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SHORELINE EROSION IN COASTAL LOUISIANA:

INVENTORY AND ASSESSMENT

Shoreline Erosion in Coastal Louisiana:

Inventory and Assessment

Final Report to
Louisiana Department of Transportation and Development

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GLOSSARY

ACCRETION. Building of or increase in area of land by natural processes.

AEOLIAN. Associated with wind, which most commonly acts as a transport agent.

BATHYMETRY. The measurement of depths of water in oceans, seas, and lakes; also, the information derived from such measurements.

BERM. The point on the beach that separates the foreshore from the backshore.

BULKHEAD. Any structure or wall designed to stop bank collapse and resist erosive forces.

CRUSTAL DOWNWARPING. A downward motion or movement of the earth's crust.

DETRITUS. A product of disintegration or wearing away.

DEWATER. To remove water from (such as by draining, pressing, or pumping).

EROSION. Wearing away; specifically, entrainment; detachment of particles of whatever size or by whatever means, as illustrated by effects of currents, water, wind, ice, etc.

EUSTATIC. Simultaneous change of level occurring on a worldwide scale, such as a rise in sea level resulting from melting of continental ice cover.

FETCH. Distance over which no, or negligible, obstruction interferes with the shear effect of wind against the surface of a waterbody.

FLOTANT. Floating marsh; vegetation covered areas held together by intertwined roots and plant debris above water or soft ooze.

GROIN. Low, artificial wall of durable material extending from land into water.

ISOSTASY. (Adj. ISOSTATIC). Equal weight or pressure, with reference to part of the earth's crust.

JETTY. Structure ordinarily protruding into water, located with the intent of influencing current direction; a wall built to confine currents, such as at a river mouth. A more general term than GROIN or BREAKWATER.

LEACHING. The process of percolating water or other liquid in order to remove a soluble part.

LITTORAL. Near shore. By some definitions limited to the tidal zone; by others, to depths of 100 fathoms. A littoral current, caused by wave action, sits more or less parallel to the shore (longshore current). Littoral deposits accumulate in nearshore, ordinarily shallow, water.

MACROPHYTE. A member of the macroscopic plant life, especially of a body of water.

MIDDEN. A refuse heap.

MORPHOLOGY. Pertaining to form or structure.

MUDFLAT. Deposit of ooze, clay, silt, etc., to water level along a shore. If tidal range is appreciable, the flat is ordinarily submerged at high tide.

MUDLUMPS. Elevations or structures caused by the rise of clayey material through covering silt or sand. Known to exist only in the Mississippi River Delta but suspected elsewhere.

OVERTOP. Pertaining to water, to move across a surface that ordinarily confines its current or extent, e.g., over the crest of a natural levee.

PERTURBATION. Any effect that makes a small modification in a physical or biological system.

PROGRADE. Advance (of shoreline) seaward, commonly as a result of sedimentary accumulation.

REVETMENT. Retaining wall or facing created to prevent retreat of banks of a stream, canal, etc. It may be composed of masonry, blocks of concrete, fascine mats of trees, etc.

RIPARIAN. Relating to or living or located on the bank of a water course (such as a river or stream) or sometimes a lake or a tidewater.

SCOUR. Mechanical wear on the bottom of a channel or bed of a body of water, ordinarily resulting from erosion associated with turbulence and frictional drag of currents.

SHORELINE. Boundary between land and water surface of a lake, sea, etc.

SUBAQUEOUS. Under the surface of water; submarine.

SUBSIDENCE. Lowering of the elevation of the land, a process that may have various causes.

SWALE. A linear depression between somewhat higher surfaces.

TOPOGRAPHY. Configuration of a surface; specifically, the surface of the land or bottom of a water body. Characteristics depend on the slopes present (if any) and differences in relief.

UPLIFT. The raising or elevation of an area of land relative to sea level or to other surrounding areas. It need not be sudden or violent.

Chapter 1

Introduction

The land area of Louisiana has increased during the past several thousand years because land gain from Mississippi River sedimentation processes has exceeded processes of land loss. Recently (in terms of geologic time) this process has been reversed, so that more land is being lost to erosion than is being formed by sedimentation. Louisiana is now losing more land than any other state (Gosselink and Baumann, in press).

The concept that more land is eroding than is forming in Louisiana is not new. It has been documented by Morgan and Larimore 1957, Gagliano and van Beek 1970, Morgan 1973, Adams et al. 1976, and most recently by Craig and Day 1977. Collectively these works suggest that erosion rates have been accelerating. The accelerated erosion rate combined with the highly dynamic nature of the Louisiana coastline area necessitate periodic monitoring of erosion in order to identify the extent of the problem both physically and culturally.

The objectives of this study are to develop a methodology that would enable decision makers to:

1) Assess the extent to which shoreline erosion is presently occurring in coastal Louisiana.
2) Determine the geographic variability of erosion rates across coastal Louisiana and relate this to variability in the physical and cultural environment.
3) Assess the implications of shoreline erosion on the physical and cultural environment.

4) Designate areas for erosion control consideration.

5) Assess the feasibility of structural and nonstructural procedures for managing erosion along designated areas of the Louisiana coast.

Impacts of Erosion

A basic understanding of the processes involved in erosion as found in coastal Louisiana is necessary for rational management. For this study, a broad definition of the term "erosion" will be applied. "Erosion," as used here, includes all those natural processes that, when active, result in the loss of vegetated areas to open water. The term "landloss," which has recently become popularized in the local literature (e.g., Gagliano and van Beek 1970, Craig and Day 1977) is a more inclusive term but can generally be used interchangeably with "erosion." "Land loss" refers to any change of wetland vegetation to some other habitat type. For example, the disposal of spoil on wetlands is often considered a wetland loss but is not erosion. For the purposes of this report, the two terms are used interchangeably, because this report is concerned only with those wetland areas that have changed to open water.

The most obvious result of erosion is the physical loss of land. The cumulative impact of all factors involved in wetland loss include: (1) the loss of marsh habitat, which is an important part of nursery grounds (this loss results in decreased productivity of sport and commercial fisheries species); (2) decrease in fur production; (3) loss of pasture land; (4) diminished possibilities of land use alternatives; (5) decrease in waste assimilation potential; (6) lessened ability to act as a buffer against high energy storms (e.g., tropical disturbances); and (7) hydrographic changes that usually result in increased salinities, which in turn can lead to further wetland losses. Although these changes are generally considered culturally undesirable, they are nonetheless brought about through both natural and cultural processes. The amount of marshland man has intentionally changed to open water is small in relation to the total area changed. Based on Craig and Day's (1977) summary of previous inventories and an inventory of Southwest Louisiana (Gosselink, in press) intentional change, most of which is in the form of dredging, accounts for approximately five to ten percent of the total loss; therefore, direct intentional change is not the most serious factor. The indirect loss caused by man's altering natural processes is felt to be far more significant. Table 1 lists factors found to be associated with change from marsh to open water. Often the change to open water is the net result of the complex interaction of several of these factors; therefore, the specific contribution of each component cannot be determined.

Geologic Factors Associated with Land Loss

Even without man's activities, erosion would certainly occur along some sections of the coast. Throughout the period when land building forces were dominant, erosion played an important role in determining the present morphology of the coastal area. All of coastal Louisiana has experienced land gain but there has never been a time when the entire area was building seaward concurrently. For example, many of the chenier ridges in Southwest Louisiana were formed during intervals when sediment supplies were reduced and coastline retreat temporarily replaced shoreline progradation. Even in active delta lobes, part of the lobe is undergoing deterioration as land is being formed in other parts.

Knowledge of the processes involved in the formation of the present Louisiana coastal area aids in understanding much of the erosion occurring today. Adams et al. (1976) provide an extensive summary of the geologic

Table 1

Activities and Processes Associated with the Change of Wetlands to Open Water*

1. Wind-induced wave erosion.

2. Boat wake erosion.

3. Tidal scour (rip currents).

4. Subsidence.

   a. Isostatic adjustments, e.g., crustal downwarping.

   b. Differential consolidation of sediments because of textural variability.

   c. Consolidation of sediments due to weight of other features, e.g., natural or artificial levees, spoil.

   d. Eustasy (sea level rise).

   e. Extraction of groundwater, oil, gas, sulphur, and other minerals.

   f. Impounding and draining causing consolidation of dewatered sediments.

5. Climatic Events.

   a. Droughts.

   b. Hurricanes and other storms.

6. Biotic effects, e.g., muskrat and goose "eat-outs".

7. Marsh buggies and other wetland transportation vehicles.

8. Dredging.

9. Waste disposal.

10. Sediment diversion, e.g., dams, channelization, leveeing.

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*Modified from: Adams et al. (1976) and Gosselink and Baumann, in press.

setting of the Louisiana coast as well as a fairly extensive bibliography leading to more detailed information. The reader is referred to the above publication if more detail is required than is contained in this report.

