OCS Study
MMS 90-0075

A Study of Marsh Management Practice in Coastal Louisiana

Volume I: Executive Summary

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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TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGMENTS

Project Management

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EXECUTIVE SUMMARY

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INTRODUCTION AND SIGNIFICANT CONCLUSIONS

Marsh management, chiefly in the form of water-level and salinity control, is viewed by many as an effective tool for preserving and enhancing wetland habitats. This study was conducted to determine the effectiveness and suitability of marsh management techniques for mitigating wetland deterioration and loss in the heterogeneous environments of coastal Louisiana. The area of study was the entire Louisiana coastal zone, located in the north-central Gulf of Mexico (figure 1). The loss of wetland habitat in this area is related to the death of vegetation caused primarily by natural and human-induced hydrologic and sedimentologic imbalances in a rapidly subsiding coastal environment. Marsh management includes structural management techniques (e.g., the use of weirs, adjustable water control structures, levees) that directly manipulate water levels and flows, and nonstructural management techniques (e.g., marsh burning and chemical intervention) that directly influence the growth of desirable and undesirable species of plants. This study was based on the premise that the ability to predict the effects of management and hence to manage marsh can be enhanced through an improved understanding of how and to what extent management techniques influence hydrologic and sedimentologic processes. This would improve our understanding of how to reduce or reverse wetland loss and preserve or improve existing wetlands.

This report focuses mainly on structural marsh management techniques because these techniques are becoming increasingly popular with private wetland owners; they require a state and federal permit; and their influence on hydrology, sediment distribution, and plant growth either has not been quantified or is poorly understood. The results of this study will contribute directly to a programmatic environmental impact statement on marsh management in coastal Louisiana being prepared by the U.S. Army Corps of Engineers.

Significant Conclusions

Although the use of structural management, particularly manipulated impoundments (i.e., active water-level management), to combat saltwater intrusion and wetland loss increased substantially during the 1980s, our knowledge of the effectiveness of this management technique is limited. A review of the secondary literature reveals large gaps in information about marsh management's influence on wetland loss, primary production, accretionary processes, nutrient cycling, and cumulative impacts. Landowner-conducted monitoring of marsh management has been of limited usefulness in evaluating the effectiveness of management. In addition, the public interest goals of the federal and state regulatory agencies toward marsh management are often contradictory and in direct conflict with one another both because of the lack of documentation of management impacts and differing agency mandates.

