Conservation Service identification number for those plans associated with the Soil Conservation Service. This information came either from the Coastal Management Division's computer data base, the parish maps completed by the Soil Conservation Service for the Coastal Management Division showing overlays of the marsh management plans, or from the 7.5' quad maps with designations by the Soil Conservation Service in the Coastal Management Division's map room.

Table 20. Page 2 of the marsh management codesheet used for the marsh management profile.

---

1. Map ID #/__________/ 2. CUP#/____________/ 3. Size/___,___ acres

4. SCS Plan#/____/____/ 5. No. Units/______/

6. Major Habitat Types: (acres by type)

Swamp	Fresh M.	Inter. M.	Brack. M.	Saline M.	Open W.
/__,___/	/__,___/	/__,___/	/__,___/	/__,___/	/__,___/

7. Vegetation (4 Dominant Species and % cover)

1/__________/___/, 2/__________/___/, 3/__________/___/,

4/__________/___/

8. Soil Types in Plan Area

/____________/, /____________/, /____________/, /____________/

9. General Activity Type

Access Control	Water Control	Harvest Tech.	Dredging	Endangered Species	Non-Struct.
/_____/	/_____/	/_____/	/_____/	/_______/	/_____/

Maintain.

/______/

10. Main Plan Goals: (rank by goal type, 1-4)

Comments/______________________________________/

Land Loss	Watr Fowl	Fur Bear	Indig Wild	Indig Fish	Imprv Access	Anti Tresp	Multi Use	Aqua
/__/	/__/	/__/	/___/	/___/	/___/	/___/	/___/	/__/

Agri	Mari
/__/	/__/

Table 20. Page 2 of the marsh management codesheet used for the marsh management profile (continued).

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11. Structural and Linear Components:

FC VC FG PM PG FV SF FL DG CL CG BK WS

(# by type)

(length in mi. by type) LE/___.___/; LR/___.___/; LP/___.___/; TR/___.___/

12. Water Control Operation Schedule (see codes): /________/

13. Monitoring Effort (# of stations by category) # years/________/

Water Y or N

Salin; Level; Qual; Veg; Sedim; Soil Chem; Nut. Cyc; L loss; Fish;

/___/; /___/; /__/; /__/; /___/; /__/; /__/; /_______/; /_____/; /

/;

Wildl;

/___/;

14. See Also (other CUP's in this Plan or Plan Area)

/______________/, /______________/, /______________/, /______________/

15. This plan is mitigation for CUPNO./______________/

16. Hydrologic Unit/______________/

17. Physiographic Unit/______________/

18. Endangered Sp./______________/

19. Archeological Site/______________/

20. Primary Habitat/______________/

It consists of a three-digit parish code followed by a two-digit plan number, separated by a slash (/).

5. **No. units.** The number of distinct contiguous management areas associated with a plan. This numeric variable was discerned from the management plan description or plan maps.

6. **Major habitat types.** Provides acreage by major habitat types. Types specified are freshwater swamp, freshwater marsh, intermediate marsh, brackish marsh, saline marsh, and open water. This acreage was estimated as a percentage of the plan area by using a combination of the 1978 habitat transparencies, 7.5- minute quad maps, and the aerial photographs closest to the permit approval date. The sum of the acreage for each marsh type often will not equal the size variable because most plans have spoil banks, upland areas, or other habitats in addition to those identified above.

7. **Vegetation.** DOMSP1, DOMSP2, DOMSP3 and DOMSP4 refer to the most dominant, and the second-, third-, and fourth-most-common vegetative species, respectively. PC1 through PC4 refer to the percentage cover for those species identified in the variable DOMSP1-4. Those species identified were dominant in the nonwater habitats only. This information was determined from field investigations done by the Coastal Management Division or the Soil Conservation Service field biologists. Care was taken to use investigations of the entire area, not just those of the structure sites. This information was not available for all permits.

8. **Soil types in plan area.** SOIL1-4 has not been developed because the data are not available in the file for the specific site. This can be input later as either a code identifying the soils present, or a code identifying the dominant soil type and the percentage of area covered by that type.

9. **General activity type.** This variable identifies seven general activities that may be associated with a plan. Activity type was determined primarily from the permit description. When an activity was identified with a plan, an X was placed in the code sheet referring to that activity type. More than one activity may be associated with a plan, and there is no relative importance identified between types when more than one has been identified for a plan. A_ACCESS refers to activities designed to facilitate or decrease access to a management area. Such activities covered by A_ACCESS include trenasse digging or cleanup, road building, blockade construction across waterways, and fences. A_WATER refers to activities designed to control the hydrology of an area. Activities included under A_WATER are the construction of water control structures, levees, and/or spoil banks. A_HARTQ refers to activities related to aquaculture or mariculture. This activity type was checked only when harvesting techniques were a major part of the plan. A_DREDG refers to dredging activities. This variable identified plans in which dredging was a significant part of the plan, or produced a significant quantity (>1000 yd^3) of dredge and fill material. A_ENDSP identified plans where management for an endangered species was a major element in a plan. This variable has not yet been used. A_NONST code is used when other than structural elements are a major part of a plan; this includes activities such as prescribed burning and vegetative plantings. A_MAINT refers to maintenance of water control structures. This variable was added because of permit applications for the maintenance of hundreds of structures already constructed over large areas of wetlands, and not limited to individual plan sites.

10. **Main plan goals.** This is a series of one-space variables ranking up to four main goals of a plan. Rankings were determined from the permit, permit application, Corps of Engineers permit application, or formal management plan. There are 12 possible goals. G_LLOSS refers to preventing land loss, including the prevention of marsh deterioration, vegetative dieback, saltwater intrusion, and shoreline retreat, as well as stated land loss prevention. G_WAFWL refers to waterfowl management; the plan's goal may be to improve or maintain habitat for waterfowl and/or improve the availability of waterfowl hunting. G_FURBR refers to the goal of improving or maintaining habitat for furbearer production and/or harvest. G_INDGW denotes the goal of improving or maintaining habitat for wildlife species indigenous to the area. G_INDGF stands for improving or maintaining habitat for indigenous fish species. G_IMPVA is improving access to portions of the plan area, usually by trenasses or roads and usually associated with hunting, fishing or trapping. G_ANTIT refers to preventing trespassing. This usually involves the construction of fences or blockades to decrease access to a managed area. G_MULTU refers to multiple uses. This means managing an area for several uses, not specifically for one resource. This is most often a secondary goal stated more as a recognition of other possible uses and of managing for the general health of the area. G_AQUA is the management of an area for the production of a specific aquatic species (usually crawfish). This variable is usually associated with a comment in G_COMM that identifies the species involved. G_COMM is a character variable of approximately two dozen spaces usually used to identify species or groups being cultured. G_AGRI refers to managing an area for agricultural production (usually pasture). The type of crop is usually identified in G_COMM. G_MARI is the management of an area for the production of marine organisms (mariculture). The managed species is not necessarily native to the area and the species managed is usually identified in G_COMM.

11. **Structural and linear components.** The number of each type of structure permitted in each plan is listed (not including the structures installed on an area before the Coastal Management Division's permitting authority (October 20, 1980)). These numbers should equal exactly those identified in the permit. Structure acronyms and descriptions are:

FC - fixed crest weirs;
VC - variable crest weirs;
FG - flap-gated culverts;
PM - pumps;
PG - plugs, dikes, or dams;
FV - flap-gated structure with a variable crest weir on the other end;
SF - slotted fixed-crest weir;
FL - flood gate, usually a guillotine-type structure;
DG - double flap-gated structure, with or without a culvert;
CL - culvert;
CG - circulation gap (usually cut in spoil banks to allow water flow);
BK - blockade/fence (usually to control trespassing);
WS - unspecified water control structure.

The four variables LE, LR, LP, TR refer to the length, to the nearest 0.1 mi, of linear features of a levee or trenasse. The term levee is used here to mean any levee, spoil bank, or dike construction or repair associated with implementation of a management plan. The lengths were taken from the permit plan, plan drawings, or from digitized information, and converted to the nearest 0.1 mi. LE refers to levees already existing that were to be used as part of the management plan. In most cases, these are probably spoil banks associated with navigation canals. These data were often not available. LR refers to miles of levees in the plan to be repaired, usually spoil banks to be rebuilt. Sometimes it was referred to in the permit as spoil bank repair. LP is miles of levees, or spoil banks, planned for construction. TR is miles of trenasses to be dug.

12. **Water control operation schedule.** A numerical code not yet developed, which can identify the type of water control operation schedule associated with the plan and its structure.

13. **Monitoring effort.** Identifies variables being monitored inside the plan area, the number of monitoring stations for some of the variables, and the number of years the plan had reportable monitoring results. Variables that may have been monitored were water salinities, water levels, water quality, vegetation (usually species composition), sedimentation, soil chemistry, nutrient cycles, land loss, fisheries, and wildlife. Few plans had any monitoring data and of those that did, not all of the variables described above were monitored.

14. **See also.** XREF1 refers to cross reference number one. If a plan is coded without acreage figures, it is a cross reference to another specific permit number. In this case, XREF1 will specify the permit number for which it is a cross reference. XREF2-4 refer to plans with which that specific plan may be associated.

15. **This plan is mitigation for CUPNO.** MITREF lists the permit number for which that plan is intended to be a mitigation measure. This number often refers to permits associated with oil and gas activities in the coastal zone.

16. **Hydrologic unit.** The hydrologic unit within which the plan or its major portion resides. Boundaries of the hydrologic basins are described in figure 1 of this volume.

17. **Physiographic unit.** This variable differentiates between the chenier and deltaic plains. The border between the two regions is described in figure F-3.

18. **Endangered species.** If an endangered species was mentioned in the permit file as occurring in the plan area, it was identified by a code consisting of the first two letters of the genus and the first two letters of the species name.

19. **Archeological site.** An archeological site was listed as being in the plan area if there was written communication in the file seeking the nature and identity of the site and an explanation of necessary restrictions. Identification numbers assigned by the Division of Archaeology and Historic Preservation of the Louisiana Department of Culture, Recreation and Tourism were coded in as this variable.

20. **Primary habitat.** This variable refers to the alphanumeric code of the dominant habitat type, as defined by Cowardin et al. (1979).

Data Entry and Manipulation

The raw data are stored in the Coastal Management Division's Data General computer as a data base in the file BIG:SASDB, but it is not necessary to enter this file to work on the data base. Every plan in the raw data base has two data pages. Data for the first page can be extracted directly from the data base or can be edited directly from a terminal. Data for the second page can be entered or edited from a terminal only.