Throughout the Quaternary period, South Louisiana was the recipient of tremendous quantities of sediments. The weight of these sediments upon the crust of the earth has caused isostatic adjustments. South of a line approximated by Interstates 10 and 12 the coast is downwarping (sinking), but northward there has been uplift.

Occurring contemporaneously with coastal downwarping has been the worldwide eustatic rise in sea level. This rise has been particularly apparent during this century (Hicks and Crosby 1974). These two phenomena have the same effect; that is, the land appears to sink in relation to the level of the water. Both processes are assumed to occur at about the same rates throughout coastal Louisiana.

The marsh surface must accrete vertically by accumulating organic and inorganic sediment in order to keep pace with subsidence and sea level rise. Areas with vigorous stands of marsh vegetation have obviously been able to maintain their elevation with respect to Mean Sea Level. Other areas where vegetation has not remained viable have opened up into ponds that gradually enlarge to form small lakes and irregular embayments. These areas lose their potential to trap sediment, and subsidence and sea level rise combine with the other factors outlined in Table 1 to accelerate the erosion process.

Within the sedimentary sequences deposited by the Mississippi River, textural (grain size) variability can be significant.

These sediments are geologically young and unstable. As additional sediments are deposited, differences in grain size from one area to the next can lead to differences in compaction rates.

The thickness of these sediments is another factor to be taken into account when considering management alternatives. Generally, the thicker the sedimentary sequence, the more potential there is for subsidence. The impounding of marshes in Southeast Louisiana is not practical because of the thick sequence of sediments that often exceeds 100 meters in depth at the coastline. In contrast, impounding in Southwest Louisiana, where the depth of Recent sediments averages 7 to 8 meters at the coast, has been moderately successful.

Shoreline Categories

An understanding of the complexity of shoreline erosion can be aided by a consideration of shoreline types. Certainly the shoreline bordering a fresh marsh lake, for example, would be expected to have a different rate of erosion than a barrier island shoreline at the coast. This report categorizes shoreline types into three categories: (1) coastline, (2) well-defined lakeshores and bays, and (3) inner marsh areas. The categories are presented and analyzed separately for each management unit.

One would expect that well-defined lakeshores and bays would have lower rates of erosion than the coastline that helps to protect these inner areas. Thus the separation of these two categories was based on the belief that there is a significant difference in the energy working on the shorelines of these two broadly based categories. Results of this study indicate that, in general, rates of shoreline erosion at the coast are several times greater than erosion rates of lakes and bays landward of the coastline. Results of the analysis of these two categories are reported in the form of linear retreat rates.

If one were to add the total losses attributable to erosion of the coastline, lakes, and bays to the area of dredged canals in wetlands, and then to compare this rate of loss to that reported by Gagliano and van Beek (1970), one would find that these losses only amounted to ten to twenty percent of the total wetland loss to open water. Thus, most of the wetland loss is occurring within broad marsh areas that have poorly defined shorelines. Consideration of these areas is necessary if one is to fully evaluate the extent of land loss. Changes in these inner marsh areas, however, cannot be evaluated in terms of linear retreat. For example, during the first time period examined, an example site may have consisted of continuous marsh but in the second time period, ponds may have developed. The absence of an initial shoreline for comparison makes measurement of linear retreat extremely difficult. A second example quite common in coastal Louisiana is that of an area that consists of many small ponds during the first time period but undergoes deterioration, which results in the coalesence of these ponds into one lake. Figure 1 representing changes in a marsh area along East Cove on Calcasieu Lake illustrates the complexity of trying to measure linear retreat for inner marsh areas.

In contrast to linear measurements of inner marsh areas, measuring the area of marsh versus water is a simpler task. The sample sites, however, vary in size, so to make them comparable, the data are presented as a percentage change. This is referred to as the change in the land/water ratio, a concept that was originally devised by Gagliano and van Beek (1970).

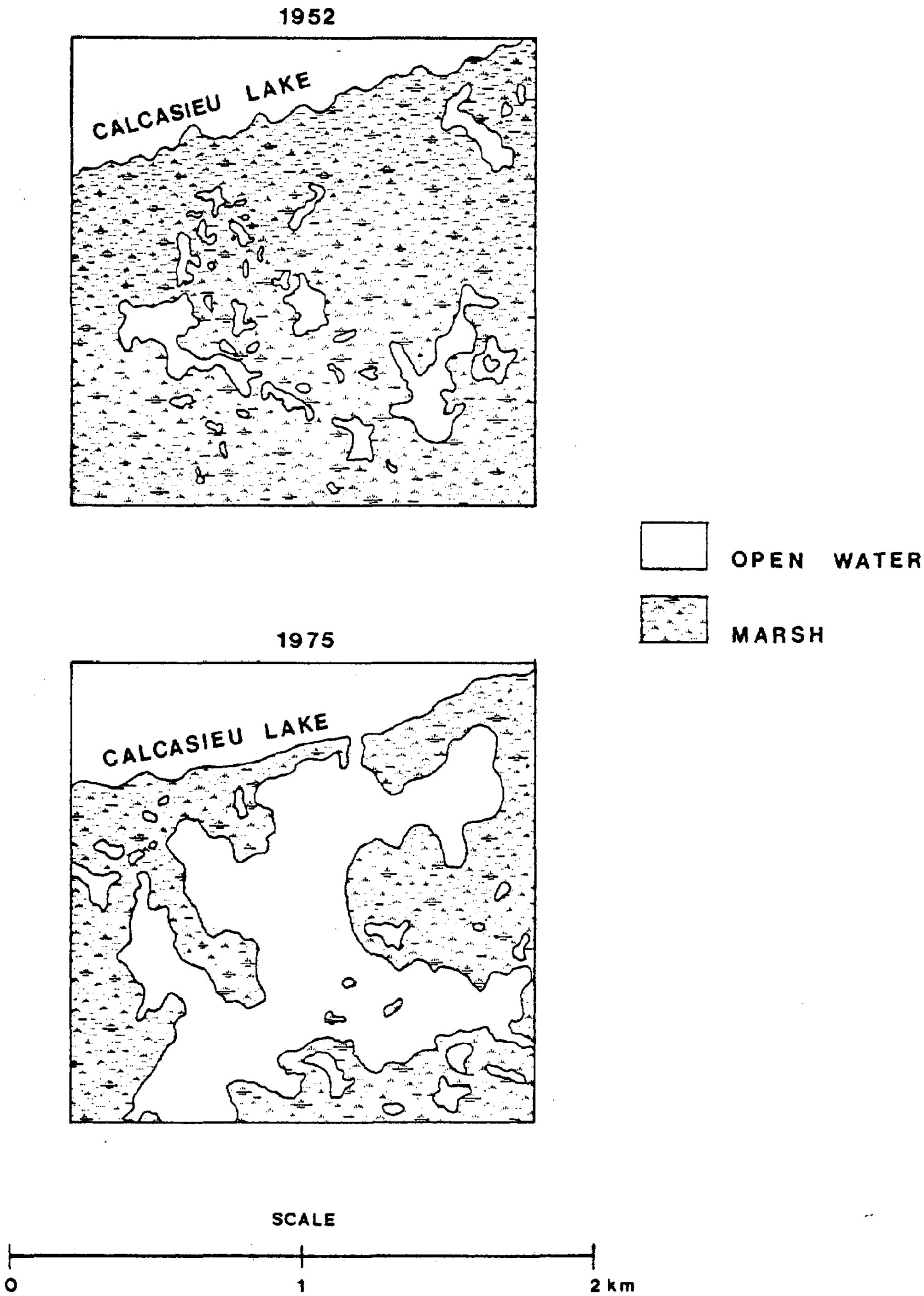


Figure 1. Land Changes in the East Cove area of Calcasieu Lake 1952-1975.

Vegetation Units

Much of the environmental data, particularly biotic data, is presented by vegetation type. Also, Gagliano and van Beek's (1970) analysis of land loss is presented in several manners, one of them being by vegetation type. For comparison, the sample sites used in this study have been divided into vegetation types. All references to vegetation type used throughout this report are modeled after Chabreck (1972) unless noted otherwise.

Climatic Influence on Land Loss

The major role of climate with respect to land loss is the input of energy. Tidal energies along coastal Louisiana are low, with tidal ranges seldom exceeding one meter. These tides cause significant land loss only in localized areas of tidal passes at the mouths of the estuaries. The additional input of wind allows for wave development, and the changing of wind direction (e.g., passage of a cold front) causes water movement. Both of these components of wind energy can lead to erosion.

Normally occurring infrequent climatic events such as tropical disturbances and droughts can lead to erosion. Tropical disturbances are high energy events that bring about direct physical removal of wetlands and can indirectly destroy wetlands through the introduction of saline waters in normally freshwater areas. The increased salinities can cause "die-backs" and the subsequent destruction of root systems. Without an extensive root system to bind the sediments, they are subject to erosion from normal energy flow regimes.