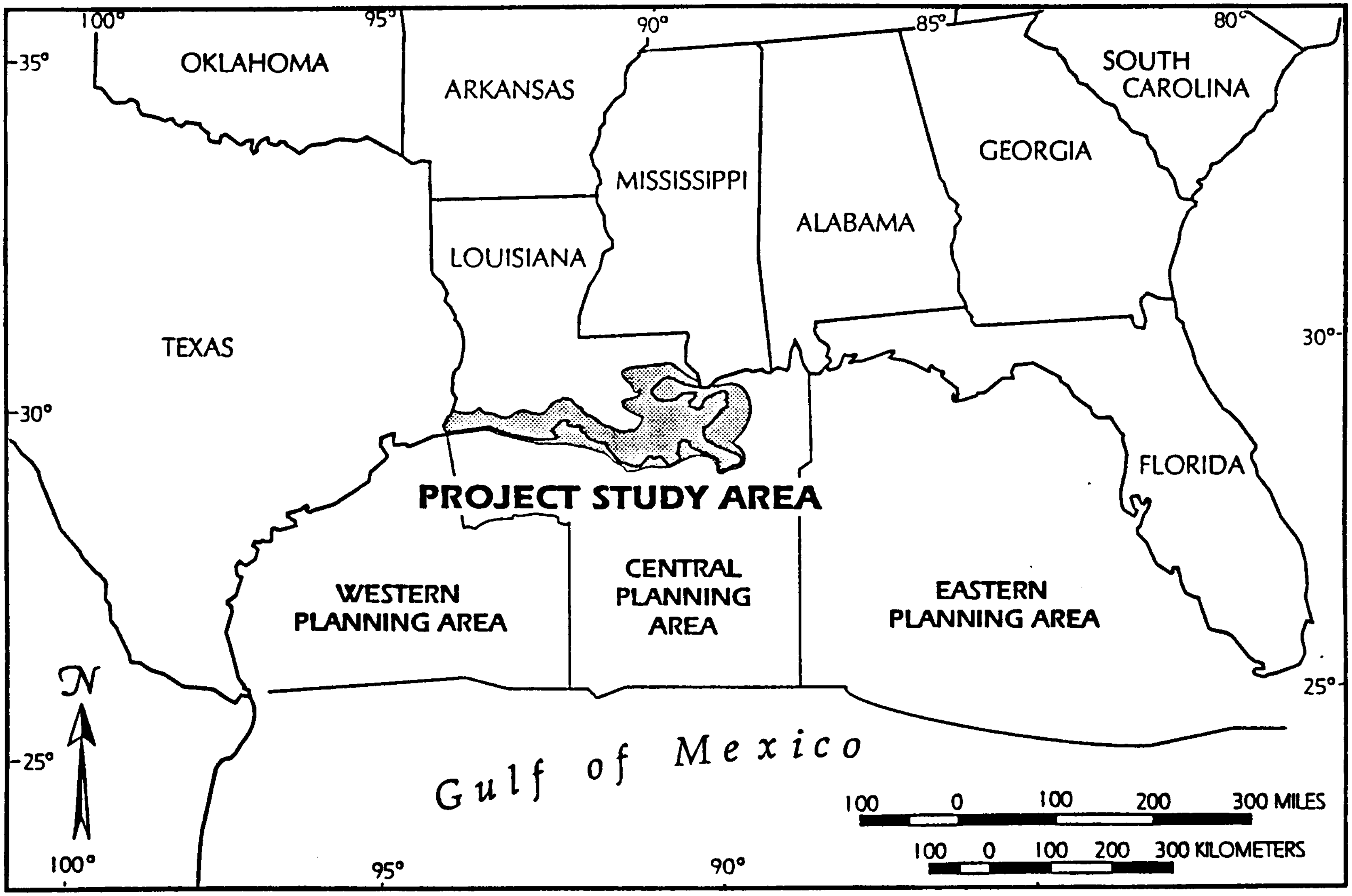

Figure 1. Study area (stippled) in relation to the Gulf of Mexico region.

Monitoring conducted during this study revealed that marsh management was effective at improving marsh-to-water ratios, changing marsh type, and increasing marsh acreage at less than half of the 16 managed sites evaluated. Field monitoring of two Spartina patens marshes during drawdown years indicated that management reduced (1) water level fluctuations; (2) the import of water, sediment, and nutrients; (3) vertical accretion; (4) soil bulk density; (5) accumulation of organic and mineral matter; and (6) the ingress and egress of marine transient fish species. Management enhanced growth of Spartina patens, the dominant plant species, at Rockefeller Refuge but not in the southern portion of the managed area at Fina LaTerre. The cause(s) for this differential response cannot be stated unequivocally, but we hypothesize that the ability to use management to create soil conditions that are less biochemically reduced, within a non-growth-limiting salinity range, is central to maintaining vigorous stands of Spartina patens within managed marshes. These findings suggest that managed marshes may become sediment- and nutrient-limited, underscoring the potential cumulative impacts of marsh management. Additional research is needed on other marsh types and during other operational scenarios in order to evaluate fully the short- and long-term biological consequences of marsh management.

PROJECT GOALS AND APPROACH

The study goal was to prepare a factual array of data and data analysis in order to determine the suitability of marsh management techniques as mitigative tools for combatting wetland loss. The project was organized into six major components: (1) a review of marsh management literature; (2) an analysis of administrative, 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 and newly collected field monitoring data; and (6) an ecological evaluation (i.e., synthesis) of marsh management effectiveness based on its biological effects and suitability for use in coastal Louisiana. The work was completed over 30 months by a team of expert scientists, lawyers, consultants, resource managers, administrators, editors, and cartographers. A Technical Steering Committee (TSC) composed of regulatory agency personnel, landowners actively involved in marsh management, and university wetland researchers was formed to advise the project staff. 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 monitoring evaluations conducted as part of this study were directed at providing answers to six major regulatory concerns and associated questions identified by the Technical Steering Committee. The questions reflect a concern that management improve marsh quantity and/or vitality and secondary production while minimizing impacts to estuarine-dependent fisheries and cumulative impacts to surrounding wetlands.

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 public scoping meetings (U.S. Army Corps of Engineers 1988), include environmental impacts, human access, and mariculture-related activities, among others. But the primary concern about structural management is its potential 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.**

Some terms from the marsh management literature 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