All programs used to access or analyze the data are located in various members of the file titled BIG:IPFURCYZ. The program FUMAKES.CLI provides access into the raw data base to correct data variables or add new plans. This is where data additions or revisions to either page of a plan can be accomplished. The program MARSHUP.SAS updates the first page of the raw data base by comparing the date in RUPDATE.SAS (this is the date the raw computer data base was last updated) with the last updated date for every permit application in the Coastal Management Division's plan file. If a permit related to aquaculture, agriculture, or marsh management in the Coastal Management Division's plan file has been altered (updated) since the data identified in RUPDATE.SAS, then that data shown in table 19 is automatically entered into the raw data base. Submitting the MARSHUP.SAS program automatically updates the date in RUPDATE.SAS as the date the program was submitted. The program MAKEMAR.SAS creates a SAS database called NOWMAR.SAS out of the raw data and places NOWMAR.SAS in the BIG:SASDB file. All SAS programs for summarizing the database use the NOWMAR.SAS database. All programs used to analyze the NOWMAR.SAS database are located in, and make up the majority of, the IPFURCYZ:BIG file. When submitted, these programs automatically access NOWMAR.SAS in the BIG:SASDB file and run their programs. The analysis and summary of the variables in the NOWMAR.SAS database was performed using SAS (1985) procedures.

RESULTS AND DISCUSSION

One hundred sixty-five permit applications (161 applications for new plans plus 4 applications to maintain existing structures) were entered into the marsh management plan data base. Permit numbers, applicant name, size, and hydrologic basin for all permits in the data base are listed in Appendix J, table 3.

Of the 165 applications, the Coastal Management Division decided 15 applications did not require a permit (status 9, table 21). Of these, seven applications were for plans located outside the coastal zone, five were for plans located in fastlands and which therefore did not affect wetlands, one was ruled unnecessary due to no significant effect, another already had a valid permit, and one entailed activities for which no permit was necessary. These applications were not included in most of the analyses described below. Also, because these applications were not processed as permits, there is generally less information about them in the files than there is for the other applications.

Eleven additional permit applications were withdrawn by the applicant (status 12, table 22). It is difficult to determine the reasons for the withdrawal of the applications because the information usually was not identified in the permit file. Usually there was a letter in the file indicating the landowner was withdrawing the permit, but not saying why. It appears that a few were withdrawn and then resubmitted with changes as a new application, two were withdrawn because of objections from government

Table 21. Status of permit applications included in the marsh management plan database as of May 15, 1989.

Status Code[1]	Status Description		Number	Acres
1	Received/Under Review		5	13,649
2	On hold for more information		7	51,115
3	Permit issued, no conditions		4	714
4	Permit issued with special conditions		120	286,753
9	No permit required		15	119,052
11	Permit awaiting signature		1	21,980
12	Permit application withdrawn		11	8,934
23	Changed to violation		1	4
24	Conditions modified by Secretary-permit issued		1	1,035
		Total	165	503,236

[1]Numerical code from Coastal Management Division's computerized data base designating the processing status and final decision of an application.

Table 22. Total number, average area (acres), and total area (acres) covered by permit applications[1] in each parish, hydrologic basin, and physiographic unit.

	Total Number	Average Area	Total Area
Parish			
Cameron	27	2,685	69,818
Iberia	10	589	5,305
Jefferson	6	3,256	13,024
Lafourche	14	8,571	102,861
Livingston	1	4	4
Plaquemines	4	1,102	4,409
St. Bernard	7	3,448	24,139
St. Charles	7	4,796	33,577
St. James	1	4,248	4,248
St. John	2	200	401
St. Mary	5	1,140	5,703
St. Tammany	4	223	893
Terrebonne	35	2,335	72,401
Vermilion	16	2,564	38,467
Hydrologic Basin[2]			
Atchafalaya	0	0	0
Barataria	26	6,247	137,444
Breton Sound	8	2,809	22,475
Calcasieu	10	1,425	12,831
Mermentau	22	3,942	86,733
Mississippi R.	0	0	0
Pontchartrain/Pearl	10	2,180	21,807
Sabine	3	198	594
Terrebonne	38	2,201	74,844
Vermilion-Teche	22	926	18,522
Physiographic Unit[2]			
Deltaic plain	87	3,320	262,322
Chenier plain	52	2,352	112,925
TOTAL	139		375,247

[1]Does not include applications of status 9 or 12.
[2]See Plate 7.

agencies, and some were withdrawn because of the landowners' objections to permit conditions. These applications were not included in many of the analyses described below.

No marsh management plan applications have been denied by the Secretary of the Louisiana Department of Natural Resources. Therefore, 139 of the 165 applications have been or are being processed as plans requiring a permit. Permits were issued for 126 (91%) of these, and of those 121 were issued with special conditions (one application had these conditions modified by the Secretary of the Louisiana Department of Natural Resources), four were issued with no conditions, and one was issued and then changed to reflect a violation (table 21). (Virtually every permit is issued with special conditions describing the effective dates of the permit, procedures for notifying the Department of Natural Resources of project implementation and of changes at the project site, and similar procedural matters. Special conditions also may establish performance standards for implementation and maintenance of the project. Such performance standards may describe specific project activities in greater detail).

The chances of an application being approved (i.e., issued a permit) can be conservatively estimated as 126/165 or 76%. Thus, a reasonable projection indicates that probably at least 10 of the 13 applications (139-126=13) pending as of May 15, 1989 will be issued a permit. Stated another way, of all applications not classified as status 9 or 12, 91% have received a permit and perhaps 98% will receive a permit. For this reason, interpretation of the data base will be based on analysis of those applications requiring a permit (139 applications in all), which includes those already issued a permit (126 applications).

Of the 126 permits that the Coastal Management Division has issued, most were issued in 1984, the year after the most applications were received. The Coastal Management Division has received an average of 18 permit applications and issued an average of 15 permits each year since it began permitting coastal zone activities. The number of permit applications per year has remained fairly constant since the 1983 high, fluctuating between 18 and 24 over five years. This does not include 1989 because several permit applications received had not yet been placed in the computer data base as of May 15, 1989, the cutoff for this data base.

The mean time between the day the application was received and the day the permit was issued was 253 days (table 23). This figure is based on only those applications for which permits were issued (status 3, 4, 23, 24). The longest period between application and issuance was 1,467 days. The average length of time between the permit issue date and the date the management plan was commenced was 218 days (table 23). The commencement date data consist of only 43 permits, but it is likely that more than 34% (43 out of 126) of permitted plans have been implemented. The Coastal Management Division relies on landowners to mail a notification slip when permitted activities are implemented, but it is possible that some landowners are not doing so. In addition, because landowners often implement management plans in stages as funds become available, notification of commencement does not necessarily mean that the plan has been fully implemented. Therefore, some of those plans for which commencement dates are in the data base have been only partially implemented. The number of fully operational plans is not known. Of the 16 plans selected for analysis all but two were fully implemented. Based on the difficulty encountered in finding 14 fully implemented plans, a reasonable

Table 23. Number of applications received, number of permits issued, average time between date received and issue date (Time1), and average time between issue date and commencement date (Time2) for permits issued by Coastal Management Division.

Year	Applications Received	Permits Issued[1]	Time1 (days)	Time2 (days)
1980	1			
1981	9	6	120	166
1982	16	12	126	333
1983	35	19	252	182
1984	20	22[2]	256	197
1985	24	18	390	292
1986	18	18	188	144
1987	23	13	308	176
1988	18	9	256	
1989	1	9		
Mean	18	14	253	218

[1]Includes only those permits having status 3, 4, 23, or 24.
[2]In some years more applications are permitted than received because of carryover from previous years.

estimate for the number of fully implemented plans would be 14-20. A complete survey of all 126 permit holders should be made to determine the number of plans initiated, partially implemented, and fully implemented.

Most permit applications covered proposed activities in Terrebonne Parish (35), followed by Cameron (27), Vermilion (16), Lafourche (14), and Iberia (10) parishes (table 22). The average area and total area applied for per marsh management plan was highest in Lafourche Parish, followed by Terrebonne and Cameron parishes. Although Iberia Parish had a fairly high number of management plans, the average management plan size in that parish was relatively small (589 acres). Most of these plans were for aquaculture or agriculture.

The Terrebonne hydrologic basin (plate 7) had the most marsh management applications (38), followed by Barataria basin (26), and the Mermentau and Vermilion-Teche basins (22 each). However, the largest total area applied for was located in Barataria, Mermentau, and Terrebonne basins, in that order. Because there were only two plans totalling 4 acres in the Pearl River basin, data from this basin were combined with that from the Pontchartrain basin. Because there were no marsh management applications for two hydrologic basins in the coastal zone (Atchafalaya basin and Mississippi River basin), these two basins were excluded from the following tables. The mean number of management units per plan was less than two for all basins except Sabine and Terrebonne (table 24). There were more applications for marsh management activities in the deltaic plain than in any other region, and those applications covered over 260,000 acres. Management of slightly over 110,000 acres was applied for in the chenier plain (table 22).

The number of permits issued (table 25) nearly equals the number for which applications were made. The number of permits issued annually and total area permitted in each hydrologic basin and physiographic unit are presented in table 26. The number of permits issued annually parallels the trend in applications submitted (tables 23 and 22). The highest number of permits issued annually occurred in the mid 1980s; the numbers have declined since 1986 to a level at or below the mean annual rate. The highest number of permits was issued for wetlands in Terrebonne, Barataria, and Vermilion-Teche basins. The largest total areas permitted for management lie in Barataria, Terrebonne, and Mermentau basins.

Only 34% (43 out of 126) of the permitted plans have been implemented (table 25), encompassing 35% of the permitted area. Not all of the 35% of the permitted area is under management at this time, however, because not all implemented plans have been fully implemented. Therefore, all references to being commenced, implemented, or under management in this and the next paragraph, and in tables 25 and 27, represent a maximum management potential for plans that have been initiated. Terrebonne Parish and Terrebonne basin have the most implemented plans, but the largest area of wetlands under management lies in Lafourche Parish and Barataria basin. Nearly four times as much of the deltaic plain wetland area has been put under management as in the chenier plain, although there is only twice as much wetland area proposed for management in the deltaic plain.

Approximately 12% of Louisiana's coastal wetlands have been proposed (i.e., permit applied for) for private management, 9% have been permitted to be privately managed, and 3% are under management by private landowners (table 27). Nearly one-quarter of the wetlands of Barataria basin have been

Table 24. Mean, minimum, and maximum number of units per management plan application[1] in the Louisiana coastal zone, October 20, 1980 to May 15, 1989.

Basin	Number of Units		
	Mean	Minimum	Maximum
Barataria	1.6	1	7
Breton Sound	1.6	1	3
Calcasieu	1.0	1	1
Mermentau	1.5	1	5
Pontchartrain/Pearl	1.6	1	6
Sabine	2.6	1	4
Terrebonne	2.3	1	15
Vermilion-Teche	1.9	1	10

[1]Does not include permit applications having status 9 or 12.

Table 25. Number of management plan permits issued[1] and number of plans commenced, with total area (acres) of each.