Prolonged droughts are thought to contribute to land loss in two ways: the lowering of the water table may result in lethal concentrations of salts, and compaction of sediments may occur in the relatively thin dewatered layer.

Cultural Influences on Land Loss

With the exception of dredging, man's actions as an agent of the conversion of wetlands to open water are largely unintentional. Boat waves can cause physical removal of sediments, especially where unstable spoil sediments border the waterway. This removal in turn can lead to high maintenance dredging costs.

The extraction of oil, gas, and groundwater from the subsurface is known to result in subsidence. Little, if any, widely distributed documentation of this process/response relationship is available for Louisiana. In the Houston-Galveston Bay area, however, it has been the subject of rather intense investigation (e.g., Kreitler 1977). The extraction of groundwater, oil, gas, or other minerals results in the compaction of overlying interbedded muds, and this is translated to the surface as subsidence.

Although the above practices have undoubtedly contributed to the overall problem, it is felt that the most significant impact man has and will have over the long term is his alteration of natural sediment dispersion. From a macroscale perspective, whether there is a net gain or loss of land is largely dependent on the balance between sediment supply and those factors that tend to lower the elevation of the land. The maintenance of the Mississippi Delta in deeper offshore waters and the construction of artifical levees have served to eliminate much of the primary source of sediment to the wetlands.

The intricate network of canals is a two-way corridor that allows saltwater intrusion, and whereas canals are expedient in carrying away stream flow and storm surges, they do so at the expense of overland flow and deposition of sediments from overbank flooding. This not only deprives the wetlands of sediment, but also leads to shoaling of the canals, which subsequently require maintenance dredging.

Other practices that divert sediments from reaching the wetlands are:

1) The construction of dams such as the Toledo Bend Reservoir. Dams are extremely effective barriers to sediment transport.

2) Pumping of surface water for irrigation such as in the rice growing area of Southwest Louisiana. Pumping decreases downstream movement and may even cause stagnation. The reduced water velocities lose their ability to transport sediment.

3) Impounding of wetlands prevents sediments from moving in and also prevents organics from exiting.

Role of the Atchafalaya River

The growth of the Atchafalaya Delta is one of the most significant geologic events in the modern development of coastal Louisiana. Its effects are more widespread than those discussed in the basin level (management unit) treatment provided in Chapter 3. The growth of the delta is important because it has reversed the trend from land loss to shoreline accretion in the Atchafalaya Bay area, and through time this reversal should be apparent in other areas as well.

The Atchafalaya River has been a distributary of the Mississippi River since the middle of the sixteenth century. It shortens the distance to the Gulf of Mexico by 320 km over the present course of the Mississippi River (Fisk 1952). This favored gradient would cause the river to divert most of its flow through the Atchafalaya Basin to the saline waters of Atchafalaya Bay and the adjacent Gulf of Mexico if the U.S. Corps of Engineers (USCE) had not succeeded in establishing the control structure at Old River. This structure limits the Atchafalaya to 30 percent of the combined Mississippi and Red River flow.

The lower Atchafalaya Basin is characterized by low lying swamps and lakes, which have been trapping the Atchafalaya's sediment load before it reached the coast. By the early 1950s, most of this low lying area was filled and sedimentation began occurring in the lower river and bay. The depth of Atchafalaya Bay had not changed appreciably since the 1858 survey until the influx of sediment in the early 1950s (Thompson 1951). From 1952 to 1962 a subaqueous delta began to evolve with deposition of clays and silty clays at the mouths of the lower Atchafalaya River and Wax Outlet.

Subaerial exposures appeared in 1971-72. These shoals were composed largely of sediment derived from dredging of a navigational channel from the Atchafalaya River Outlet through the Point au Fer Shell Reef. A few small shoals not associated with dredge spoil also appeared during this period on the eastern side of the navigational channel. The first of three consecutive major floods occurred in the spring of 1973. By the time the waters receded, well-developed natural subaerial lobes were apparent on both sides of the channel. In subsequent years, the delta has continued to increase its exposure above low water datum in direct proportion to the magnitude of peak floods on the Atchafalaya River. A 6 m by 122 m navigation channel is maintained by frequent dredging from the mouth of the Lower Atchafalaya River 19.3 km across Atchafalaya Bay to Eugene Island. A bar channel is also maintained by dredging beyond the Point au Fer Shell Reef about 22.5 km offshore in the Gulf of Mexico (Roberts et al., unpublished ms.).

Along the Gulf of Mexico shoreline west of the Atchafalaya Bay, extensive mudflats blanketed the shoreline in the late 1950s. These mudflats stranded numerous previously active beaches from near Atchafalaya Bay to Cameron Beach, some 200 km to the west. These deposits separated the ephemeral shell beaches of the Chenier Plain from gulf waters with a hundred meters or more of fluid mud (Morgan et al. 1953). Subsequent colonization by marsh vegetation welded portions of these mudflats to the shoreline. This process is the same one that formed the Chenier Plain marshes, producing elongated wetlands parallel to the coast and trapped between beach ridges marking former shorelines. This alternation of marsh and beach deposits resulted from shifts in the locus of Mississippi River sedimentation. Deltas in the western portion of the Deltaic Plain, such as the present Atchafalaya Delta, favor progradation of mudflats with subsequent formation of marshes. As long as a sufficient source of fine sediment is available in the offshore zone, shoreline progradation will predominate. Deltas in the eastern portion of the Deltaic Plain, such as the modern birdfoot delta of the Mississippi River, favor shoreline retreat in the Chenier Plain marshes and the formation of beach ridges at the retreating coastline (Howe et al. 1935). The past seven thousand years of Mississippi River history are characterized by shifts in delta location back and forth across coastal Louisiana (Frazier 1967).

Mudflats are not actively forming on the Chenier Plain; in fact, some erosion of previously deposited mudflat marshes has occurred. We can anticipate that erosion will predominate over periodic mudflat formation until sufficient offshore accumulations of Atchafalaya River clays create a situation favorable to long-term coastal marsh progradation.

Concept of Management Units

Several factors relating to land loss are reasonably constant throughout coastal Louisiana, others are more variable over space, and still others exist in some locales but not in others. The result is a wide spectrum of rates varying from excessive erosion to major accretion across the coastal area. In order to systematically examine the variability of erosion rates, it is necessary to divide the coast into units. The rate of sedimentation is an important factor governing land loss in Louisiana. Whereas aeolian processes may transport some sediment and are particularly important along beaches, the dominant agent of sediment transport is water. There is little doubt that aspects of water such as movement, quality, level, and quantity are responsible for much of the diversity of elements of the landscape across the coastal area. These aspects of water are variable over space and through time, but the spatial aspect can be organized into basins and sub-basins. This traditional procedure works well for upland areas where surface-water basins can be geographically well defined. In the wetlands, physical barriers to water movement are usually not as prevalent, which makes the lower parts of these hydrologic basins somewhat less definable. Although some of the hydrologic boundaries in wetlands are somewhat obscure, we have used them as organizational (management) units for presentation of the land loss data for:

1) Comparison of rates between different units within coastal Louisiana, and
2) Comparison of land loss rates with other data sets that are also organized by management units.

Figure 2 delineates Management Units as used in this report. Criteria used for delineating these units were developed in comprehensive studies previously completed by LSU Center for Wetland Resources personnel