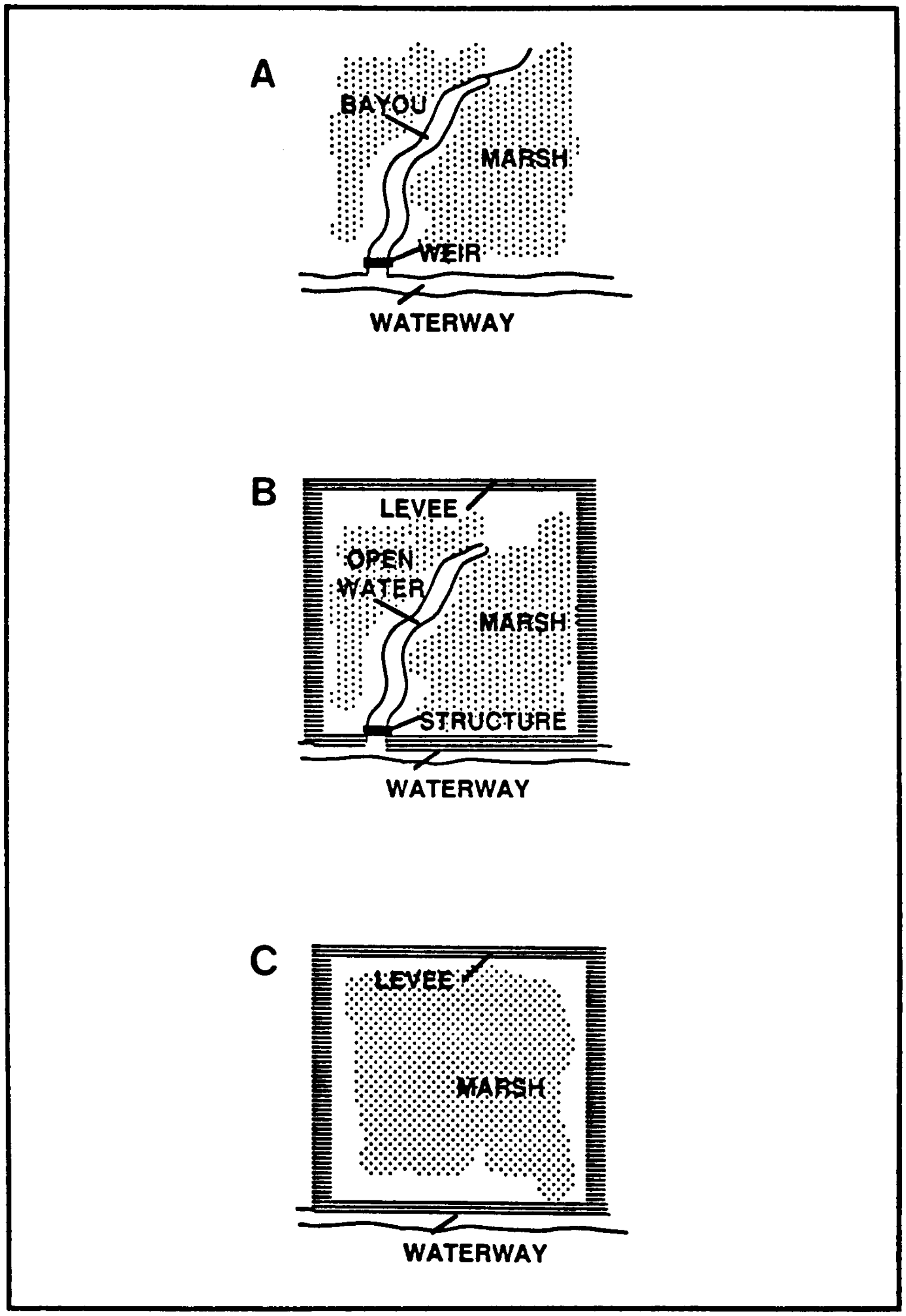

Figure 2. The three basic types of structural marsh management techniques: (A) weir management, (B) manipulated impoundment, (C) unmanipulated impoundment.

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; their water levels vary with the water table. This technique has also been called 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.

Unintentional Impoundment

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.

SUMMARY OF FINDINGS

The important findings of this study are summarized below. Each summary bullet is cross-referenced to the chapter in the main body of the text (volumes 2 and 3) from which it was drawn. The monitoring findings can also be related to questions (i.e., regulatory concerns) posed by the Technical Steering Committee. These questions can be found in the following section of the Executive Summary and in chapter 12.

Literature Review

The reader is referred to chapter 2 for a detailed description of the literature review.

The effect of structural management on fisheries was the most frequently reported topic (30%) in the literature reviewed, followed by effects on plant species composition (20%), water quality (15%), and waterfowl and wildlife (10% each).

Impoundment techniques were the most frequently discussed management method (45%), followed by research on fixed-crest weirs (25%).

The literature review identified a number of significant data gaps and research needs, including the following:

> The impact of structural management on the flux of matter, vertical accretion, accumulation of matter, plant growth, subsidence, and land loss. The effects of structural marsh management on land loss have been reported in only 6% of the literature reviewed.
>
> The cumulative impacts of structural management on hydrologic processes, land loss, and secondary production.

Design of water control structures that minimize trade-offs between effective control of hydrologic factors and ingress and egress of estuarine-dependent organisms.

The environmental effects of operational failure or abandonment of a management plan.

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

Administrative Framework

The reader is referred to chapter 3 for a detailed description of the administrative framework within which marsh management is regulated.

State and federal regulations affecting marsh management are complex, often contradictory, and a source of frustration to applicants. The regulatory system can present a confusing front to prospective marsh managers because the intricate interactions between the permitting agencies and the commenting agencies are designed to safeguard various widely divergent public interest goals.

Public Interest Goals

The reader is referred to chapter 4 for a detailed description of the public interest goals that affect marsh management in Louisiana.

The public interest goals that affect marsh management in Louisiana are widely divergent and sometimes contradictory. Major goals include the desire to prevent land loss, provide incentives for landowners to undertake marsh management, foster marine fisheries, allow public access to wetlands, maintain state and private ownership rights, and make profits from landholdings.

Public policy goals are sometimes contradictory and in direct conflict with one another partly because of the lack of documentation of management impacts and because of differing mandates.

Shifts in policy are needed to diminish conflicts. Otherwise, deadlocks will probably have to be broken by legislative action at both the state and federal levels. The process of policy reform will benefit from additional research on management effects.

Engineering and Construction Techniques

The reader is referred to chapter 5 for a detailed description of the engineering and construction techniques presently being employed in coastal Louisiana.