	Number Issued	Area (acres)	Number Commenced	Area (acres)
Parish				
Cameron	24	24,602	4	7,564
Iberia	10	5,305	5	3,931
Jefferson	5	8,130	0	0
Lafourche	12	102,217	4	40,785
Livingston	1	4	0	0
Plaquemines	4	4,409	1	272
St. Bernard	7	24,139	1	2,999
St. Charles	7	33,577	1	205
St. James	1	4,248	1	4,248
St. John	1	31	0	0
St. Mary	5	5,703	1	613
St. Tammany	4	893	3	892
Terrebonne	31	47,642	16	29,296
Vermilion	14	27,606	6	12,232
Hydrologic Basin[1]				
Barataria	24	132,550	6	45,305
Breton Sound	8	22,475	1	2,999
Calcasieu	10	12,831	1	6,847
Mermentau	19	30,856	5	7,693
Pontchartrain/Pearl	9	21,437	4	1,097
Sabine	2	414	1	70
Terrebonne	33	49,441	17	29,909
Vermilion-Teche	21	18,502	8	9,117
Physiographic Unit[1]				
Deltaic plain	79	231,665	28	79,823
Chenier plain	47	56,858	15	23,214
TOTAL	126	288,513	43	103,037

[1]Includes only those permits having status 3, 4, 23, or 24.

Table 26. Number of permits issued[1] (top number) and total area (bottom number, in acres) permitted for marsh management activities in each hydrologic basin and physiographic unit during each year.

	Year								
	81	82	83	84	85	86	87	88	89[2]
Hydrologic Basin[3]									
Barataria	1	2	4	5	7	0	1	1	3
	2,108	735	15,381	18,996	45,536		+	46,222	3,572
Calcasieu	0	2	0	2	1	1	1	2	1
	894		808	+	6,847	490	2,353	1,439	
Mermentau	0	1	2	4	2	3	4	2	1
	174	4,179	10,377	3,268	8,017	2,916	1,561	364	
Verm-Teche	2	2	5	3	1	5	2	0	1
	1,413	412	2,611	2,965	+	9,943	320		838
Sabine	0	1	0	1	0	0	0	0	0
	344		70						
Terrebonne	3	2	3	5	6	5	3	3	3
	2,947	474	4,470	8,738	11,652	7,487	5,653	8,020	0
Pontchartrain	0	1	0	0	1	4	2	1	0
	3			885	7,438	13,110	1		
Breton Sound	0	1	5	2	0	0	0	0	0
	3,571	14,203	4,701						
Physiographic Unit									
Deltaic plain	5	7	13	13	14	10	6	5	6
	5,571	5,192	34,228	34,035	58,073	17,978	18,763	54,243	3,572
Chenier plain	1	5	6	9	4	8	7	4	3
	897	1,415	6,616	12,620	3,268	21,754	3,746	3,914	2,641

[1]Includes only those permits having status 3, 4, 23, or 24.
[2]As of May 15, 1989.
[3]See Plate 7.
+No data available.

Table 27. Percentage of total wetland area[1] for which marsh management permits have been applied for, issued, and implemented.

Basin	Wetland Area[2] (acres)	Applied For	Permits Issued	Permits Implemented
Barataria	566,788	24	23	8
Calcasieu	151,408	8	8	5
Mermentau	461,054	19	7	2
Vermilion-Teche	303,770	6	6	3
Sabine	184,682	<1	<1	<1
Terrebonne	573,142	13	9	5
Pontchartrain	463,576	5	5	<1
Breton Sound	247,347	9	9	1
Entire Coastal Zone	3,165,396	12	9	3

[1]Calculated from data in table 22.
[2]Data from 1984 (table 16). Values are the sum of the following categories: broken marsh, marsh, beach, floating vegetation.

proposed and permitted to be privately managed. Nearly one-fifth of Mermentau basin wetlands and 13% of Terrebonne basin wetlands have been proposed for management. However, the area actually under management is considerably less than the area proposed and permitted to be managed.

The activity for which marsh management permits are most frequently sought is manipulation of water levels (table 28). Water control is a major activity in 122 plans, with most of the applications for areas in Terrebonne, Barataria, Vermilion-Teche, and Mermentau basins (table 29). Dredging (>1,000 yd^3), nonstructural management (e.g., burning and vegetative plantings), or access control is a significant component of 34 or fewer plans. Marsh management has not been used primarily to protect endangered species, although they may benefit from having a managed area nearby. The harvest of commercial species has not been proposed on any marsh management application, but mariculture in approved marsh management plans has been authorized under state law in certain situations. (See chapter 3 for discussion of mariculture laws). The Louisiana Department of Wildlife and Fisheries has issued 10 mariculture permits for use in approved marsh management plans. Even though it has not been specifically mentioned in marsh management applications, commercial harvest has probably occurred within management areas and at water control structures in some instances.

Even though dredging is a significant component of only 34 plans, nearly every marsh management plan involves some dredge and fill activities (table 30). Dredge and fill activities encompassing nearly 7,000,000 yd^3 have been applied for since 1980. The Terrebonne basin (>50%) has the most dredge and fill activity, followed by Vermilion-Teche, Mermentau, and Barataria basins. The amount of dredging requested for a plan ranges from a low of 5 yd^3 to a maximum of 1,550,000 yd^3, with an average of 56,857 yd^3. Typical dredging for marsh management includes filling around structures, building plugs and spoil banks, repairing spoil banks, and constructing trenasses.

Of the 130 applications that identified a primary goal (rank=1) for the management plan, mitigating land loss was named in 81 plans (table 31, all activities combined). The second most common primary goal was the improvement of waterfowl habitat (13 plans). When the number of requests to manage marsh to reach a specified goal (regardless of that goal's rank on the permit application) are summed, the most important goals for marsh management are found to be mitigating land loss (89), improving waterfowl habitat (55), and improving furbearer habitat (39). The analysis of management goals by activity type reveals a similar pattern. For 80 plans, the primary goal of controlling water levels is mitigating land loss, followed by improving waterfowl habitat (12 plans), and aquaculture (11 plans). When all rankings are combined, mitigating land loss and improving waterfowl and furbearer habitat are the three most common goals (88, 53, and 39 plans, respectively) of manipulating water levels. The same pattern holds true for dredging, although the number of plans using substantial dredging to achieve the goals is much lower. The goal behind nonstructural activities is equally divided among mitigating land loss, improving waterfowl habitat, and improving furbearer habitat. Like dredging, nonstructural techniques are much less frequently used than water control.

An analysis of management goals by hydrologic basin reveals that mitigating land loss and improving waterfowl and furbearer habitat are the most important goals in each basin (table 32). The only exceptions are Sabine

Table 28. Number of requests[1] for permission to conduct marsh management, by activity type, in the Louisiana coastal zone, October 20, 1980 to May 15, 1989.

Activity	Number of requests
Access control	19
Water control	122
Harvest techniques	0
Endangered species	0
Dredging	34
Non-structural	20
Maintenance	4

[1]Does not include permit applications having status 9 or 12.

Table 29. Number of permit applications,[1] by activity type, for each hydrologic basin and physiographic unit in the Louisiana coastal zone (October 20, 1980 to May 15,1989).

	Access Control	Water Control	Dredging	Non-structural	Maint.
Hydrologic Basin					
Barataria	5	23	3	2	2
Calcasieu	1	9	1	0	0
Mermentau	3	21	8	5	0
Vermilion-Teche	2	22	4	6	0
Sabine	0	3	1	0	0
Terrebonne	6	29	12	3	2
Pontchartrain	2	7	4	3	2
Breton Sound	0	8	1	1	0
Physiographic Unit					
Deltaic plain	14	72	19	10	4
Chenier plain	5	50	15	10	0

[1]Does not include permit applications having status 9 or 12.

Table 30. Number of permit applications for dredge and fill activities, and the mean, minimum, and maximum amount of dredge and fill (cubic yards) per marsh management plan application[1] in the Louisiana coastal zone.

Basin	Number	Volume of Dredge and Fill (yd^3) Mean	Minimum	Maximum	Total
Barataria	22	21,785	60	88,000	479,279
Calcasieu	8	29,391	15	191,400	235,129
Mermentau	20	33,661	37	375,000	673,234
Vermilion-Teche	17	66,746	45	999,999	1,134,684
Sabine	3	27,488	125	47,340	82,465
Terrebonne	34	115,756	271	1,550,000	3,935,709
Pontchartrain	9	15,324	590	65,800	137,922
Breton Sound	8	25,307	5	88,400	202,461
TOTAL	121	56,857			6,880,883

[1]Does not include permit applications having status 9 or 12.

Table 31. Number of applications[1] by management goal rank for each activity in the Louisiana coastal zone, October 20, 1980-May 15, 1989.

Activity	Management Goal	Rank on application 1	2	3	4	Total
Access control						
	Anti-trespassing		1		2	3
	Improve access	10	1	2		13
	Land loss	4				4
	Waterfowl	3	2	1		6
	Furbearers		3	1		4
	Indigenous wildl.		2			2
	Indigenous fish.			2		2
	Aquaculture	1				1
	Multiuse	1				1
Water control						
	Anti-trespassing		1		2	3
	Improve access			3		3
	Land loss	80	2	6		88
	Waterfowl	12	30	11		53
	Furbearers	2	15	20	2	39
	Indigenous wildl.	1	11	3		15
	Indigenous fish.		2	5	4	11
	Aquaculture	11		1		12
	Mariculture	3				3
	Agriculture	2				2
	Multiuse	6	7	1	2	16
Dredging						
	Land loss	20		2		22
	Waterfowl	3	6	1		10
	Furbearers	1	2	5		8
	Indigenous wildl.		6			6
	Indigenous fish.		1	1	1	3
	Aquaculture	4				4
	Mariculture	2				2
	Agriculture	1				1
	Multiuse	2	1		1	4
Nonstructural						
	Anti-trespassing				1	1
	Improve access			2		2
	Land loss	11		4		15
	Waterfowl	7	6	5		18
	Furbearers		10	5	1	16
	Indigenous wildl.		2	1		3
	Indigenous fish.			1		1
	Multiuse	2	1		2	5

Table 31. Number of applications[1] by management goal rank for each activity in the Louisiana coastal zone, October 20, 1980-May 15, 1989 (continued).

Activity	Management Goal	Rank on application 1	2	3	4	Total
Maintenance						
	Land loss	4				4
All Activities Combined[2]						
	Anti-trespassing		1		2	3
	Improve access	11	1	3		15
	Land loss	81	2	6		89
	Waterfowl	13	31	11		55
	Furbearers	2	15	20	2	39
	Indigenous wildl.	1	11	3		15
	Indigenous fish.		2	5	4	11
	Aquaculture	11		1		12
	Mariculture	3				3
	Agriculture	2			2	4
	Multiuse	6	7	1	2	16

[1]Does not include permit applications having status 9 or 12.
[2]Totals for all activities combined do not equal the sum of all activities because some applications were for more than one activity type.