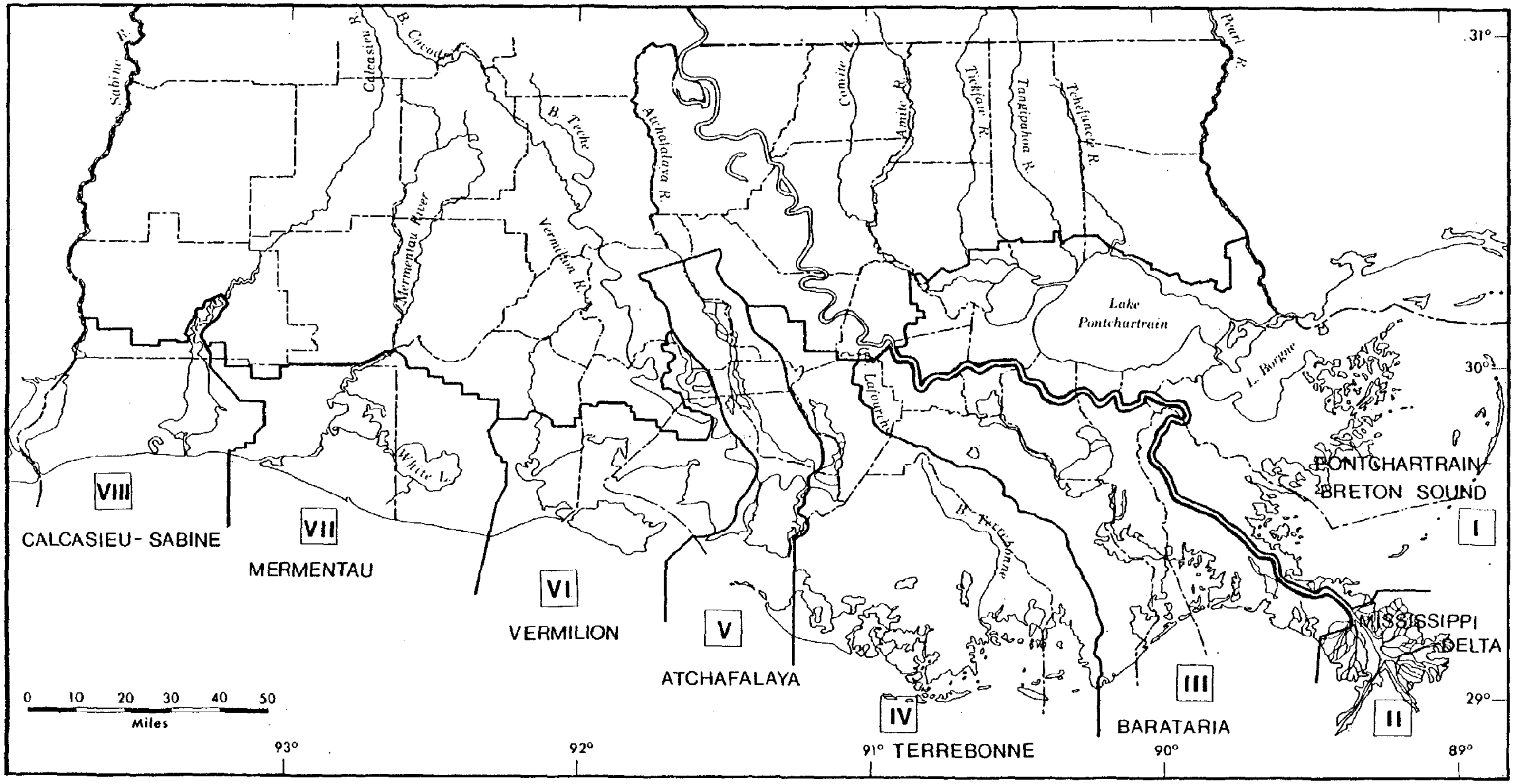


Figure 2. Management Units of Coastal Louisiana as used in this study.

under contract to the Louisiana State Planning Office, with funding from the Office of Coastal Zone Management, U.S. Dept. of Commerce.

Chapter 2

Methods

There are two basic approaches to determining shoreline erosion, by direct monitoring and by studying maps and/or aerial imagery. One can directly monitor specific shorelines by establishing physical points of reference and surveying these reference points at intervals through time. Such a microscale approach has the advantage of providing an accurate account of erosion. However, it has the disadvantages of requiring data collection over a period of time (usually years) and requires many man-hours if there are numerous shorelines to be investigated. Such a monitoring scheme is in practice in parts of California, Michigan, New York, and Rhode Island. Areas where this intensive monitoring effort is being conducted are not necessarily those where erosion rates are high. Rather, it is more common for this effort to be initiated along sections of eroding coasts where cultural pressures are great.

The second basic approach deals with erosion from a macroscale perspective. The use of aerial photography and U.S. Geologic Survey (USGS) quadrangle maps provides a temporal data series over a wide geographic area. The major disadvantage of using this approach is the resolution of the data. Naturally, the larger the scale of the photography or maps, the better the resolution of the data. Although a considerable quantity of aerial imagery spanning over a forty year period for coastal Louisiana exists, the quality and scale of much of the imagery is less than adequate. Maximum resolution is five and ten meters, respectively, for the two scales used. This resolution is generally adequate for assessing areas of major erosion from which decision makers can decide which areas, if any, require direct monitoring.

Because of the resolution of the data (photographs and maps) and the degree to which erosion is generally occurring along Louisiana shorelines, a minimum of ten years is required to make an assessment. Longer time intervals beyond this minimum time requirement provide a more accurate assessment of erosion rates; however, they also place more dependence on <u>average</u> rates and provide less information on the periodicity of erosion. For example, if one were to examine erosion during the past one hundred years using only two time intervals, one might find a section of shoreline to be stable when in reality the coast prograded for a number of years and then retreated back to approximately its same position. On the other hand, short-term assessment may also be misleading. For example, approximately one-half of the erosion of several lakes in Southwest Louisiana from 1952 to 1974 was the result of a single event, Hurricane Audrey. If one were to examine the erosion during a ten-year period, the results would indicate a considerably higher erosion rate than a twenty year analysis, both of which included the same event.

Given the above limitations combined with problems of data availability, the most recent twenty year period is considered the best representative period for assessing present shoreline erosion.

Assessment of Topographic Maps

Topographic maps have an advantage over aerial photographs in that the scaling has already been accomplished. The two best resolution scales of USGS topographic maps for the Louisiana coastal area are 1:24000 (7-1/2 minute) and 1:62500 (15 minute). Although 1:24000 is preferred, completion of these maps for all of coastal Louisiana is relatively recent, with final publication of some areas still forthcoming.

An assessment was made of the mapping accuracy of shorelines depicted on standard USGS topographic maps. Those maps that were updated with 1971 aerial photography were compared with high altitude color infrared photography taken during 1972 (NASA mission 194). The 1972 photography was enlarged to a scale of 1:62500 using a procedure outlined later in this section. The photography is not tidally controlled; however, the shoreline for lakeshores and inner marsh areas is defined as the shorewardmost point that supports emergent macrophytic vegetation. Thus, unless water levels are excessively high (e.g., during tropical disturbances in which vegetation is submerged), this shoreline is easily and consistently depicted.

The results of the comparative analysis between aerial imagery and USGS topographic maps indicate that the maps are within the standard of accuracy used in this study for well-defined lakeshores but are of poor resolution for determining marsh loss for less rigorously defined inner marsh shorelines.

Assessment of Aerial Imagery

Numerous investigations have shown that color infrared photography is the most cost efficient method for depicting the boundary of vegetation/open water (Klemas et al. 1973, Daiber et al. 1976, Graff 1976). Black and white infrared is often sufficient for delineating this boundary for coastal wetlands; however, the numerous mudflats that are exposed predominantly during low water levels accompanying cold front passages in coastal Louisiana are not easily distinguished from vegetated areas during period of low primary productivity. The addition of color enhances the vegetation, hence, the boundary.

NASA 1974 missions 289 and 293 are the most recent high quality color infrared photography taken over a wide area of the Louisiana coast. This imagery covers approximately seventy percent of the area south of Interstates 10 and 12. Areas not covered by this imagery are covered by NASA 1972 mission 194.

Having established the 1972-1974 period as the baseline, data was sought from approximately twenty years earlier. Black and white aerial photography taken during 1952 by the United States Navy covers almost the entire Louisiana coastal area. The scale varies with the mission selected but is usually either approximately 1:20000 or 1:40000. In addition, 1:20000 tidally controlled black and white infrared photographs of the Louisiana coastline taken in 1953-1954 by the Jack Ammann Corp. are available. Maps generated from this set of imagery (Morgan and Larimore 1957) have been used as the basis for determining the coastline of Louisiana under the 1953 Submerged Land Act. Using this series as a base and comparing it with 1969 USCE photomosaics, coastline erosion has been analyzed.

Coastline Analysis

The same methods as used by Morgan and Larimore (1957) were adopted for this study and are outlined below:

1) Measurements were made along lines perpendicular to the 1954 coastline.
2) Each perpendicular was located at each meridianal line, except for the Chandeleur Islands, where each minute of latitude was used. Thus the sampling points were approximately one nautical mile apart.

3) Linear changes in the 1954 to 1969 coastlines were rounded to the nearest 30 meters and then divided by fifteen to obtain an average annual change.

4) The values thus obtained were deemed representative of the coastline to a distance midway to the next sampling station.

The entire coastline, except for the active Mississippi Delta area, was analyzed using this procedure. The delta proper cannot be considered in the same manner as the remaining coastline because of the rapid areal changes that result from processes such as deltaic sedimentation, wave erosion, and subsidence of the thick sequence of unconsolidated sediments, which are characteristic of the active delta. One of the resulting surface expressions of these processes is a highly irregular and poorly defined shoreline. For this reason, only sample areas within the delta proper were examined and were analyzed by the procedure outlined for inner marsh areas. For a more detailed analysis of land change trends on the Mississippi Delta, the reader is referred to Gagliano and van Beek (1970) and Morgan (1973).

Well-Defined Lakeshores and Inner Marsh Areas

An analysis of all shorelines in coastal Louisiana is a virtually impossible task because there are literally hundreds of thousands of kilometers of shorelines. Consequently, a representative sampling procedure was developed. A completely random sampling was not practical because of data limitations and the desire to analyze some specific areas where erosion created immediate cultural problems.