There are two basic structural management techniques currently used in coastal Louisiana: weir management, also called passive water management; and manipulated impoundments, also called active water management. Unmanipulated impoundments have rarely been constructed and are no longer likely to be permitted.

Passive water management is achieved usually by wooden or metal fixed-crest weirs with a weir crest height usually at 15 cm below marsh elevation. Alternative weir designs have been investigated that would permit more movement of aquatic organisms and still provide hydrologic control, such as the vertical slot weir and the rock weir.

Manipulated impoundments manage water levels through a combination of water control structures and levees. This form of active water management requires expensive and relatively sophisticated control structures, is more labor intensive than passive management, and requires a thorough knowledge of local hydrological and biological conditions. However, this type of management provides the marsh manager with greater flexibility in managing water flows.

Marsh Management Profile

The reader is referred to Chapter 7 for a detailed discussion of existing marsh management activities in coastal Louisiana.

As of May 15, 1989, 165 applications had been submitted to the state to manage 503,000 acres of coastal marsh, 12% of all coastal marsh habitat. The mean processing time for an application was eight months, with the longest processing time being four years. The annual application rate has remained relatively high during the past five years. Most applications are for wetlands in the Terrebonne, Barataria, Mermentau, and Vermilion-Teche basins.

One-hundred thirty-nine of the 165 applications required a permit. As of May 15, 1989, 126 applications were issued a permit. These permits are to manage 288,000 acres of privately-owned coastal marsh habitat (9% of all wetlands). Implementation of management has commenced for approximately one-third (43) of these permits, but the number of fully implemented plans 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.

Active water-level manipulation is the primary activity requested; the primary purpose of management is to mitigate land loss. The second and third most commonly stated goals are to improve waterfowl and furbearer habitats.

Most applications are requests to manage brackish marsh, followed by fresh marsh, but more acres of fresh marsh are proposed for management, followed by brackish and intermediate marsh.

The ability of managers to evaluate the effectiveness of their plans and the potential need to modify the designs are limited because most managers are not collecting required monitoring data; those data which are collected are often descriptive and include little analysis or interpretation.

Feasibility of Constructing, Operating, and Maintaining Management Structures

The reader is referred to chapter 8 for a detailed description of the environmental factors that affect the construction, operation, and maintenance of management structures in coastal Louisiana. Feasibility is considered to range from low to high, because with enough money practically anything can be constructed in the marsh. The data and comments presented here should be used only as an indication of the general feasibility of marsh management in an area, and are not meant to supplant site-specific data.

Eight environmental factors were identified as affecting the feasibility of implementing marsh management in Louisiana: soil properties, relative sea level rise, habitat stability, marsh type, tidal flux, size of managed area, erosional forces, and distance from the Gulf of Mexico. The first three factors probably exert the greatest influence on management.

The organic content of a soil frequently determines the management tools and techniques that can be used. Undrained, highly organic soils are poor candidates because they are too soft to support many marsh management structures. Additional construction measures, and therefore expense, must be undertaken in these soil types. In general, other soil types, particularly those with higher mineral content, are considered to be more feasible for management.

High rates of subsidence and sea level rise may increase construction and maintenance costs for levees and diminish the efficiency of water control structures used for gravity drainage.

Areas with low habitat stability (i.e., high rates of land loss and large amounts of open water) have a lower management feasibility than areas with high habitat stability (i.e., low rates of land loss and small amounts of open water). Constructing and maintaining levees is more difficult and expensive in open water because of the influence of flowing water and waves.

Monitoring Results

Landowner Programs

The reader is referred to chapter 10 for a detailed discussion of the monitoring programs employed by permittees and their consultants.

The monitoring data base on file at the Department of Natural Resources is small in relation to the number of implemented managed areas (9 plans out of approximately 20 fully and 30 partially implemented plans).

The intensity of the monitoring programs varies greatly. Some efforts are dedicated to creating long-term data bases; other monitoring efforts have ceased.

The quality of the monitoring programs varies greatly. The monitoring programs focused on measuring plant species composition, water parameters (e.g. level and salinity), and habitat change. However, these variables were rarely measured in a nearby unmanaged marsh for comparison. Only one of the monitoring programs provided data on plant growth and no programs provided data on abiotic factors that may affect plant growth, such as water and matter flux, nutrient cycling, sediment distribution and accretion, soil conditions, subsidence, and evapotranspiration.

The ability of the monitoring programs to evaluate the effectiveness of management is limited by the variation in monitoring intensity and quality.

<u>Habitat Change Analysis</u>

The reader is referred to chapter 11 for a detailed discussion of the influence of management on habitat change based on an analysis of 16 management programs.

Marsh management is not consistently effective at increasing marsh acreage, reversing the influence of salinity on habitat composition, or improving marsh-to-water ratios. When analyzed over the entire interval of management, some managed areas became fresher, or had improved marsh-to-water ratios compared to their unmanaged area, while some unmanaged areas showed improvement when compared to their managed area. For example, five managed areas showed improvement in marsh-to-water ratios when compared to their unmanaged areas, while three unmanaged areas showed improvement in marsh-to-water ratios when compared to their managed areas. However, for 50% of the comparisons, there was no difference between the changes occurring at the managed area and those occurring at the unmanaged area.