Table 32. Number of applications, by management goal rankings, for each hydrologic basin and physiographic unit in the Louisiana coastal zone (October 20, 1980 to May 15, 1989)[1].

	Goal	Rank on Application 1	2	3	4	Total
Hydrologic Unit						
Barataria	Land loss	15				15
	Waterfowl	2	6	4		12
	Furbearers		3	2	1	6
	Indig. wildl.		3			3
	Indig. fish.		1	2	1	4
	Improve access	1				1
	Anti-trespassing	1	1		2	4
	Multiuse	1	1	1		3
	Aquaculture	4		1		5
	Agriculture				1	1
	Mariculture	5				5
Calcasieu	Land loss	8	1			9
	Waterfowl	1	2	1		4
	Furbearers			2		2
	Indig. fish.		1			1
	Improve access	1				1
	Aquaculture	1				1
	Agriculture				1	1
Mermentau	Land loss	13		1		14
	Waterfowl	6	7	4		17
	Furbearers		7	6		13
	Indig. wildl.		2			2
	Indig. fish.			2	3	5
	Improve access	1		1		2
	Multiuse	1	1		2	4
	Aquaculture	5	1			6
	Agriculture	1				1
Vermilion-Teche	Land loss	12	1	5		18
	Waterfowl	6	2	1		9
	Furbearers	2	6	1		9
	Indig. wildl.	1	3			4
	Indig. fish.			1		1
	Improve access			2		2
	Multiuse		4	1		5
	Aquaculture	1	1			2
	Agriculture	2				2
Sabine	Aquaculture	2				2

Table 32. Number of applications, by management goal rankings, for each hydrologic basin and physiographic unit in the Louisiana coastal zone (October 20, 1980 to May 15, 1989)[1] (continued).

	Goal	Rank on Application 1	2	3	4	Total
Terrebonne	Land loss	27				27
	Waterfowl	3	11			14
	Furbearers			7		7
	Indig. wildl.	1	4	3		8
	Improve access	6	3			9
	Multiuse	1	1			2
	Aquaculture	4				4
	Mariculture	1				1
Pontchartrain	Land loss	4				4
	Waterfowl		3	2		5
	Furbearers			1	1	2
	Improve access	2				2
	Multiuse	3	1			4
	Aquaculture	1				1
Breton Sound	Land loss	8				8
	Waterfowl		3			3
	Furbearers			3		3
Physiographic Unit						
Deltaic plain	Land loss	57		1		58
	Waterfowl	6	24	5		35
	Furbearers	1	4	13	2	20
	Indig. wildl.	1	8	3		12
	Indig. fish.		1	2	1	4
	Improve access	9	3	1		13
	Anti-trespassing	1	1		2	4
	Multiuse	4	3	2		9
	Aquaculture	10		1		11
	Agriculture				1	1
	Mariculture	6				6
Chenier plain	Land loss	30	2	5		37
	Waterfowl	12	10	6		28
	Furbearers	1	12	9		22
	Indig. wildl.	1	4			5
	Indig. fish.		1	3	3	7
	Improve access	2		2		4
	Multiuse	1	5		2	8
	Aquaculture	8	2			10
	Agriculture	3			1	4

[1]Does not include permit applications having status 9 or 12.

basin, for which only three plans have been submitted, and Terrebonne basin, for which improving access and maintaining habitat for indigenous wildlife are as important as improving furbearer habitat. Mitigating land loss and improving waterfowl and furbearer habitats are also the most important goals in both the chenier and deltaic plains. In the deltaic plain, the next most common goals are improving access (13 plans), maintaining habitat for indigenous wildlife (12 plans), and aquaculture (11 plans). In the chenier plain, the next most common goals are aquaculture (10 plans), multiuse (8 plans), and maintaining habitat for indigenous fish (7 plans).

Nearly 1,100 water control structures have been permitted or applied for since 1981 (tables 33 and 34). The number of new structures applied for is far less than this, however, because the four maintenance permits described in tables 28, 29, and 30 were issued in 1989 to maintain 585 existing structures (370 FC, 2 VC, 212 PG and 1 FV). These structures are represented in the 1989 data in table 33. Excluding these data, an average of 59 new structures (range=34 to 76) was permitted each year from 1982 to 1988. The number of fixed-crest weirs (FC) permitted each year increased steadily through 1985, declined in 1986 and 1987, and increased to 1985 levels again in 1988. These types of structures are used for passive water management. Of the structures used for active water management (i.e., drawing down water levels-VC, FG, FV, and DG), the number of variable-crest weirs (VC) permitted each year remained fairly constant, the number of flap-gated culverts (FG) declined sharply after 1984, no flap-gated structures with variable-crest weirs (FV) were permitted before 1984 but an average of 14 have been permitted each year since, and the number of double flap-gated structures has declined dramatically from an average of 10 per year since 1985. Excluding the 1989 data, plugs and fixed-crest weirs, which provide passive water management, represent the largest total number of structures (101 and 99, respectively). In comparison, structures capable of drawing down water levels totalled 216. Most water control structures were applied for in Terrebonne, Jefferson, and Lafourche parishes in Terrebonne and Barataria basins, and in the deltaic plain. If the maintenance permits are excluded from the analysis, 362 new structures have been applied for in the deltaic plain since October 20, 1980, for a total of 507 for the entire coastal zone.

Over 70% (371) of all new structures applied for are expected to manipulate water levels to mitigate land loss (table 35). The structures most commonly used for this purpose are plugs, flap-gated variable-crest structures, and fixed-crest weirs. Plugs and fixed-crest weirs provide passive water management and flap-gated variable-crest structures provide active water management. In all, 186 of the structures built to mitigate land loss are capable of active water management, while 71 structures provide passive water management. The annual trend in numbers and types of structures permitted for the purpose of mitigating land loss does not differ substantially from the trend for all goals combined (table 35).

More than 360 mi of levees are included in the management plan applications submitted as of May 15, 1989 (table 36). As defined above, the term levee is used collectively to refer to any levee, spoil bank, or dike constructed as part of a management plan. Of this total, approximately 85 mi existed at the time of application, 200 mi were proposed for repair, and 78 mi of new levees were requested. The majority of this levee work--approximately 80 mi of existing levee, 165 mi of levee repair (mostly spoil bank repair),

Table 33. Total number of each type of water control structure permitted[1] and for which applications are pending in the Louisiana coastal zone.

Year[3]	Structure[2] FC	VC	FG	PM	PG	FV	SF	FL	DG	CL	CG	BK	WS	TOTAL
Permitted														
1981	5													5
1982	8	4	8	4				2		1			7	34
1983	14		16	2	12			1	18		1	2		66
1984	12	7	11	1	12	9		3	2	1	8		2	68
1985	20	5		1	5	14			10	8		1		64
1986	6	5		1	21	22		3	2	13	3			76
1987	6	8	2		8	14			3					41
1988	21	6		2	17	10		3	4	3				66
1989	1	0			2	4	1							8
	(370)[4]	2			(212)	1								(585)
Applied for														
Pending[5]	7	20	1		26	15				2	8			79
TOTAL	100	55	38	11	103	88	1	12	39	28	20	3	9	507
	(370)	(2)			(213)	(1)								(585)

[1]Does not include permit applications having status 9 or 12.
[2]See methods section for description of structures.
[3]Year permit issued.
[4]Numbers in parentheses represent the number of existing structures permitted for maintenance.
[5]Data are from applications pending as of May 15, 1989.

Table 34. Number of each type of water control structure applied for[1] in the Louisiana coastal zone, by parish, hydrologic basin, and physiographic unit, October 20, 1980 to May 15, 1989.

	Structure[2]													
	FC	VC	FG	PM	PG	FV	SF	FL	DG	CL	CG	BK	WS	TOTAL
Parish														
Cameron	2	9	6	5	8	24	0	7	2	15	2	0	0	80
Iberia	8	0	5	0	4	0	1	0	0	0	0	0	0	18
Jefferson	177	0	0	0	98	1	0	0	0	0	0	0	0	276
Lafourche	39	3	7	0	25	23	0	4	9	0	8	1	0	117
Livingston	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plaquemines	2	1	3	0	4	0	0	0	0	0	0	0	2	12
St. Bernard	0	1	13	0	4	1	0	0	20	0	0	0	0	39
St. Charles	3	5	0	2	5	4	0	0	3	0	0	2	0	24
St. James	0	0	0	0	0	0	0	1	0	0	0	0	0	1
St. John	0	0	0	1	0	2	0	0	0	0	0	0	2	3
St. Mary	5	1	2	2	6	0	0	0	1	0	0	0	5	22
St. Tammany	1	0	0	0	1	0	0	1	0	2	2	0	0	7
Terrebonne	229	32	2	1	153	8	0	2	2	10	2	0	0	443
Vermilion	4	5	0	0	7	26	0	1	2	1	6	0	0	52
Hydrologic Basin														
Barataria	218	3	7	3	124	18	0	1	9	0	0	3	4	390
Calcasieu	2	4	0	2	3	12	0	4	2	5	0	0	0	34
Mermentau	2	7	5	1	7	25	0	2	0	10	8	0	0	67
Vermilion-Teche	15	0	7	2	15	13	1	0	2	0	0	0	5	70
Sabine	0	3	1	2	0	0	0	2	0	1	0	0	0	9
Terrebonne	229	33	2	1	153	14	0	2	3	10	10	0	0	457
Pontchartrain	4	6	0	0	7	6	0	1	3	2	2	0	0	31
Breton Sound	0	1	16	0	6	1	0	0	20	0	0	0	0	44

Table 34. Number of each type of water control structure applied for[1] in the Louisiana coastal zone, by parish, hydrologic basin, and physiographic unit, October 20, 1980 to May 15, 1989 (continued).

Physiographic Unit														
Deltaic plain	456	43	32	6	296	39	0	4	35	12	12	3	9	947
Chenier plain	14	14	6	5	19	50	1	8	4	16	8	0	0	145
TOTAL	470	57	38	11	315	89	1	12	39	28	20	3	9	1092

[1]Does not include permit applications having status 9 or 12.
[2]See method section for acronym identifications.

Table 35. Number of each type of water control structure for applications[1] in which the primary goal is to mitigate land loss.

Year[2]	Structure[3] FC	VC	FG	PM	PG	FV	SF	FL	DG	CL	CG	BK	WS	TOTAL
<u>Permitted</u>														
1981	3													3
1982	1	4	8											13
1983	6		13		9				18					46
1984	11	3	11		11	8		1	2	1	8		2	58
1985	20	5		1	5	14			7	8				60
1986		5			3	15		2	2	5				32
1987	6	7	2		7	14			3					39
1988	17	6		2	16	10		3	4	1				59
1989[4]	1				2	4	1						8	
<u>Applied for</u>														
Pending[5]	6	14			26	7								53
TOTAL	71	44	24	3	79	72	1	6	36	15	8	0	10	371

[1]Does not include permit applications having status 9 or 12.
[2]Year permit issued.
[3]See methods section for acronym descriptions.
[4]1989 data do not include maintenance permits.
[5]Data are from applications pending as of May 15, 1989.