Initial sites were selected by including a minimum of one site of each vegetation type within each management unit. Lakes and marsh areas or portions of such sites where aerial coverage was not sufficient were not evaluated. The final group of sites analyzed totaled more than one hundred and represented several thousand kilometers of shoreline.

The outline of present (1972-1974) shorelines was made from NASA high altitude color infrared photography. This imagery is commonly available on 23 cm by 23 cm transparencies; however, the scale in this form is not sufficient for an accuracy of 5 meters. Thus, enlargement of the imagery was necessary. This was accomplished by photographing the color transparencies with Ektachrome 64 color slide film with a copy camera equipped with a Nikkon 55 mm flat-field macro lens. The light table and camera were leveled to minimize distortion. Care was taken to shoot the sites in the center of the slide as well as the center area of the NASA film frames.

The slides were projected on a vertical drawing board with a Kodak Carousel projector equipped with a Kodak flat-field zoom lens. The projector was leveled, and the projected image was centered vertically and horizontally. The image was scaled with USGS quadrangle sheets with a zoom lens. The shoreline was then traced by following the land-water interface.

Establishment of the 1952 shoreline was accomplished by directly tracing USGS 1:24000 quadrangles, which were updated with aerial photography taken between 1951-1953. Only a small portion of the total coastal area is covered by this series. The first alternative method used where this series was not available was the use of US Navy (USN) 1952 low altitude black and white aerial photography $\simeq$ 1:20000.

Each frame was individually scaled. Lengths from permanent cultural features to the shoreline were then measured. The same measurements were taken with the 1974 shoreline, and the resulting differences in the two measurements represent the change in the shoreline.

The final alternative method was to use USGS 1:62500 quadrangles where no USGS 1:24000 were available and the USN 1952 imagery was of insufficient quality. Dates of the photorevision of the quadrangles vary between 1939 to 1964. Comparison was then made to the 1974 shoreline.

After establishing the shorelines for two different time periods for each site, both the areal and linear change was determined by using a Calmagraphic II digitizing system (0.25 mm sensitivity).

Inner marsh areas, because of their poorly defined shorelines, had to be treated in a slightly different manner. Linear measurements could not be made; therefore, these sites are represented by changes in the land/water ratio through time (percent of land loss). The peripheral boundary of each inner marsh is defined by either easily recognizable cultural or natural non-marsh features or by a grid area of not less than 50 ha.

Based on reported land loss statistics for Louisiana (Gagliano and van Beck 1970), an average expected rate of wetland loss is 42.8 km^2 (0.2%/yr). This value is used as a guideline for all basins and all wetland types. Categories representing losses that deviated from the average value were chosen on the basis of a normalized distribution of the losses reported for each individual 7-1/2 minute quadrangle sheet by Gagliano and van Beek (1970) and later modified with the addition of results obtained from this study.

Chapter 3

Results and Discussion

Introduction

This chapter presents the results of the shoreline erosion assessment. The areas are organized by management units and then subdivided by shoreline type. The rationale for this approach has been previously discussed in Chapter 1.

Those persons who desire a more regional approach may refer to the state summary section, which follows. The summary tables included at the end of each management unit discussion are comprehensive with respect to quantitative values for individual sites. Sites are listed according to management unit, vegetation type, shoreline type, and parish.

State Summary

Louisiana has no rival with respect to the amount of coastal erosion presently occurring. Land loss in coastal Louisiana is attributed largely to natural processes associated with deteriorating deltaic sediments and is intensified by various ongoing cultural activities in the area.

We have not attempted to assign a single land loss rate for the entire area; however, Gagliano and van Beek's (1970) net value of 42.8 km^2/yr (16.5 mi^2/yr) appears a reasonable estimate. It is emphasized here and shown elsewhere that a high degree of variability exists both spatially and temporally with respect to the above mean annual total. From a macroscale perspective, the variability in natural erosion is due primarily to differences in geologic conditions and the amount of energy impacting an area.

Except for the Atchafalaya and Mississippi Deltas, most of coastal Louisiana is presently sediment deficient. Erosional processes are dominant over land building processes. Erosion appears more critical on the coastline, where comparisons with previous studies (e.g., Morgan and Larimore 1957) indicate that it is accelerating.

Most of Louisiana's coastline is composed of easily eroded peats, uncemented sands, and shell hash. It is widely exposed to southerly wave development, which is expended at the coast. Along areas such as Marsh Island, where offshore oyster reefs dampen wave energy, and the coastline leeward of the Mississippi Delta, erosion rates are lower than neighboring areas of similar sediment composition.

All of the larger lake and bay shorelines along coastal Louisiana are experiencing erosion except those in the Atchafalaya Management Unit. The variability in erosion rates is due to the differences in wave energy, sediment composition, and vegetation type (the latter two are often related). Swamp forest is the wetland vegetation most effective in retarding erosion; highly organic fresh marshes are the most easily eroded. Southern shorelines (northerly facing), which have a tendency to erode at a faster rate, reflect the greater strength of northerly components of wind. Southern shorelines on larger water bodies generally are comprised of a thicker sequence of Recent sediments than northern shorelines, and this increase in subsidence potential may be a contributing factor to the above trend. Generally, and particularly in Southeast Louisiana, water bodies located in depressions near natural levees tend to erode fairly rapidly. This rapid erosion is thought to be related to the weight of these features, which cause instability in surrounding sediments.

Gagliano and van Beek (1970) showed that the greatest loss of wetlands overall in the state is associated with brackish marshes. Our analysis supports the high rate for brackish marshes but it also indicates a high loss of fresh marshes. We attribute this to a combination of highly organic soils that are easily eroded, the effects of Hurricane Audrey and subsequent droughts on the fresh marshes in Southwest Louisiana, and the proximity of fresh marshes to intensive cultural development.

The Deltaic Plain of Southeast Louisiana is expected to experience more erosion than the Chenier Plain of Southwest Louisiana. This expectation is based on the difference in overall stability of sediments within the two regions as discussed in Chapter 1. Although the detailed analyses presented at the end of this section support this hypothesis, there is much variation from site to site. A brief discussion of each of the management units is presented below.

The Pontchartrain-Breton Sound Management Unit (Unit I) is the most stable of the units east of the Atchafalaya River, but because of large population centers around Lake Pontchartrain, the erosion that is occurring poses an immediate problem. Comparison of results of this study with Saucier (1963) indicates that erosion along Lake Pontchartrain may be accelerating, which should be considered for future cultural development along the lakeshore. The coastline of this unit is represented by the Chandeleur Islands, which act as a buffer against erosion for the more inland marshes. These barrier islands are eroding and being displaced landward at an average rate of 5.4 m/yr (1954-1969). Most of this displacement, however, has occurred as a result a single event: Hurricane Camille (1969).

The Mississippi Delta Management Unit (Unit II) experiences rapid areal changes associated with deltaic sedimentation and subsequent wave erosion and subsidence. The works of Gagliano and van Beek (1970) and Morgan (1973) indicate that the delta is slowly prograding seaward but has not increased in total area over the past twenty years. Thus the gains in land area along some of the seaward margins of the delta are negated by losses in other portions of the delta. The ephemeral nature of many features and the general instability of the sediments are prohibitive to cultural development.

The Barataria and Terrebonne Management Unit (Units III and IV) are experiencing the highest overall loss of wetlands to open water. This loss is partly attributable to the relatively young age of Lafourche-Mississippi sediments that blanket a large portion of these two basins. Brackish marshes are being lost to open water approximately three times faster than the state average for all marsh types. Fresh marshes are being lost at an equivalent rate in the Barataria Unit but at a greatly reduced rate in the Terrebonne Unit. The loss in the Barataria Unit is associated with the easily eroded floating marshes bordering relatively large freshwater lakes, whereas the fresh marshes in the Terrebonne Unit are receiving some benefit from the Atchafalaya River, especially in the northwest part of the basin above Four League Bay.

Both of these units are undergoing severe erosion at the coastline. The Lafourche Parish coastline area has the highest rate of retreat in the state, amounting to some 207 meters between 1954 and 1969. The use of structures at Grand Isle appears thus far to be moderately successful in retarding erosion (see Chapter 4) but has been partly at the expense of neighboring barrier islands.

Erosion is not presently considered a problem in the Atchafalaya Management Unit (Unit V). Most areas of fresh marsh and bay shorelines are advancing. Brackish marshes along the western end of Point Au Fer Island are eroding at rates comparable to brackish marshes in the Terrebonne Unit. Apparently Atchafalaya River sediments have not been deposited in this area in sufficient quantities to reverse the trend. However, continued growth of the Atchafalaya Delta is expected to influence this area. Point Chevreuil marks the bay shoreline boundary between the Atchafalaya and Vermilion Management Units' boundary. It also marks the westernmost point of bay shoreline advance resulting from Atchafalaya River-derived sediments.