During the last photographic interval (1985-1988), actively managed marshes sometimes produced improved marsh-to-water ratios (5 of 10 sites), net gains in marsh (2 of 10 sites), and a net change of water to marsh (4 of 10 sites) when compared to nearby unmanaged marshes.

Passive management, with very few exceptions, produced no gains in marsh-to-water ratios or marsh acreage.

<u>Field Studies</u>

The reader is referred to chapter 12 for a detailed presentation of the methods and results of the field investigations. The field monitoring findings are based on data collected during a drawdown year at two sites, Rockefeller Refuge and Fina LaTerre Mitigation Bank Site. For the Fina LaTerre site, the findings pertain only to the southern portion of the managed area and the unmanaged reference area south of Falgout Canal.

Management was successful at isolating the managed marsh from most local hydrologic influences and controlling and stabilizing water levels at both field sites. In contrast, the unmanaged marshes were influenced by diurnal tidal variations, winter storms, and lunar tidal effects.

The impacts of management on hydrology and sedimentology were similar in the southern portion of the Fina LaTerre site and management unit 4 at Rockefeller Refuge. Tidally-driven flux of water and matter, vertical accretion, soil bulk density and accumulation of organic matter were significantly lower and soil organic matter content significantly higher at the managed areas compared to the unmanaged areas. The rate of accumulation of mineral matter was also lower at unit 4 in Rockefeller Refuge.

Although management effects on hydrology and sedimentology were similar at both sites, management effects on soil substrate conditions were significantly different. The southern portion of the Fina LaTerre managed marsh had more organic soils, more reduced soil conditions, and higher interstitial salinities than the unmanaged marsh during the 1989 growing season. In contrast, the managed marsh at Rockefeller Refuge had less-reduced soil conditions, lower interstitial salinity, and lower interstitial sulfide concentrations than the unmanaged marsh.

Water-level marsh management can have a positive or negative effect on the productivity of the dominant plant species, Spartina patens. Growth of Spartina patens was enhanced in the managed marsh at Rockefeller Refuge but not in the southern portion of the managed area at Fina LaTerre. The cause or causes for this differential response cannot be stated unequivocally, but we hypothesize that the ability to create less biochemically reduced soil conditions during management, within a non-growth-limiting salinity range, is central to maintaining vigorous stands of Spartina patens within managed marshes.

Water-level marsh management can have either a positive or no effect on plant species diversity. Species diversity was enhanced in the managed marsh at Rockefeller Refuge but there was no difference in species composition between the managed and unmanaged areas studied at Fina LaTerre. Total vegetative cover and cover of the dominant species, Spartina patens, were significantly lower in the southern portion of the managed marsh at Fina LaTerre compared to the unmanaged marsh.

At Fina LaTerre, total fish biomass was similar in managed and unmanaged areas, but fish species composition was different. More marine transient species were caught in the unmanaged area and more of the following resident species were caught in the managed area: grass shrimp, least killifish, sailfin molly, and mosquitofish. More fish species were collected in the unmanaged area than in the managed area.

Water salinity in the managed area at Fina LaTerre was similar to or higher than in the unmanaged area. Pockets of water with slightly different salinities were found within the managed area, but not within the unmanaged area. Thus, the managed area appears to have less water circulation than the unmanaged area.

REGULATORY CONCERNS

Information collected from all of the monitoring efforts was synthesized and used to answer the questions related to the concerns of the regulatory agencies described above. Not all questions could be addressed or completely answered because of the limitations of our data base. We present here those questions and answers which summarize the key findings of this study in order of priority as determined by the advisory committee, not in the order in which the data were discussed above.

What are the differences in the loss of emergent vegetated wetlands and aquatic vegetation between areas with and those without structural marsh management?

A substantial majority of sites lost marsh in both the managed and unmanaged areas during the intervals in question (implementation through 1988). A total of 12 managed and 15 unmanaged areas had marsh loss after management implementation. The average loss was similar at both managed and unmanaged areas (10% vs. 9%). In seven managed areas, the magnitude of marsh loss was greater than that in the companion unmanaged area, while six unmanaged areas had marsh losses higher than those in their associated managed areas. Several managed areas gained marsh (4, mean = 3%), and one unmanaged area gained marsh (1%). Overall, differences between managed and unmanaged marsh losses were small. Aquatic vegetation was not present at many sites. This may be an artifact of the aerial imagery methods employed in the study. Of the areas studied that had aquatic vegetation immediately before implementation and at the end of the study (1988), three of six managed areas and three of three unmanaged areas had gains. The acreages involved were small in most areas.

What impact does structural marsh management have on sediment transport, vertical accretion, erosion, and organic matter accumulation within manipulated impoundments compared to unmanaged areas?