Table 36. Total levee[1] length (mi) (existing, repaired, or constructed) and trenasse length (mi) in permit applications[2] for the Louisiana coastal zone, by parish, hydrologic basin, and physiographic unit.

	Levees				Trenasses
	Existing	Repair	New	Total	Total
Parish					
Cameron	32.1	30.4	13.9	76.4	19.5
Iberia	0	0.5	0	0.5	0.4
Jefferson	13.4	31.4	0	44.8	0
Lafourche	4.7	52.0	11.0	67.7	6.0
Livingston	0.3	0	0	0.3	0
Plaquemines	0	0	2.7	2.7	0
St. Bernard	2.6	3.2	11.5	17.3	6.0
St. Charles	0	4.1	0	4.1	0.6
St. James	0	0.5	0.3	0.8	0
St. John	0	0	1.9	1.9	0
St. Mary	0	3.1	2.3	5.4	2.3
St. Tammany	0	0	0	0	1.2
Terrebonne	1.0	52.9	33.3	87.2	17.7
Vermilion	30.4	20.5	1.3	52.2	0.4
Hydrologic Basin					
Barataria	18.1	84.1	12.1	114.3	2.9
Calcasieu	25.3	4.1	3.4	32.8	6.3
Mermentau	29.5	44.9	6.8	81.2	13.4
Vermilion-Teche	7.7	2.8	2.9	13.4	2.9
Sabine	0	1.5	3.7	5.2	0
Terrebonne	1.0	57.4	34.5	92.5	21.4
Pontchartrain	0.3	0.7	0.8	1.8	1.2
Breton Sound	2.6	3.2	14.0	19.8	6.0
Physiographic Unit					
Deltaic plain	22.0	147.3	63.0	232.3	33.8
Chenier plain	62.5	51.4	15.2	129.1	20.3
TOTAL	84.5	198.7	78.2	361.4	54.1

[1]The term levee is used collectively to refer to any levee, spoil bank, or dike constructed as part of a management plan.
[2]Does not include permit applications having status 9 or 12.

and 50 mi of new levees--has been permitted as of May 15, 1989 (table 37). The length of new levee permitted declined sharply after 1984 while the length of levee repair fluctuated widely from 1981 to 1988. Terrebonne Parish and Terrebonne basin have had the most new levee construction--nearly three times that of any other parish or basin. The most levee (spoil bank) repair has occurred in Terrebonne and Lafourche parishes and Terrebonne and Barataria basins. Consequently, nearly four times more new levee construction and three times more levee repair occurred in the deltaic plain than in the chenier plain. It should be noted that the existing levee data probably underestimates the length of existing levees (i.e. spoil banks, dikes, and levees) used in marsh management because these data are not always stated in permit applications.

Approximately 54 mi of trenasses have been applied for as part of marsh management plans (table 36); 51 mi had been permitted as of May 15, 1989 (table 37). The number of miles of trenasse permitted each year has fluctuated widely but has remained relatively high for the past three years. The most trenasse construction has been applied for in Cameron and Terrebonne parishes and Terrebonne and Mermentau basins. The total miles of trenasse construction applied for in the deltaic plain is more than half again as much as in the chenier plain.

Approximately 90% (318 mi) of all levee work and 30% (17 mi) of all trenasse construction applied for is designed to mitigate land loss (table 38). This includes over 90% of all existing levees and levee repair work, and 75% of all new levee construction applied for. The trend in the amount of levee and trenasse work applied for annually to mitigate land loss does not differ substantially from the annual trend for all goals combined. Traditionally, trenasses are constructed to provide access to interior marshes for the purpose of harvesting waterfowl and wildlife. How trenasse construction is related to mitigating land loss is not clearly explained in the applications. Clarification of this issue should be sought by the agencies reviewing applications.

The total area of each marsh type described in the marsh management plan applications is presented in table 39 for each parish, basin, and physiographic unit. Nearly 300,000 acres of marsh and open-water habitat have been identified in the marsh management plan applications. On an areal basis, fresh, intermediate, and brackish marsh are the habitats most common in marsh management plans, with fresh swamp and saline marsh a distant fourth and fifth (see entire coastal zone totals, table 39). In Barataria basin, most management is proposed for intermediate and saline marsh, followed by open water and fresh marsh. In contrast, most management in Terrebonne basin is proposed for fresh marsh and fresh swamp. In Mermentau basin in the chenier plain, most management is proposed for fresh marsh, with brackish and intermediate marsh a distant second and third. For Barataria basin, most management is proposed in Lafourche Parish, with St. Charles and Jefferson parishes a distant second and third.

The management goals specific to each marsh type are summarized in table 40. Mitigating land loss is overwhelmingly the most common primary goal (rank=1) for all marsh types. Improving conditions for waterfowl and furbearer harvest are the most common secondary and tertiary goals in all marsh types.

Table 37. Total levee[1] length (mi) (existing, repaired, or constructed) and trenasse length (mi) permitted[2] or applied for in the coastal zone, by year.

	Levees				Trenasses
	Existing	Repair	New	Total	Total
Permitted					
1981		1.9	0.1	2.0	9.4
1982	3.2	3.1	12.4	18.7	0.5
1983	2.6	15.4	11.8	29.8	9.0
1984	10.7	34.3	11.9	56.9	0.2
1985	4.7	58.3	2.0	65.0	3.3
1986	23.0	4.1	3.9	31.0	13.4
1987	3.1	15.5	3.2	21.8	8.0
1988	15.1	20.8	3.9	39.8	7.0
1989	16.6	11.4	2.0	30.0	0.3
Applied for					
Pending[3]	5.5	33.9	27.0	66.4	3.0

[1]The term levee is used collectively to refer to any levee, spoil bank, or dike constructed as part of a management plan.
[2]Does not include permit applications having status 9 or 12.
[3]Data are from applications pending as of May 15, 1989.

Table 38. Total levee and trenasse length (mi) for applications[1] in which the primary goal is to mitigate land loss.

	Levees				Trenasses
	Existing	Repair	New	Total	Total
Permitted[2]					
1981	0.0	1.9	0.0	1.9	0.0
1982	1.0	0.0	5.2	6.2	0.0
1983	2.6	10.6	11.3	24.4	6.0
1984	10.7	34.3	9.5	54.5	0.2
1985	4.7	58.3	2.0	65.0	0.2
1986	21.9	2.0	2.6	26.5	0.0
1987	0.0	15.0	3.0	18.0	0.1
1988	15.1	16.2	3.9	35.2	7.0
1989[3]	16.6	11.4	2.0	30.0	0.3
Applied for					
Pending[4]	5.2	33.2	17.5	55.9	3.0
TOTAL	77.8	182.9	57.0	317.6	16.8

[1]Does not include permit applications having status 9 or 12.
[2]Year permit issued.
[3]Data are from applications submitted as of May 15, 1989.
[4]Data are from applications pending as of May 15, 1989.

Table 39. Area (in acres) of each marsh type identified in marsh management applications[1] for each parish, hydrologic basin and physiographic unit of the Louisiana coastal zone, October 20, 1980 to May 15, 1989.

	Marsh Type					
	Fresh Swamp	Fresh Marsh	Inter. Marsh	Brack. Marsh	Saline Marsh	Open Water
Parish						
Cameron	86	32,782	4,192	8,458	929	100
Iberia	8	93	1,252	2,931	--[+]	--
Jefferson				8,688	--	--
Lafourche	847	3,438	38,122	7,314	21,689	19,639
Livingston	2	2	--	--	--	--
Plaquemines	9	--	--	2,334	277	26
St. Bernard	822	--	--	16,290	4,036	968
St. Charles	4,170	15,158	2,194	3,632	--	--
St. James	4,248	--	--	--	--	--
St. John	366	--	--	--	--	--
St. Mary	272	1,799	1,728	--	--	--
St. Tammany	6	621	--	--	--	--
Terrebonne	18,909	27,570	4,602	7,336	184	55
Vermilion	--	4,545	9,968	15,407	--	--
Hydrologic Basin						
Barataria	5,509	18,071	38,122	16,164	21,966	19,665
Calcasieu	43	14	1,068	1,048	829	--
Mermentau	43	37,313	12,364	16,175	100	100
Vermilion-Teche	219	1,739	3,345	9,447	--	--
Sabine	--	--	363	126	--	--
Terrebonne	19,704	28,248	4,602	7,336	184	55
Pontchartrain	3,405	623	2,194	4,177	4,036	818
Breton Sound	822	--	--	17,917	--	150
Physiographic Unit						
Deltaic plain	29,648	48,588	46,646	45,594	929	20,688
Chenier plain	97	37,420	15,412	26,796	26,186	100
Entire coastal zone	29,745	86,008	62,058	72,390	27,115	20,788

[1]Does not include permit applications having status 9 or 12.
[+]Acreage not identified.

Table 40. Number of permit applications[1], by management goal rankings, for each habitat type[2] in the Louisiana coastal zone, October 20, 1980 to May 15, 1989.

Goal	Habitat								
	Freshwater Habitat			Intermediate-Brack. Habitats			Brackish-Saline Habitats		
Rank =	1	2	3	1	2	3	1	2	3
Land loss	21	1	2	36	0	5	30	1	3
Waterfowl	5	13	1	4	12	6	4	9	7
Furbearer	1	5	7	2	9	9	1	9	7
Indigenous wildl.	1	4	2	0	6	1	0	3	1
Indigenous fish.	0	0	3	0	0	3	0	0	1
Improve access	7	0	2	2	0	1	1	0	1
Anti-trespass.	0	1	0	0	0	0	0	0	0
Multiuse	5	2	1	1	4	0	1	2	0
Aquaculture	0	0	0	3	0	0	1	0	0
Mariculture	0	0	0	0	0	0	1	0	0
Agriculture	1	0	0	2	0	0	1	0	0

[1]Does not include permit applications having status 9 or 12.
[2]Only those permits which include >50% of one of these three habitat classes were included in the analysis. Percentage habitat coverage was calculated for those plans with habitat data by the following formula:

$$\text{Freshwater habitat} = \frac{\text{Acres of swamp + fresh marsh + intermediate}}{\text{Total acres}} \times 100$$

$$\text{Intermediate/brackish habitat} = \frac{\text{Acres of intermediate + brackish marsh}}{\text{Total acres}} \times 100$$

$$\text{Brackish/saline habitat} = \frac{\text{Acres of brackish marsh + saline marsh}}{\text{Total acres}} \times 100$$

Marsh management plans have been applied for in 32 different Cowardin primary habitat types (Cowardin et al. 1979) (table 41). More than 30 applications are for areas in brackish marsh (E2EM5P5), more than 20 applications are for fresh marsh (PEM), and twelve plans are for estuarine open water (E1OW). No other habitat type is identified in more than six plans. The primary and secondary dominant vegetation type was identified in approximately half of the applications (table 42). Of those applications identifying the primary vegetation type (usually over 30% cover), more than half (36), occurred in Spartina patens brackish marsh, while the next most common primary vegetation was Spartina alterniflora (eight plans).