Most of the bay and lake shorelines in the Vermilion Management Unit (Unit VI) have remained stable or undergone small rates of retreat during the time period examined. None of the marshes examined north of East and West Cote Blanche Bays and north and west of Vermilion Bay have undergone more than average losses, and several examples have remained stable. Considering the fetch across these bays, the rates of erosion are lower than could be expected. The reduced rates are thought to be caused in part by the dominant southerly and southeasterly winds as they push sediment-laden waters from Atchafalaya Bay into East and West Cote Blanche and Vermilion Bays.

A noticeable characteristic of erosion along the coastline of the Vermilion Unit is the spatial variability. The coastline along Marsh Island has remained essentially stable from 1954 to 1969 except for the extreme eastern and western ends. The presence of offshore oyster reefs in this area is apparently an effective agent in mitigating erosion. West of Marsh Island to Freshwater Bayou Canal the coastline is generally eroding, except for a small segment at Cheniere au Tigre that has prograded slightly. A comparison of the 1954 to 1969 changes with the 1932 to 1954 changes (Morgan and Larimore 1957) for this section of coastline shows that erosion rates have generally increased. Whether this is a trend or whether this simply reflects the effects of Hurricane Audrey (1957) is unknown.

The Mermentau Management Unit (Unit VII) is wholly within the Marginal Deltaic Plain and is therefore expected to be generally more stable. The relatively low loss rates of inner marsh areas supports this assumption but the high rates of erosion for the coastline and lakeshores is in contradiction.

Private landowners have constructed levees around certain areas of White Lake in an attempt to retard the high rates of erosion. The high erosion along this lake as well as Grand Lake and Lake Misere is thought to be related to raised water levels resulting from management practices associated with the Mermentau water management area. Lakes in more brackish environments have generally faired better. Saline lakes immediately landward of the coastline are filling in as a result of storm deposits that wash over the beach.

Although the overall loss rate of inner marsh areas to open water is low in the Mermentau area, specific locales have experienced high rates of loss. The loss of some of these areas has been related to natural phenomena such as hurricanes and droughts (Valentine, unpublished ms.), but the loss of other areas is the unintentional result of poor management practices of man.

The coastline from the mouth of the Mermentau River east to Dewitt Canal has eroded an average of 165 meters from 1954 to 1969. Although there is no cultural development along this rapidly eroding coastline, much of the land is in public ownership.

The Calcasieu-Sabine Management Unit's (Unit VIII) coastline has experienced a net progradation from 1954 to 1969. This progradation is the result of the Calcasieu ship channel jetties, which trap sediment coming from the east. West of these jetties to Sabine Pass, the coastline is either eroding at moderate rates or has remained stable. Comparison of rates with those reported by Morgan and Larimore (1957) indicates that much of this western sector had been accreting previously. Consequently, communities of Peveto and Ocean View Beaches now have reason to be concerned about erosion. Comparison of rates at Holly Beach indicate that erosion has remained fairly constant, with most of it occurring as a result of storms.

Considering the size of Calcasieu and Sabine Lakes, erosion rates are generally low. Artificial oyster reefs in Calcasieu Lake have helped to reduce erosion rates on the southern shorelines.

Brackish marshes east of Calcasieu Lake have experienced relatively high rates of loss, and the area around Black Lake has the highest density loss of marsh for any example examined in the study. Losses on the eastern margin of Sabine Lake are largely associated with cultural activities.

Data Interpretation Key

An index map is located at the end of the discussion for each management unit. On these maps are a series of code numbers that refer to an individual site in the accompanying summary tables. The key is listed below in Table 2.

Table 2

Key for Cross Referencing Index Maps with Basin Summary Tables

---

The key is composed of a five digit code:

1st digit - Management unit
2nd digit - Shoreline type
3rd digit - Vegetation type
4th and
5th digit - Site number

Management Units	Code Number
Pontchartrain-Breton Sound	1
Mississippi Delta	2
Barataria	3
Terrebonne	4
Atchafalaya	5
Vermilion	6
Mermentau	7
Calcasieu-Sabine	8
Shoreline Type	
Coastline	1
Well-defined Lakeshores and Bays	2
Inner Marsh	3
Vegetation Type (after Chabreck 1972)	
Salt Marsh	1
Brackish Marsh	2
Intermediate Marsh	3
Fresh Marsh	4
Swamp Forest	5
Non-wetland (Pleistocene)	6

For example, let us consider 23301. Reading from right to left, this would translate as site number one, of intermediate marsh, in an inner marsh area of the Mississippi Delta Management Unit. The number will appear on the index map and again on the accompanying summary table, which provides additional information about each site. This includes the name of the site, linear rate of retreat (or percent of land loss), parish the site is in, data sources, time period examined, and the name of the latest U.S. Geologic Survey (USGS) quadrangle (7-1/2 or 15 minutes) that portrays the area. An additional map lists the place names that appear in the text.

In the discussions of inner marsh land loss throughout this section, qualitative terms are often substituted for the quantitative values that appear in the summary tables for each management unit. The terms that appear and their equivalent range of land loss are listed below (Table 3). The method used in determining these categories is outlined in Chapter 2.

Table 3

Inner Marsh Land Loss Categories

Qualitative Term	Equivalent Percent of Land Loss (Gain)/Year
Accretion	All values of land gain > 0.025
Stable	0 ± 0.025
Below Average	> 0.025 to 0.10
Average	> 0.10 to 0.30
Above average	> 0.30 to 1.00
Excessive	> 1.00

Management Unit I -- Pontchartrain-Breton Sound

Coastline Erosion. The coastline of the Pontchartrain-Breton Sound Management Unit is represented by an arc of discontinuous barrier islands (Fig. 4). These islands (Chandeleur, Grand Gossier, and Breton) are the product of the reworking of an older Mississippi Delta known as the St. Bernard Delta complex. This complex was active from approximately 4800 years B.P. (Before Present) to 600 years B.P. (Frazier 1967). Thus this area has been subsiding and eroding longer than most of the other barrier island coastlines along Louisiana. Therefore, it should be expected that erosion would occur along the Chandeleur/Breton Island chain at a rate less than younger Barrier Island coastlines to the west along (Morgan and Larimore 1957). Table 4 shows the comparison of coastline retreat rates to relative age of sediments for those barrier islands that have not been structurally controlled.

Table 4

Relationship Between Barrier Island Erosion Rates and Age of Sediments

Area Listed in Order of Increasing Age	Coastline Retreat 1954-1969 (m/yr)
Timbalier Islands	9.3
Isles Dernieres	8.0
Chandeleur Islands	6.9

The unconsolidated sands and other material that comprise the Chandeleur Islands are subject to rapid changes during tropical disturbances, when these islands are often breached or washed away. However, the islands tend to gradually rebuild and reappear in other areas. Hurricane Camille (1969) caused extensive damage to this area, and because the latter set of photography used (1969) was post-Camille, the resulting changes are included. Thus, the erosion rates may be somewhat greater than other fifteen-year time periods. In addition, the reader is cautioned in evaluating the results determined for the Chandeleur Islands because many of them are barren; therefore, the land-water interface is less rigorously defined. This, combined with the dramatic shoreline changes associated with Hurricane Camille, makes it difficult to maintain the same resolution of accuracy in measuring shoreline changes.

Well-Defined Lakeshores and Bays. Saucier (1963) documented erosion along Lakes Borgne, Maurepas, and Pontchartrain. Using maps from the 1850s and large-scale air photos from the 1930s and 1950s, Saucier concluded that erosion was dominant along these shorelines and that erosion rates were accelerating. He summarized the causes of erosion as follows:

> If only the balance between subsidence and sedimentation is considered to be a controlling factor in shoreline movement, the lakeshores should be eroding more rapidly at the present time. To this factor, however, must be added the facts that as the lake (or lakes) increase in size, the length of fetch increases and the depth of the lake proportionately increases. Both of these would have the effect of accelerating shoreline retreat. The slight rise in sea level which is apparently occurring at the present time is another factor which must be considered in this respect.
>
> In regards to subsidence, there can be no doubt that it is a prevalent process in the Pontchartrain Basin today. Since the last opening of the Bonnet Carre Spillway in 1950, there have been no Mississippi River sediments reaching the basin. The only other sources of sediment are the streams which drain the Prairie terrace to the north and west and it is evident that these contribute only insignificant quantities of alluvium.

Despite the opening of the Bonnet Carre Spillway since Saucier's work, our analysis compared with Saucier's confirms that rates of erosion are accelerating in Lakes Borgne, Maurepas, and Pontchartrain (Table 5).

Table 5

Comparative Rates of Current (1950s-1970s) Erosion with Saucier (1963) for Selected Lakes in the Pontchartrain-Breton Sound Management Unit

Lake	Mean Rate or Erosion (m/yr/km)	
	Saucier (1963) 1930s-1950s	This study 1950s-1970s
Borgne*	1.5	2.0
Maurepas	0.6	0.8
Pontchartrain**	1.6	2.3

*From Chef Menteur Pass to Rigolets
**Includes only those shorelines that do not contain structures designed to reduce erosion.