This study's analysis of two management areas indicates that, during years when water levels are drawn down, exchange of water and associated suspended and dissolved materials was greatly reduced through the water control structure. At Fina LaTerre, exchange measurements were only made at the main water control structure on the south side. It is not known what influence the structures in the northern area have on materials exchange. In regard to accretionary processes, these data suggest that management significantly reduced vertical accretion, soil bulk density, soil mineral matter content, and accumulation of organic and mineral matter. All of these variables were uniformly low during each operational phase of the structure in the managed areas. The influence of management on accretionary processes in the northern portion of the managed area at Fina LaTerre is not known. These data suggest that the effect of management on the flux of matter and accretionary processes was the same for management areas near and far from the coast.

How does management influence vascular plant production (emergent, floating, and submerged) compared to that in unmanaged areas?

The results of this study reveal that in Spartina patens-dominated brackish marsh, marsh management can either positively or negatively affect plant health and net primary productivity depending on the local environmental conditions and marsh management-associated factors (e.g., operation schedule, design, and drawdown ability).

This one-year field analysis indicated that the marsh management plan at Fina LaTerre resulted in lower leaf CO_2 exchange rates and net aboveground primary productivity than in the adjacent unmanaged marsh. The cause of the lower productivity cannot be determined unequivocally, but we hypothesize that the greater soil-reducing conditions in the managed marsh may have been the primary factor. Soil interstitial salinity differences between the managed and unmanaged marshes at Fina LaTerre were not large enough to have caused this effect on productivity. At Rockefeller Refuge, the effect of marsh management was exactly the opposite of that found at Fina LaTerre: the total leaf CO_2 exchange rates and net aboveground primary productivity were significantly greater in the managed area than in the unmanaged marsh. The more productive vegetation in the managed marsh was most likely due to the less-reduced soil conditions and the lower salinity within this management unit.

In summary, if the marsh can be managed without causing increased soil biochemical reduction and salinity, Spartina patens health and vigor can be maintained or even improved. However, this investigation has demonstrated that these objectives are not always possible to achieve.

How effective are different types of water control structures in reducing saltwater intrusion and salt concentrations?

At Rockefeller Refuge, marsh management significantly reduced interstitial soil salinity, presumably through a combination of decreased tidal-water inundation and increased containment of fresh water from precipitation. At Fina LaTerre, management's ability to reduce salinity depended on time of the year and distance of the particular marsh site from the water control structure. Interstitial salinities in May and July were higher in the managed marsh closest to the water control structure, while salinity in the unmanaged marsh increased as ambient salinities increased during the year. As a result, by September and November 1989, salinities were the same in the managed and unmanaged marshes. Thus, although marsh management at Fina LaTerre did have some influence on salinity, the effect was not enough to lower the marsh salinity below ambient.

The salinity of pond water in both the managed and unmanaged marshes at Fina LaTerre exhibited a similar temporal pattern. During the drawdown phase, however, water salinity was consistently higher (1 ppt) in the managed marsh. During the drawdown, the structure may trap higher-salinity waters behind it, or evapotranspiration combined with lack of flushing may contribute to higher salinities. When the structure is open, it may mediate salinities.

How do the various water control structures influence water levels and frequency and duration of inundation in manipulated impoundments compared to unmanaged marsh areas?

Water levels were stabilized in managed marshes with the elimination of diurnal tidal effects. Consequently, the frequency of inundation was decreased in these marshes. During the drawdown phase of operation, water levels can be lowered to below the marsh surface. The ability to draw down the water levels was directly related to the efficiency of the structural design, meteorological conditions, and tidal amplitude at the site. We have no data on the duration of inundation.

Do manipulated impoundments influence the rate of sediment and nutrient exchange between the impoundment and the marsh outside it?

Our analysis of two management areas indicated that the import of sediment and nutrients into the managed marshes was significantly reduced. The pattern of sediment and nutrient exchange through the control structures studied was similar for marshes near and far from the coast. Under certain hydrologic conditions, especially those encountered during drawdown operations, the data suggest that sediment may be exported from Rockefeller Refuge. These conclusions for Fina LaTerre are for the southern water control structure and it is not known what influence the structures in the northern area have on total flux.

How does structural marsh management influence soil oxidation state, presence of toxic compounds, and cycling of nutrients between plants, soil, and water?

Management can affect soil redox potential positively or negatively. At Fina LaTerre, a lower soil redox potential was associated with marsh management. At Rockefeller Refuge, the ability to draw down the water level of the management area 20-30 cm below the marsh surface has resulted in a more oxidized soil environment than in the unmanaged marsh.

How does management affect fisheries production, standing crop, species composition, access to nursery and foraging areas, and harvest of commercially important species?