Landowners given permission to implement a marsh management plan are required by the Louisiana Department of Natural Resources to provide annual monitoring data on the physical conditions of the managed area (see chapter 3) once management commences. To date, monitoring data has been submitted for only nine plans (table 43), or 21% of all commenced plans. For several of these, monitoring is being conducted by the Department of Natural Resources and the Soil Conservation Service in cooperation with the landowner. The data consist primarily of water quality parameters, such as salinity and turbidity, water level, and vegetation composition and cover. The longest monitoring record covers three years. These monitoring data are generally descriptive and contain limited analysis or interpretation. The main focus is on plant succession; such ecological processes as production, nutrient cycling, and sedimentation are rarely analyzed. Monitoring of fisheries resources is not required of the permittee. Rarely are data collected in an unmanaged area for comparison. In general, the results are of limited usefulness in assessing impacts and evaluating the need to modify the management design.

Eleven management plan applications have been made for areas within the immediate vicinity of an endangered species habitat (e.g., American bald eagle) and/or an archaeological site (e.g., a shell midden) (table 44). Caution is required during construction, maintenance, and monitoring at these sites to avoid damaging these aspects of the area. With proper planning and management, these unique environmental features should have neglibile impact on the efficacy of a plan.

Because marsh management, particularly structural management, is expensive, landowners often depend on financial assistance from major corporations, which provide the support as mitigation for environmental impacts resulting from another project, often located elsewhere. Nineteen management plans have benefited from funds or work provided as mitigation for other permits issued by the Department of Natural Resources. Eighteen of the projects requiring mitigation are related to oil and gas development and one is a commercial fishing facility.

SUMMARY AND CONCLUSIONS

Area

Approximately 1,650,000 acres of Louisiana's coastal habitats are managed as state or federal refuges, planned for private management, or proposed and permitted for private management. Approximately 850,000 acres of coastal habitat are managed as state or federal refuges; most of these use structural

Table 41. Number of permit applications[1] by Cowardin primary habitat type[2] for the Louisiana coastal zone (October 20, 1980 to May 15, 1989).

Habitat Type	Mean Acres	Number of Applications	Total Acres
E1OW+	918.33	3	2,755
E1OWt+	150.00	1	150
E1OWx	486.00	2	972
E1OW	1,709.80	9	8,549
E1OWo	119.00	1	119
E1OWt	1,377.50	3	2,755
E2EM5N4	9,555.75	5	38,223
E2EM5N4d	2,268.00	1	2,268
E2EM5P5	2,545.23	31	78,902
E2EM5P5d	3,537.00	1	3,537
E2EM5P5w	883.00	1	883
E2EM5P6	2,302.57	7	16,118
E2EM5P6d	20.00	1	20
E2EM5PG+	1,891.00	1	1,891
E2EU5P6+	2,055.00	1	2,055
EZEM5P5+	5,454.00	1	5,454
L1OWhx+	2,809.00	1	2,809
L2OW	3,251.00	1	3,251
PEM	6,709.05	22	140,890
PEMd	2,912.00	1	2,912
PF01/2	370.00	1	370
PF0214	4,248.00	1	4,248
PFO1/2	378.50	6	2,271
PFO1/3	516.00	1	516
PSS1	211.00	1	211
PSS1/3	149.00	1	149
R1AB5o	477.00	1	477
R1OWo	1,600.00	2	1,600
UDV1	385.00	2	770
UDV2	450.00	1	450
UFO1/3/4	3.00	1	3
USS1s	252.33	4	757

[1]Does not include permit applications having status 9 or 12.
[2]Cowardin et al. (1979).
+Coding error of habitat label.

Table 42. Number of permit applications[1] identifying dominant or secondarily dominant vegetation and mean percentage cover.

Taxa	Primary Vegetation Number of Applications	% cover	Secondary Vegetation Number of Applications	% cover
Acer rubrum			2	15
Alternanthera philoxeroides			2	12
Baccharis halimifolia	1			
Carex sp.			1	20
Ceratophyllum demersum			1	
Cyperus sp.			2	20
Distichlis spicata	3	31	10	24
Echinochloa walteri	2			
Eichhornia crassipes			1	5
Juncus roemerianus	1	50	1	8
Eleocharis sp.			1	15
Nelumbo lutea	1			
Panicum hemitomon	1		1	35
Paspalum virginiatum	1	30	2	15
Phragmites communis			1	10
Quercus sp.	1	15		
Ruppia maritima			3	5
Sagittaria falcata	6	62	6	10
Sagittaria lancifolia	2	35		
Scirpus californicus	2	55	2	20
Scirpus olneyi			9	22
Scirpus validus			1	20
Spartina alterniflora	8	56	5	29
Spartina cynosuroides			4	25
Spartina patens	36	61	6	17
Taxodium distichum	3	50	1	35
Typha sp.			2	18
Zizaniopsis miliacea	1		1	7

[1]Does not include permit applications having status 9 or 12.

Table 43. Monitoring data summary for implemented marsh management plans in the Louisiana coastal zone, October 20, 1980 to May 15, 1989.

Permit #	Applicant Name	Variables Monitored	Years
P810233	Avery	salinity	1
P821512	McIlhenny	salinity, vegetation	2
P821533	Little Pecan WMA	salinity, water level, turbidity	1
P830450	Cameron Grav. Drain. Dist IV	salinity, water level	3
P831153	Lafourche Real.	salinity, water level, water quality, vegetation, fish	3
P840349	Fina-Laterre-Mit. Bank	salinity, water level, water quality, vegetation, land loss, wildlife	3
P850484	Avoca Island	vegetation	1
P859463	Vermilion Corp.-Platform 1	salinity, vegetation, land loss	2
P851028	Amoco-West Black Lake	salinity, vegetation, land loss	2

Table 44. Permit applications[1] for lands near endangered species habitat or archeological sites.

Permit Number	Endangered Species	Archeological Site
P811151	Bald eagle	
P830438	Bald eagle	
P831340		16SC1
P830538	Bald eagle	16SC1
P850048		16MV18
P850376		16TR66
P860053	Bald eagle	
P860415	Bald eagle	
P870486	Bald eagle	
P880600	Bald eagle	
P880786	Bald eagle	

[1]Does not include permit applications having status 9 or 12.

management to some degree for portions of their property. Government-owned refuges encompass 10% of Louisiana's coastal habitats. Another 350,000 acres of privately owned coastal habitat are targeted for management under plans developed by the Soil Conservation Service before 1980. Since 1980, private landowners have submitted 165 applications to the state to manage 503,000 acres, or 12%, of Louisiana's coastal habitat. This represents 12% of all coastal marsh habitat. The state has issued 126 permits to manage nearly 300,000 acres of coastal habitat, or 9% of all coastal marsh habitat. Approximately 90% of Louisiana's coastal wetland habitats are privately owned; 6% of these habitats have been proposed for private management as of May 15, 1989.

Applications

The mean processing time for a marsh management plan application is eight months. The longest time required to process an application was four years. Apparently, delays in the processing of permits have caused some landowners to withdraw their applications after waiting one or two years. Despite the slow processing rate, the annual application rate has remained relatively high during the past five years. Most applications are for lands in the Terrebonne, Barataria, Mermentau, and Vermilion-Teche basins.

Permits

The state has issued 126 permits to manage more than 288,000 acres of its privately owned coastal habitat (9% of all its wetlands). The number of permits issued by the state has declined since 1985. To date, most permits have been issued for wetlands in Terrebonne, Barataria, and Vermilion-Teche basins. Implementation has been commenced for approximately one-third (43) of these permits, but the number of plans fully implemented is not known. Terrebonne basin has the highest number of applications and implemented plans but Barataria basin has the most area proposed for and under management.

Activities and Goals

The activity for which permission is most commonly requested by landowners is water level manipulation for the primary purpose of mitigating land loss. The second and third most commonly stated goals are improving waterfowl and furbearer habitats.

Structures

Recent permit applications have put more emphasis on versatility in manipulating water levels. Over 70% of all new structures applied for are meant to manipulate water levels to mitigate land loss. Consequently, requests for flap-gated culverts and double flap-gated structures have declined sharply in recent years, while requests for flap-gated variable-crest structures have increased. Requests for variable-crest and fixed-crest weirs have remained fairly constant. Permission to construct more than 50 mi of new levee (i.e., levee, spoil banks, and dike) and 50 mi of new trenasse has been requested since 1980. Requests for levee construction and repair are three to four times more common for areas in the deltaic plain than in the chenier plain. Approximately 90% of all levee work and 30% of all trenasse construction is intended to mitigate land loss.

Marsh Type

For the entire coast, most applications have been made for managing brackish marsh, followed by fresh marsh, but more acres of fresh marsh are proposed for management, followed by brackish and intermediate marsh. For those plans in which marsh type was identified, more area has been applied for management in Barataria, Mermentau, and Terrebonne basins than in other basins. More fresh marsh has been proposed for management in Terrebonne and Mermentau basins than any other marsh types, while in Barataria basin more intermediate and saline marsh has been proposed for management than other marsh types (see table 39).

Monitoring

Landowner response to the state's monitoring requirements is poor. Only 21% of commenced plans have ever resulted in monitoring data; most of that has been mainly descriptive and incorporated little or no analysis or interpretation. Hence, the ability of managers to evaluate the effectiveness of the plan and the potential need to modify the design is limited.

Funding

The landowners bear the entire financial cost of implementing the management plans. Additional funds have been provided to permit holders for 19 of these plans from outside sources as mitigation for other permits issued by the state for oil and gas development (18 plans) and commercial fishing (1 plan).

Chapter 8

FACTORS AFFECTING THE FEASIBILITY OF CONSTRUCTING, OPERATING, AND MAINTAINING MARSH MANAGEMENT IMPOUNDMENTS IN COASTAL LOUISIANA

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INTRODUCTION

This chapter describes the environmental and socioeconomic conditions that affect the feasibility of marsh management in coastal Louisiana. This discussion will provide a broad-scale description of where marsh management is and is not feasible. Because this report is intended for general reference and not as a definitive identification of the feasibility of marsh management at every location within Louisiana, the suitability of specific locales for management will not be discussed. Data and comments provided in this report should be used only as an indication of the general feasibility of marsh managrement in an area. The data in this report are not meant to supplant, nor should they be substituted for, site-specific data.