The variability found in erosion rates around the lakes parallels those found by Saucier (1963) except for the shoreline near Frenier. This discrepancy may be related to the influence of the Bonnet Carre Spillway.

The pattern of relatively low rates of erosion along the north shore near Mandeville was evident for both studies. Saucier (1963) attributes this to the shallow depths (2 to 3 meters), to more resistant Pleistocene sediments, and to a relatively more resistant marsh resulting from firm washover deposits.

Comparison of rates of lakeshore erosion in the Pontchartrain-Breton Sound Unit with other units in the Deltaic Plain reveals that rates are considerably less for the Pontchartrain area. This is consistent with the pattern found for coastline and inner marsh erosion.

Inner Marsh Land Loss. The marshes in this unit have been eroding and subsiding for several thousand years so that the present marsh area represents approximately 30 to 40 percent of the former maximum extent of marsh. Although the area is still undergoing subsidence, most of the more unstable marsh surfaces have been eroded away. The presence of the Chandeleur Islands and the shallowness of Chandeleur and Breton Sounds (former sites of marsh) help to reduce wave energies and should result in a relatively more stable land/water ratio for those remaining areas of marsh.

Of the four sites of saline and brackish marsh examined, two remained stable and two experienced average losses. This is consistent with rates found for other types of erosion in the unit (lakeshore and coastline) and is also consistent with the relationship between ages of deltaic areas and rates of erosion originally discussed by Morgan and Larimore (1957) and mentioned elsewhere in this report.

The example sites represent areas that, to the extent of our evaluation, have not been greatly affected by man's activities; consequently areas of higher land loss rates should be expected to exist in this unit. However, none were found for natural areas.

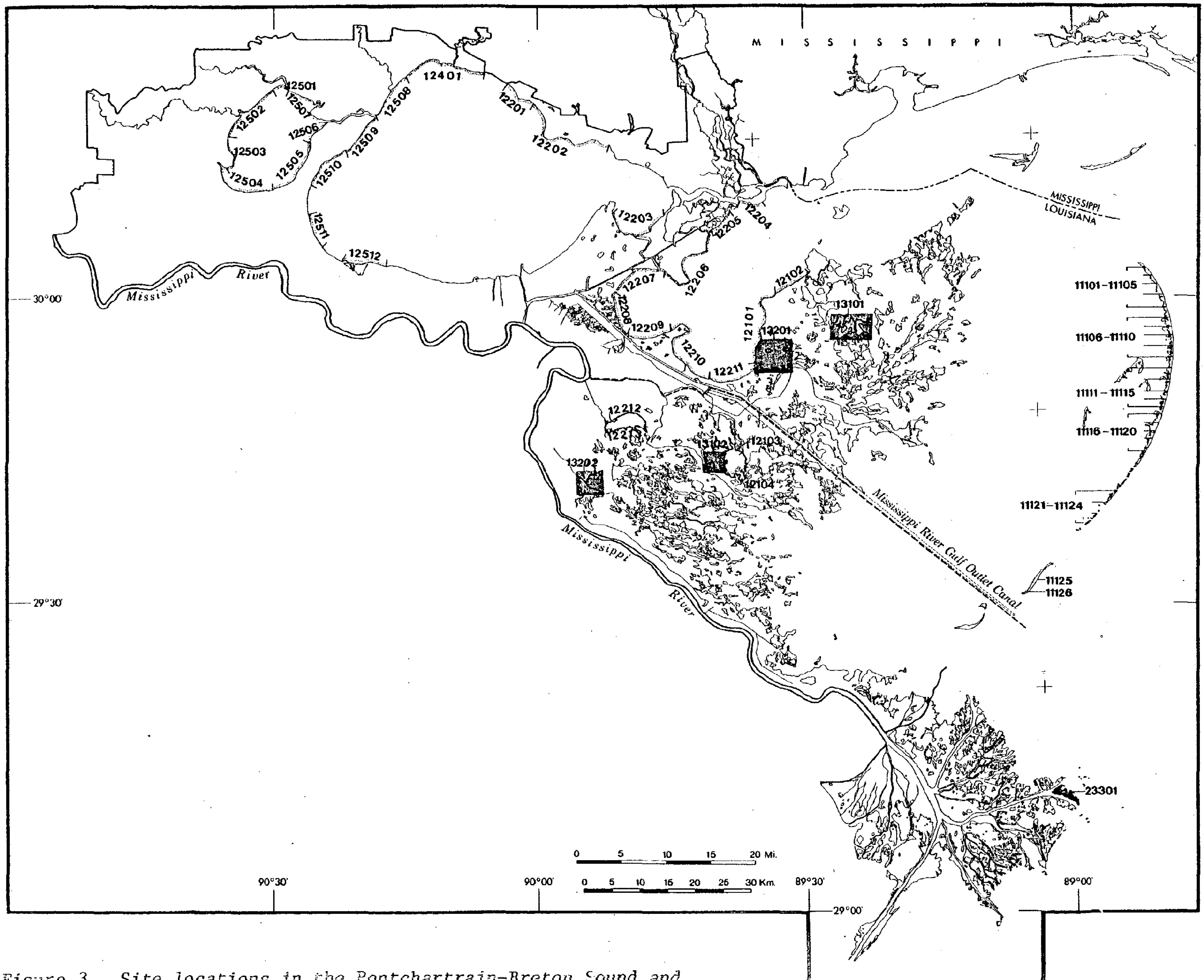


Figure 3. Site locations in the Pontchartrain-Breton Sound and Mississippi Delta Management Units.

Table 6

Erosion Rates for Sites Analyzed in the
Pontchartrain-Breton Sound Management Unit

Management Unit / Shoreline Type / Vegetation Type / Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr	or	% Land Loss
1 1 1 01	Chandeleur Islands Lat. 30° 03'	St. Bernard	Chandeleur Light 7-1/2	1954 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	3.9		
1 1 1 02	Lat. 30° 02'	"	"	"	"	0		
1 1 1 03	Lat. 30° 01'	"	North Islands 7-1/2	"	"	0		
1 1 1 04	Lat. 30° 00'	"	"	"	"	0		
1 1 1 05	Lat. 29° 59'	"	"	"	"	2.1		
1 1 1 06	Lat. 29° 58'	"	"	"	"	2.1		
1 1 1 07	Lat. 29° 57'	"	"	"	"	3.9		
1 1 1 08	Lat. 29° 56'	"	"	"	"	3.9		
1 1 1 09	Lat. 29° 55'	"	"	"	"	3.9		
1 1 1 10	Lat. 29° 54'	"	"	"	"	6.0		
1 1 1 11	Lat. 29° 53'	"	"	"	"	8.1		
1 1 1 12	Lat. 29° 52'	"	New Harbor Islands 7-1/2	"	"	8.1		
1 1 1 13	Lat. 29° 51'	"	"	"	"	8.1		
1 1 1 14	Lat. 29° 50'	"	"	"	"	9.9		
1 1 1 15	Lat. 29° 49'	"	"	"	"	9.9		
1 1 1 16	Lat. 29° 48'	"	"	"	"	9.9		
1 1 1 17	Lat. 29° 47'	"	"	"	"	9.9		
1 1 1 18	Lat. 29° 46'	"	"	"	"	14.1		
1 1 1 19	Lat. 29° 45'	"	"	"	"	14.1		
1 1 1 20	Lat. 29° 44'	"	Stake Islands 7-1/2	"	"	3.9		
1 1 1 21	Lat. 29° 41'	"	"	"	"	24.0 ?		
1 1 1 22	Stake Islands	"	"	"	"	6.0 ?		
1 1 1 23	Curlew Islands Lat. 29° 39'	Plaquemines	Stake Islands 7-1/2	1954 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	8.1 ?		
1 1 1 24	Lat. 29° 38'	"	"	"	"	8.1 ?		
1 1 1 25	Grand Gossier Is. Lat. 29° 32'	" "	Grand Gossier Is. 7-1/2	"	"	14.1		
1 1 1 26	Lat. 29° 31'	"	"	"	"	0		
1 2 1 01	East Lake Borgne	St. Bernard	Yscloskey 15	USGS Quadrangle From 1952 photos	1974 NASA MX293	3.0		
1 2 1 02	East Lake Borgne	"	Rigolets 15	USGS Quadrangle From 1955 photos	"	1.6		
1 2 1 03	No. L. Jean-Louis Robin	St. Bernard	Yscloskey 15	USGS Quadrangle From 1952 photos	1974 NASA MX293	1.6		
1 2 1 04	So. L. Jean-Louis Robin	"	Black Bay 15	USGS Quadrangle From 1946 photos	"	1.0		
1 2 2 01	No. L. Pontchartrain	St. Tammany	Covington 15	USGS Quadrangle (1950) no photo	1974 NASA MX293	1.1		
1 2 2 02	No. L. Pontchartrain	"	Slidell 15	" date	"	2.4		