The study was not designed to measure secondary productivity, just standing crop. At Fina LaTerre, fishery organisms were grouped into two categories: (1) resident species that spend their entire life cycles in the estuary, and (2) transient species that spend only part of their lives in the estuary. The management plan affected the two categories differently. The standing crop of resident organisms (primarily grass shrimp, least killifish, sailfin molly, and mosquitofish) was larger in number, but not in biomass, in the managed area than in the unmanaged area. Individuals of these species are tiny and have no economic importance. They are important ecologically as forage for commercial and sport species. However, it is probable that relatively few were consumed by marine transient species in the managed area because few marine transients were captured there. We have no information on the numbers or biomass of these tiny resident organisms that were exported out of the managed area. The managed marsh had a smaller standing crop of marine transient organisms than the unmanaged marsh. Management appears to limit access of the marine transient organisms to nursery and foraging areas within the managed marsh. Because very few economically important marine transient organisms are able to utilize the managed area, the area probably does not contribute many organisms to the commercial or sport harvest. Productivity of an area is a combination of standing crop and turnover rate (the rate at which the population is replaced). Assuming all individuals are of the same weight, two areas may have the same standing crop (i.e., number of individuals), but if the population in one area is replaced at twice the rate of that in another area, then the area with the faster turnover rate has twice the annual production. Because the structures limit water and organism movement, managed areas have the potential for lower turnover rates than unmanaged areas.

How do the various water control structures and management in general affect ingress/egress of estuarine-dependent fisheries and nekton?

Because our study was designed to sample only standing crops of organisms, we can only hypothesize that because the numbers of marine transient organisms were so low in the managed area at Fina LaTerre, their ingress into the area was probably impeded.

To what extent do managed areas interfere with transport of detritus out of the enclosed area?

The export of detritus from the two managed marshes we monitored was significantly reduced during the times we sampled.

What are the differences in plant species diversity, dominance, and composition in managed versus unmanaged areas?

Our monitoring of two management areas revealed important differences in the impacts of management on plant species diversity, dominance, and composition. At Rockefeller Refuge, which has been managed for nearly 30 years, plant species were much more diverse at the managed marsh. At Fina LaTerre, however, which has been managed for only 4 years, no important differences existed in species diversity or composition between the managed and unmanaged brackish marsh zones. The effect of management on species diversity in the fresh marsh zone was not measured.

Landowner monitoring at Lafourche Realty indicates that vegetation composition varies greatly between stations and years but there appears to be a trend of saline species being replaced gradually by brackish species in the managed marsh. The trend for the unmanaged marsh is less clear because there are only three stations and samples have been collected for fewer years. However, the marsh outside the managed area does not appear to be getting more saline.

What is the cumulative effect of using many marsh management plans within one basin or sub-basin?

The results from Rockefeller Refuge suggest that the presence of many marsh management units within an area can increase tidal amplitude and alter marsh drainage patterns. The results of the flux and accretion analyses at both marsh sites indicate that management greatly reduces the tidally driven flux of water and suspended matter into managed areas. The influence of riverine driven fluxes is unknown at Fina LaTerre. Consequently, if many management areas were implemented within a region, it is likely that much of the water and sediment entering the upper basin would flow past the managed marshes without being utilized, thus altering flushing rates and sediment distribution patterns within the region. The interaction of structural management with other management techniques, such as diversions of fresh water or sediment, should be investigated. Our data suggest that unless special provisions are made in the design and operation of management units to capture fresh water and/or sediment from the diversions, the managed marshes will be relatively isolated and not benefit from regional increases in fresh water and sediment load.

Other regional impacts are not known and should be investigated. For example, will reducing tidal fluxes in numerous managed areas likely increase tidal fluxes in unmanaged areas? If so, what will the effects of this be? Will design specs on existing water control structures in managed areas become obsolete with higher tidal ranges? What will be the cumulative effect of numerous managed areas in a region on fisheries production? There is still much to be learned concerning cumulative effects of water management.

What is the long-term impact of implementing and then abandoning a marsh management plan?

The data from both Fina LaTerre and Rockefeller Refuge indicate that rates of vertical accretion and matter accumulation are low in managed marshes (approximately 1 mm/yr) during drawdown years. Unless accretion is greater during non-drawdown years or the marshes are able to compensate for the lack of vertical accretion by increased plant production (which our plant growth data for Fina LaTerre suggest is not happening), these accretion data suggest that managed marshes will not keep pace with relative sea level rise. Because Fina LaTerre draws down water levels each year and plant production was reduced in the managed marsh, this suggestion seems reasonable for this site. At Rockefeller Refuge, however, rates of vertical accretion and plant production during non-drawdown years (three out of every four) should be measured to verify this suggestion.

The long-term implication of this suggestion is that managed marshes have a sediment deficit, which has two potential impacts. If management ceases (i.e., the structures are not operated, and the levees and structures are not properly maintained) and the elevation of the managed marsh surface is lower than the surface of the unmanaged marsh because of the cumulative effect of many years of sediment deficit, sea level in the managed marsh will instantaneously rise. The effect of such a change on the health of vegetation could be detrimental. Even if the management area is never abandoned, the cumulative effect of many years of sediment deficit could result in a gradual lowering of the marsh surface with a concomitant decrease in the ability to drain the marsh by gravity. Eventually, gravity drainage may cease. Surface elevation changes in managed marshes should be investigated.

ECOLOGICAL EVALUATION OF MARSH MANAGEMENT

Data collected from the literature, review of engineering techniques, evaluation of the environmental characteristics of the coastal zone, and the monitoring program were synthesized into an ecological evaluation of marsh management. The evaluation included an explanation of the biological consequences and suitability of marsh management and a discussion of research needs.