This report focuses on structural marsh management, which is usually implemented on a large scale (>200 acres). Nonstructural management techniques, such as vegetative plantings, chemical intervention, and marsh burning are usually carried out on a smaller scale and hence subject to very localized conditions. Predicting the feasibility of such localized management is difficult and impractical for a report of this scope.

The first step in determining feasibility is to identify those factors (e.g., soil type) most likely to affect the success of structural marsh management. These factors exhibit a range of qualities from supportive to nonsupportive. This allows for the identification of those coastal wetlands in which structural management is least feasible. Feasibility of marsh management is often described in terms of failures, i.e., explanations of specific causes of structural failure or the inability to achieve management objectives. In contrast, conditions supporting marsh management are rarely graded in terms of good, better, best, but rather described simply as "supportive." Because of this tendency, this chapter focuses on those environmental conditions that prevent, severely limit, or make questionable the use of structural marsh management in coastal Louisiana. By identifying areas of low feasibility, we are <u>ipso facto</u> identifying areas of higher feasibility.

The term feasibility has two implicit definitions: the possibility of a plan's success versus the cost or worth of that success. These definitions directly affect the selection of environmental criteria to be used to determine the feasibility of structural management by including economic considerations (the cost or worth of a plan) with those environmental factors that may affect the plan's success. Structural marsh management may be technologically possible anywhere in coastal Louisiana if sufficient money and effort are expended. We have attempted to identify environmental variables which, in some instances, make management so costly to implement or maintain as to render it impractical.

Before factors controlling the feasibility of structural marsh management can be discussed, some aspects of structural management that relate to feasibility should be described. For the purpose of this chapter, structural marsh management is defined as "the use of structures to manipulate local hydrology for the purpose of reducing or reversing wetland loss and/or enhancing the productivity of natural renewable resources." Structural marsh management may use such tools as fixed- or variable-crest weirs, slotted or rock weirs, flap-gated culverts, plugs, trenasses, spoil banks, and/or levees. Each tool controls hydrology (e.g., water level, flow rates, circulation) in a different way and provides different management results. This chapter will not attempt to identify factors affecting the feasibility of each type of structural management. Weirs, plugs and trenasses are used for various reasons, and such structures are reported to have variable effectiveness depending on the factors studied. The Coastal Management Division of the Louisiana Department of Natural Resources and the Soil Conservation Service (Coastal Management Division and Soil Conservation Service 1988) provide some general guidelines about marsh types and characteristics for which various types of weirs are most appropriate. However, these structures are relatively common throughout many habitats in the coastal zone. Because there are few if any wetland habitats in which fixed-crest weirs, plugs, and trenasses cannot feasibly be built, and because these measures are less expensive to build than many other types of water control structures, we have not attempted to identify areas in the coastal zone where they are not feasible.

Impoundment is a more intensive form of structural management that utilizes a levee system (or spoil banks) along with water control structures (variable-crest weirs, flap-gated culverts, and/or pumps) to control the hydrology inside an area. Impoundment, combined with water level drawdown, is the only form of marsh management reported to decrease land loss in the coastal zone (Hess et al. 1989; Soil Conservation Service 1988b, 1989) and may become more common as Louisiana's land loss problem continues. For this reason, plus the high cost of impoundment, and because the success and longevity of impoundments are more closely tied to environmental conditions, we have restricted the discussion of factors affecting marsh management feasibility to those affecting impoundment feasibility.

Other factors not used to determine management feasibility are the effects and effectiveness of marsh management. Impoundments currently are used in coastal Louisiana primarily to improve waterfowl and wildlife habitat, to reduce land loss, or to restore marsh. However, some ecologists suggest that impounding marshes accelerates land loss, while others believe that natural marshes are more productive than impounded ones. If this were so, impounding marshes to enhance wildlife or reduce land loss would not be feasible. In this chapter we will assume that the goals for which a marsh is impounded can be at least partially achieved using impoundment tools and techniques and that the effectiveness of impoundment will not be used as a criterion for determining the feasibility of structural management.

METHODS

Environmental factors affecting the feasibility of structural marsh management (table 45) were identified by perusing literature pertinent to marsh management and by consulting with personnel involved in structural management.

Table 45. Environmental factors affecting the feasibility of marsh management in Louisiana.

Soil properties
Marsh type
Relative sea level rise
Habitat stability
Tidal flux
Acres controlled
Erosional forces
Distance from the Gulf of Mexico

Several reports have discussed structural marsh management and identified factors that cause the failure of managed areas: storm overwash (Harrison and Kollmorgen 1947; Turner and Neill 1983), poor soils (Harrison and Kollmorgen 1947; Fredrickson and Taylor 1982; Turner and Neill 1983; Broussard 1988; Coastal Management Division and the Soil Conservation Service 1988), and boat wash (Nichols 1959; Ensminger 1963). Personnel from the Center for Wetland Resources and the Louisiana Geological Survey at Louisiana State University, from the Soil Conservation Service, and from the Louisiana Department of Wildlife and Fisheries also were consulted to identify environmental factors that may affect the feasibility of structural marsh management.

The environmental factors identified affect feasibility by increasing construction and/or maintenance costs, increasing the possibility of structural failure, or decreasing the expected longevity of a management program. All environmental criteria are related to economic factors because they can increase the costs of maintaining successful management to the point at which landowners can no longer afford to manage the area. It is not possible to identify a per-acre cost, beyond which marsh management becomes unfeasible. The availability of land investment funds, the potential uses of and income generated from an area, and the aesthetic and cultural value of the land are factors that may affect the economic feasibility of marsh management. Regardless of data provided in this report, it should be understood that most of Louisiana's coastal wetlands, including low feasibility areas, are manageable if the landowner has and is willing to invest, sufficient money.

Although all criteria listed play a part in determining the feasibility of structural management, three environmental criteria are most useful: soil properties, habitat stability, and relative sea level rise. These factors were selected because they are extremely important in determining the success and longevity of marsh management and because data pertaining to geographic variations of each are readily available. Each of these variables is defined and described in detail and its effects on the feasibility of structural management have been identified. Areas in the coastal zone where each variable renders structural marsh management least feasible are depicted on maps. Finally, those criteria not selected for in-depth analysis or mapping have been defined and their possible effects on management feasibility briefly described.

RESULTS

Soil Properties

Those soils considered to render an area least feasible for structural marsh management were identified through soil taxonomic classifications. These classifications are based on the amount of organic matter and the placement of organic layers within the soils. The Histosol soil order was identified as the least appropriate for structural management because of its highly organic nature. A soil must contain 12-18% organic carbon (20-30% organic matter) in at least half of the upper 80 cm of the profile to be classified as a Histosol (Soil Survey Staff 1975). Furthermore, the organic materials in Histosols must also meet the following requirements: 1) they may not be overlain by a mineral layer 40 cm thick or more, nor may they contain such a layer with an upper boundary within 40 cm of the surface; and 2) the organic materials may not include mineral layers that have a cumulative thickness of 40 cm or more within the upper 80 cm of the control section.

The organic content of a soil frequently determines the management tools and techniques that can be used. Undrained Histosols are poor candidates because they often are too soft to support many marsh management structures or grazing livestock. Water control structures built on organic-rich Histosols (Typic Medisaprists) are often expensive because of the extra support required. Levees or spoil banks constructed on these soils often must be placed on artificial mats or they will sink into the surrounding substrate. This support material raises the cost of constructing levees three- to four-fold (Broussard 1988). However, Terric Medisaprists and Hydraquents are more suited to extensive drawdown than Typic Medisaprists because of their higher mineral content. When drained, Histosols dry and shrink irreversibly. Deep cracks form that do not close when the soil is rewet. The upper 2-3' may become firm, but the layer below the water table remains semifluid and unstable. Levees constructed of Histosols shrink upon drying, eventually losing up to 94% of their volume to the decay of organic matter and loss of pore space (Coastal Management Division and Soil Conservation Service 1988).

Histosols in brackish and saline waters are least feasible for structural marsh management because of the negative effects of salinity on management capabilities and construction costs. The salinity of soils in coastal wetlands influences vegetation and wildlife habitat. Encouraging vegetation beneficial to waterfowl, a major goal of many management plans, becomes more difficult as marshes change from fresh to saline. Soils high in salt content have physical and chemical properties unfavorable for most cultivated crops. When dried, some saline soils become highly acidic and will allow little vegetative growth (Neely 1962).

Water and soil salinities also can create problems with metal structures not designed to tolerate such conditions (Broussard 1988). Metal components of structures are more susceptible to corrosion than most other materials used in construction. To extend the life expectancy of metal structures in saline environments, metal parts should be coated to standards set by the American Society for Testing Materials (Broussard 1988), the metal should be cathodically protected, or thicker metal should be used. The Department of Wildlife and Fisheries is using aluminum structures to prevent corrosion. All these techniques, however, increase the initial cost of constructing water control structures, thereby decreasing structural feasibility. The Department of Wildlife and Fisheries is also experimenting with high quality plastic structures in an attempt to find an inexpensive and long-lasting material, but data on such structures are not yet available.

Six Histosol soil associations in the coastal zone have been identified as least feasible for structural management because of soil type and salinity (table 46). The Lafitte series has been rated as having very high subsidence potential when drained, having moderate to high salinities, being unsuitable for cattle grazing, having very low cropland potential, and having the highest development difficulty (Coastal Management Division and Soil Conservation Service 1988). Those authors did not rate the other low-feasibility associations. Soil association maps (Louisiana Department of Agriculture and Forestry 1988) were used to identify boundaries of soil associations identified as least feasible for structural management, which are shown in plate 8. These soil associations cover major portions of the southern sections of Breton, Barataria and Terrebonne basins and the Mississippi delta.

Table 46. Soil codes, associations, and characteristics of Histosols or Histosol-dominated associations in coastal Louisiana.[1] Code numbers are as they appear in Louisiana Department of Agriculture and Forestry (1988) maps and reports.

Code	Soil Association	Characteristics
0005	Allemands-Carlin	fresh
0101	Kenner-Allemands	drained
0111	Lafitte[2]	moderately saline
0116	Maurepas	fresh
0117	Maurepas-Hydraquents	fresh
0119	Medisaprists	fresh
0121	Medisaprists-Haplaquolls	fresh
0123	Medisaprists-Hydraquents	fresh
0124	Medisaprists-Hydraquents[2]	moderately saline
0125	Medisaprists-Hydraquents[2]	saline
0310	Allemands-Kenner-Larose	fresh
0385	Kenner-Allemands	fresh
0405	Lafitte-Clovelly[2]	moderately saline
0492	Timbalier-Scatlake[2]	saline
0500	Timbalier-Bellpass[2]	saline

[1]The reader is referred to table 1 in appendix L for a description of the taxonomic classification for the soil series and soil associations.
[2]Least suitable for structural marsh management.

These maps provide a general indication of the feasibility of certain soils for supporting marsh management structures. It is not advisable to use the broad-scale soil association maps (e.g., 1:250,000) to determine the feasibility of marsh management on a specified tract of marsh. The Soil Conservation Service recommends using detailed soil survey maps (1:20,000) and on-site soil boring to determine management feasibility and to site structures.

Habitat Stability

The term "habitat stability" has been coined to describe relative land loss rates along the coast. Areas in which relatively little emergent marsh has turned into open water have high habitat stability, whereas areas experiencing rapid land loss (i.e., hot spots) have low habitat stability.

Habitat stability is probably related to some extent to soil type and sea level rise. Although Leibowitz and Hill (1987) were unable to correlate land loss with any series of variables, they did not include soil type or sea level rise in their model. These variables as described in this chapter are probably responsible for some of the land loss in areas where habitat stability is lowest.

Areas with low habitat stability also have low management feasibility for several reasons. They tend to have a higher water:land ratio than more stable areas. Constructing levees is more difficult and expensive in areas that have open water, regardless of whether it is in the form of ponds or channels interspersed with the vegetation. Levee material will slide and fail unless special precautions are taken when the levee is built across channels and ponds. Such precautions include using expensive artificial support mats or filter cloth on water bottoms. In addition, wave wash across open water next to levees increases maintenance costs and the chance of levee failure. A break in a levee at the wrong time can destroy management progress for an entire year.

Because reducing land loss is the most common goal of marsh management (table 32), those areas in which land loss is greatest may well be those that landowners most desire to manage. Unfortunately, areas with high rates of land loss are also those with low habitat stability, and hence low marsh management feasibility. Again, economic factors may be most important in deciding whether management is successfully implemented and maintained in these areas. Areas with low habitat stability are manageable, but at a higher cost than other areas.

Areas with extremely low habitat stability were identified by means of geographic information system techniques. The Earth Resources Data Analysis System was used to compare digital 1956 and 1978 U.S. Fish and Wildlife Service habitat data for the entire coastal zone. A 1956-to-1978 habitat change map for the coastal zone was made, from which a map showing only land loss was produced; it was then scanned with a roving "window" of 34.75 acres, consisting of 225 cells, to assign a land loss density value to each cell. The window scanned each 25-m land loss cell, moving column by column through the map file. The land loss cells occurring in the window at any time were counted; the cell at the center of the window was assigned a density value corresponding to the number of land loss cells occurring within the window at that location. This value is actually a percentage of the area in each window.

Areas of land loss of over 29 acres (85% of the area in each window) were identified as least feasible for marsh management. (A value of 192 (out of 225 cells) is equivalent to >29 acres). All values over 192 in the 1956-to-1978 coastal zone land loss map were output in map form (scale 1:500,000) to identify areas with more than 29 acres of land loss (plate 8). Although many pixels meeting this criteria were not printed on this map due to low resolution, areas where large numbers of "low stability" pixels were clustered are evident.

Areas with high rates of land loss (i.e., with low habitat stability) lie in the chenier plain (primarily the Sabine and Calcasieu hydrologic basins) and the Mississippi River birdsfoot delta (plate 8).

Relative Sea Level Rise

Relative sea level rise is the vertical change in elevation of the marsh surface relative to sea level. It is a complex process caused by a number of factors (Penland et al. 1988):

1) eustatic change;
2) regional subsidence caused by crustal downwarping from sedimentary loading;
3) compaction of Tertiary and Pleistocene deposits;
4) compaction of Holocene deposits;
5) localized consolidation;
6) tectonic activity; and
7) subsurface fluid withdrawal.

Subsidence is the downward displacement of the surface with respect to sea level and is caused by factors 2-7, above. Relative sea level rise, therefore, is a result of eustatic change and subsidence.

Relative sea level rise affects structural management feasibility by:
1) increasing the costs of maintaining levees;
2) decreasing the effectiveness of many water control structures; and
3) increasing the duration and effects of inundation caused by storm tides and precipitation.

It costs about $40 per linear meter to construct the levees used in structural management (Coastal Management Division and Soil Conservation Service 1988). Although maintenance costs are not as high as those for initial construction, maintaining levee height and shape may be expensive enough in rapidly subsiding areas to force landowners to discontinue management. In addition, rapidly subsiding areas outside levees turn into open water faster than those in other areas. This increases maintenance costs because landowners must continually fortify levees damaged by wave action.

Structures built in coastal marshes tend to subside at a rate different from that of surrounding marshes. Often they are attached to pilings driven into the hard clay substrate underlying the organic and mineral soil layers. Occasionally, marsh management structures are installed without pilings. With or without pilings, structure elevation in relation to the surrounding marsh and water elevations often changes over time. As structure elevation changes, the efficiency of some structures for controlling hydrology is diminished: drawdown capability decreases, the ability to move water into or out of an area decreases, and the capability to rapidly move storm waters off a marsh may decrease. Because subsidence rates of over 2.5 cm/yr have been estimated for some marshes in coastal Louisiana (Ramsey and Moslow 1987), the height of a structure in relation to the surrounding marsh may change by almost 1′ in 10 years. The cost of replacing or altering such structures every several years may decrease structural management feasibility in high-subsidence environments.

The rate of relative sea level rise in coastal Louisiana varies locally and regionally. Ramsey et al. (1985), Ramsey and Moslow (1987), and Penland et al. (1988) analyzed tide gage records and geodetic leveling data from dozens of stations across the Louisiana coast to determine rates of regional sea level rise. Ramsey and Moslow (1987) subdivided relative sea level rise rates in the Louisiana coastal zone into 0.5-cm/yr contours. We used only the most extreme subsidence rate (over 2.5 cm/yr) to identify areas in which structural management was least feasible. These areas are shown on plate 8. The only portion of the Louisiana coastal zone having rates above 2.5 cm/yr was the southern portion of the Terrebonne basin.

Unquantified Feasibility Criteria

Several other environmental factors also can affect the feasibility of structural management, namely, marsh type, tidal flux, and boat wash. Although their effects may be difficult to quantify, in some situations they may have as much, if not more, impact on management feasibility as soil type, sea level rise, or habitat stability.

Marsh type refers to four categories of coastal habitats based on prevailing salinities: fresh, intermediate, brackish, and saline. Marsh type affects management feasibility by restricting the potential uses of the marsh. For example, mariculture (the production of predominantly marine organisms) requires a natural source of brackish or saline water and therefore cannot feasibly be accomplished in fresh and intermediate marshes. Impoundments for crawfish or catfish are most feasible in fresh marshes. Salinity also affects the type of vegetation and wildlife for which an impoundment can be managed. Growing of vegetation beneficial to waterfowl and furbearers is difficult in saline marshes, but becomes increasingly easier as salinities decrease.

Management feasibility may also be reduced in flotant marsh. Flotant marshes are fresh marshes having from a few inches to more than several feet of semifluid or fluid material below a floating root mass. Impoundment feasibility may be low in flotant marshes because water level drawdowns are impractical in these habitats. Also, constructing levees on flotant marsh is difficult, costly, and sometimes impossible. The distribution of flotant marsh in coastal Louisiana has been mapped by Kolb and Van Lopik (1966).

Tidal exchange refers to both the height of the tide and velocity of the current affecting an impounded area. Many structures used to control water movement between impounded and outside areas cannot function without some variation in tidal exchange. Impoundments in non-tidal areas may require pumps for proper management. Episodes of high rainfall may alter scheduled drawdowns in pumped areas because of the inability of pumps to rapidly drain water from a marsh. The added cost of purchasing and running pumps may increase the cost of managing a marsh to the point that it is no longer feasible. Tidal exchange also affects management feasibility because levee maintenance costs may be much higher if a levee is situated next to a canal controlling a large drainage area.

Erosional forces other than tidal flux can increase the cost and decrease the feasibility of impoundments. Ensminger (1963) reports that the greatest damage to an impoundment levee is caused by boat wash. There is a direct correlation between the rate of erosion and the amount of boat traffic in a canal. Narrow berms between the canal and levee can be quickly eroded away and with heavy usage, erosion will soon attack the base of the levee. Recognizing the high cost of maintaining levees along canals used by boats, the Louisiana Wildlife and Fisheries Commission has required that new oil development on Louisiana's Rockefeller Wildlife Refuge be accomplished with board roads rather than canal systems (Ensminger 1963). Levees adjacent to heavily travelled canals require frequent maintenance and have a much higher incidence of breaks than levees farther away from canals. This additional maintenance cost can be quite high and may rapidly convince landowners to discontinue management. Wind-driven waves can also damage levees. If a long fetch parallel to the direction of the prevailing wind is present, the costs of repairing damaged levees may become prohibitive.

Impoundments may not be feasible on an extremely small or large scale. The cost of erecting levees or maintaining levee integrity and installing water control structures may render management less feasible for small areas, especially if those areas have minimal natural resource value. Impounding large areas increases the necessity of several water control structures to properly manage the hydrology, thereby increasing construction costs considerably. Subdividing large areas into several smaller impoundments increases management capabilities and allows management for a variety of resources. It also ensures that, if a levee is breached, only one impoundment in a system is compromised, not the entire area. However, the expense of installing and maintaining additional levees and water control structures may decrease management feasibility so much that many landowners will forego building impoundments.

Impoundment feasibility may be extremely low in areas near the Gulf of Mexico. Hurricanes are a constant hazard in coastal Louisiana between July and November; a hurricane hits the Louisiana coast on the average of every 2.2 yr (Neumann et al. 1981). Hurricane storm surge several feet high can extend many miles inland, especially along waterways. This surge may inundate and severely damage levees, inflating the costs of maintaining such structures.

Feasibility Quantification

The areas of low feasibility described above can be subdivided into areas of low feasibility, lesser feasibility, and least feasibility. In general, areas "least" feasible for structural management are those in which low feasibility areas of all three environmental factors overlap. No area in Louisiana has been identified as having all three low feasibility environmental factors overlapping (plate 8). Areas of "lesser" feasibility are those in which two of three low feasibility factors overlap. Several areas in Terrebonne, Barataria and Breton Sound basin at the Mississippi River birdsfoot delta have two overlapping low feasibility factors (plate 8). An area of "low" feasibility is one in which only one low feasibility factor is present. The magnitude of an environmental factor's effect on the feasibility of structural marsh management also varies. The Soil Conservation Service rates soil type and habitat stability as approximately equal in importance, but more important than subsidence in determining management feasibility (Broussard 1989).

The comparison of factors affecting management feasibility would be improved if the operational status of all structures permitted in the coastal zone were known. Few landowners report to the Coastal Management Division that their plans have been implemented (table 25), and no agency maintains contact with the landowner to keep up-to-date records of structural integrity. Maps and data bases should be developed showing the type, placement, and status of all water control structures in the coastal zone. Areas of high structural failure should be examined to determine the factors contributing to the failure.

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. The includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. Administration.