Biological Consequences of Marsh Management

Before summarizing our current state of knowledge of biological responses, the limitations of the existing data base should be noted. Our current marsh management monitoring data base does not contain information from all management sites or all the important environmental variables from each management site. Most of the data analyzed in this report are from 16 or fewer management plans and not all of the 16 sites have generated field monitoring data. Only a few of all managed sites have been monitored intensely for any length of time (see chapter 10), and only a portion of those have compared managed with unmanaged marshes. Partially implemented and abandoned management areas usually generate little or no monitoring data. Probably 20 to 30 of the approximately 50 implemented management areas are in this category. Hence, this analysis of management effects is based on an incomplete understanding of only the best examples of management.

Marsh management with manipulated impoundments often requires managers to make a series of trade-offs when setting operational schedules for the structures. Benefits to target resources resulting from management may sometimes be achieved only at the expense of another resource. Because manipulated impoundments are closed systems, the operation of which is mandated by the natural cycles of plant growth (e.g., germination) and wildlife behavior (e.g., fall waterfowl migrations), it may not be possible for a management plan to take full advantage of freshwater and sediment resources or always to avoid such detrimental impacts as decreased population size of marine transient species, reduced vertical accretion, or increased plant stress related to flooding. The cumulative effects of these trade-offs must be considered also. For example, what are the long-term implications of reduced vertical accretion rates in managed marshes or creating extensive networks of impoundments on coastal fisheries production? Consequently, structural management is constantly evolving in order to minimize the consequences of these trade-offs. But until management evolves to the point that trade-offs are no longer necessary, if possible, the biological response and the success of management in general depends on the interaction of the following factors: the environmental setting (e.g., tidal regime, marsh type, freshwater availability), the management objectives, types of structures employed, and the schedule of operation of the structures. Hence, the biological response to structural management often varies between sites.

The biological consequences and design concerns related to manipulated impoundments are often the result of trade-offs related to the timing of operation of the structures that managers must accept in order to achieve their objective. In general, reduced salinities and controlled water levels are often incompatible with optimization of fish, sediment, and nutrients; and spring drawdowns diminish freshwater and sediment access.

Weir management has been accomplished mainly with fixed-crest weirs in coastal Louisiana, but occasionally variable-crest weirs are employed. Because levees are not employed and marsh surface water exchange is not eliminated (i.e., the marsh is not converted to a closed system), there are not as many trade-offs associated with this type of structural management as there are with manipulated impoundments. Consequently, the success of weir management depends mostly on the environmental setting (e.g., tidal regime and marsh type). Also, because of the smaller number of environmental factors to be considered, it may be easier to decide on the optimal trade-offs.

RESEARCH NEEDS

The literature review and monitoring program results indicated data needs related to the biological consequences of marsh management. Several research topics have been identified.

Marsh Accretionary Processes

The impact of management on the flux of matter, vertical accretion, accumulation of matter, and plant growth needs to be evaluated in all marsh types: fresh, intermediate, brackish, and saline. In addition, all these variables should be measured during non-drawdown (i.e., maintenance) as well as drawdown years. So far they have only been measured in two brackish marshes during drawdown years. These data should be synthesized with data on marsh surface elevation changes measured by benchmarks established at the site to evaluate the changes in marsh surface elevation in managed and unmanaged marshes.

Plant Growth

What controls successful vegetative growth in manipulated impoundments should be determined, both experimentally and by monitoring of natural populations. In particular, the rates of above- and belowground plant production and plant decomposition should be determined.

Fisheries Access

A sizable body of literature has been developed indicating that manipulated impoundments and weir management diminish fisheries access to managed marshes. Future research should be directed at determining the feasibility of retrofitting management structures to allow for ingress and egress of aquatic organisms.

Monitoring Procedures

Standardized monitoring procedures should be developed for use at all managed sites. Standard methodologies should be employed for a prescribed set of variables. Variables related to water quality, accretionary processes, substrate conditions, plant growth rates and species composition, and waterfowl, wildlife, and fish production should be monitored. Development of a standardized monitoring program will facilitate comparison of data collected at different managed sites.

Once data bases of sufficient size have been developed, computer models should be developed at the scale of a marsh management area to be used iteratively with new monitoring data in designing the best management scenario (i.e., design and schedule of operation).

Cumulative Impacts

Very little is known about the cumulative effects of structural management. Three approaches are recommended. First, the influence of management on adjacent marshes should be investigated. Pre- and post-implementation data collected from managed and unmanaged areas should be compared to determine the effect of management on neighboring marshes. Second, the interaction of structural water-level management with other management techniques, such as freshwater and sediment diversions, should be determined. Techniques should be developed to capture sediment and fresh water in managed marshes in the outfall of diversions, otherwise the managed marsh will most likely not benefit from the diversions. Third, regional impacts to sediment distribution, water flows and levels, and marsh health should be determined. Regional computer models should be developed from the standardized monitoring data bases within a basin to facilitate this analysis.

REFERENCES CITED

U.S. Army Corps of Engineers, New Orleans District 1988. Scoping document: marsh management. Unpublished manuscript.

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. This 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.