Table 6 continued

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rates m/yr	or	% Land Loss
1	2	2	03	L. Pontchartrain near Chef Menteur Pass	Orleans	Chef Menteur 15	USGS Quadrangle from 1955 photos	1972 NASA MX194	2.8		
1	2	2	04	NW L. Borgne	St. Tammany	Rigolets 15	"	1974 NASA MX293	2.0		
1	2	2	05	"	Orleans	"	"	"	2.6		
1	2	2	06	W L. Borgne	"	"	"	"	1.8		
1	2	2	07	SW L. Borgne	"	Chef Menteur 15	"	"	3.2		
1	2	2	08	"	St. Bernard	St. Bernard 15	USGS Quadrangle From 1952 photos	"	1.0		
1	2	2	09	"	"	"	"	"	5.3		
1	2	2	10	SE L. Borgne	"	Yscloskey 15	"	"	0.1		
1	2	2	11	SE L. Borgne	St. Bernard	Yscloskey 15	USGS Quadrangle From 1952 photos	1974 NASA MX293	5.6		
1	2	2	12	N L. Levy	"	Delacroix & Belle Chase 15	USGS Quadrangle (1951) no photo date	"	2.9		
1	2	2	13	S L. Levy	Plaquemines	"	"	"	1.9		
1	2	4	01	NW L. Pontchartrain	St. Tammany	Covington 15	USGS Quadrangle (1950) no photo date	"	1.6		
1	2	5	01	NW L. Maurepas	Livingston	Pontchatoula 15	USGS Quadrangle (1951) no photo date	1972 NASA MX194	2.4		
1	2	5	02	W L. Maurepas	"	Springfield 15	USGS Quadrangle (1939) no photo date	"	0.7		
1	2	5	03	SW L. Maurepas	"	Mount Airy 15	USGS Quadrangle (1939) no photo date	1972 NASA MX194	0.4		
1	2	5	04	SE L. Maurepas	St. John the Baptist	"	"	"	0.5		
1	2	5	05	E L. Maurepas	"	Bonne Carre 15	USGS Quadrangle from 1955 photos	"	0.5		
1	2	5	06	NE L. Maurepas	"	Pontchatoula 15	USGS Quadrangle (1951) no photo date	"	2.4		
1	2	5	07	N L. Maurepas	Tangipahoa	"	"	"	0.7		
1	2	5	08	NW L. Pontchartrain	"	"	"	"	2.5		
1	2	5	09	W L. Pontchartrain	St. John the Baptist	"	"	"	3.8		
1	2	5	10	W L. Pontchartrain	"	Bonnet Carre 15	USGS Quadrangle from 1955 photos	"	0		
1	2	5	11	SW L. Pontchartrain	"	"	"	"	7.7		
1	2	5	12	S L. Pontchartrain	St. Charles	"	"	"	2.9		
1	3	1	01	Bob's Lakes	St. Bernard	Lake Eugenie 15	USGS Quadrangle from 1952 photos	1974 NASA MX293			0
1	3	1	02	L. Jean-Louis Robin	"	Black Bay 15	USGS Quadrangle (1964) no photo date	"			0.11
1	3	2	01	SE L. Borgne	"	Pte. Aux Marchettes 15	USGS Quadrangle from 1952 photos	"			0.18
1	3	2	02	Spanish Lake	Plaquemines	Pointe a la Hache 15	USGS Quadrangle from 1961 photos	"			0

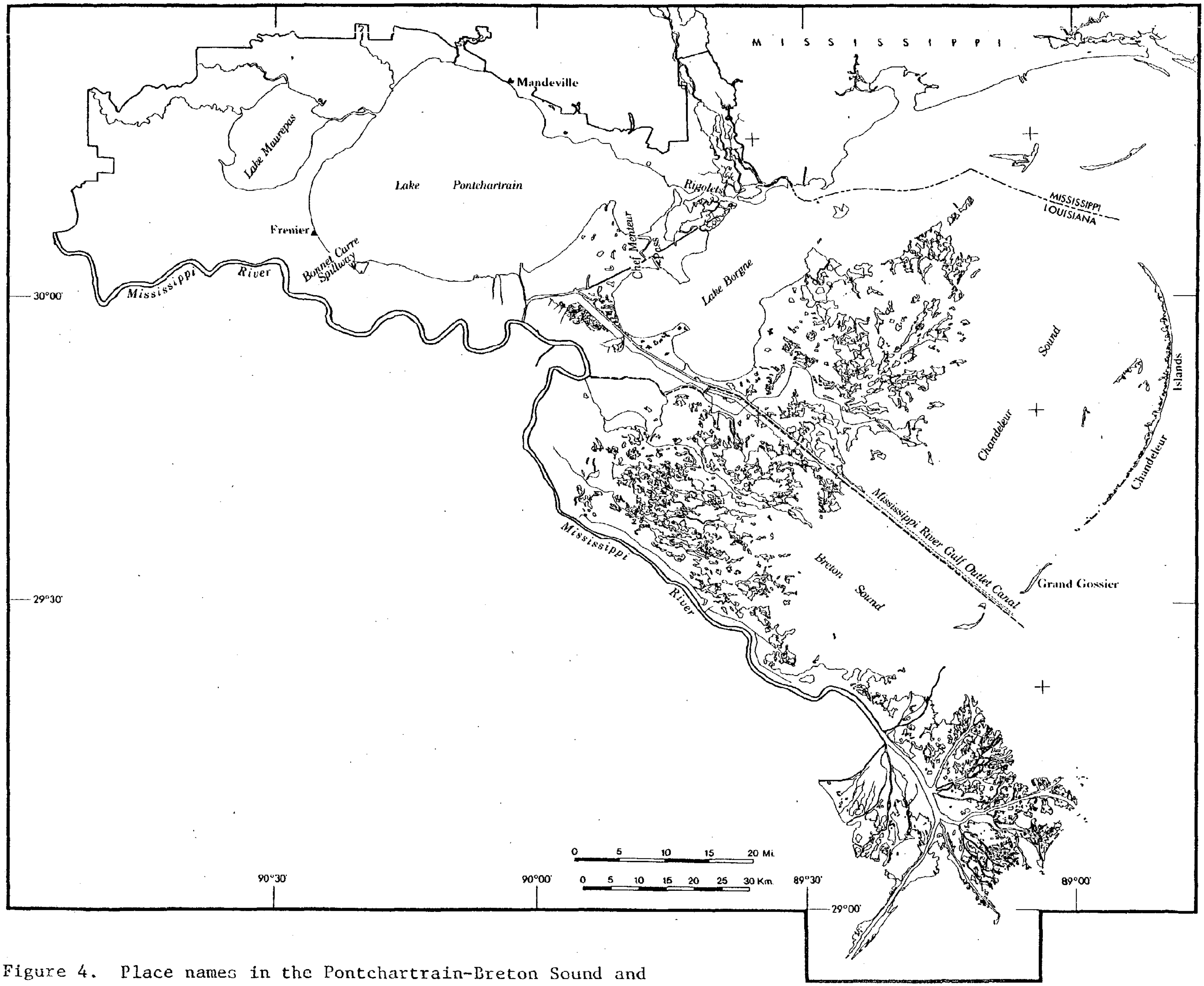


Figure 4. Place names in the Pontchartrain-Breton Sound and Mississippi Delta Management Units.

Management Unit II--Mississippi Delta

The Mississippi Delta generally has a poorly defined, highly irregular shoreline that is subject to the very rapid changes that result from periods of deltaic sedimentation, wave erosion, and subsidence of unconsolidated sediment. Traditionally thought of as an accreting area, evidence suggests that over the past fifteen to twenty years, the Mississippi Delta has actually decreased in total area although it has slowly prograded seaward (Morgan 1973). The growth of the delta has certainly been slowed, and this trend should continue as long as the main receiving basin of sediment is the deeper offshore waters.

The irregularity and ephemeral nature of much of the delta area limits analysis to the inner marsh type method (percent area change). Morgan (1973) presents a rather detailed account of land change trends in the delta from the time of the earliest surveys to the present. In addition, Gagliano and van Beek (1970) present data on some of the more recent changes in the land area of the delta. The reader is referred to these studies for a more detailed account.

A detailed analysis of the entire delta is not only a tedious task, but results may be questionable because of the resolution of available data. The low lying delta experiences rapid changes depending upon water level. Thus, during spring floods, the actual exposed area of the delta would be less than low water following the flood or low water occurring during the winter months preceding the flood. To further complicate the method of analysis, a given unit area will possibly experience both accretion and erosion contemporaneously. Figure 5 portrays an area in the delta that has experienced both net erosion and also localized accretion during the time period examined.

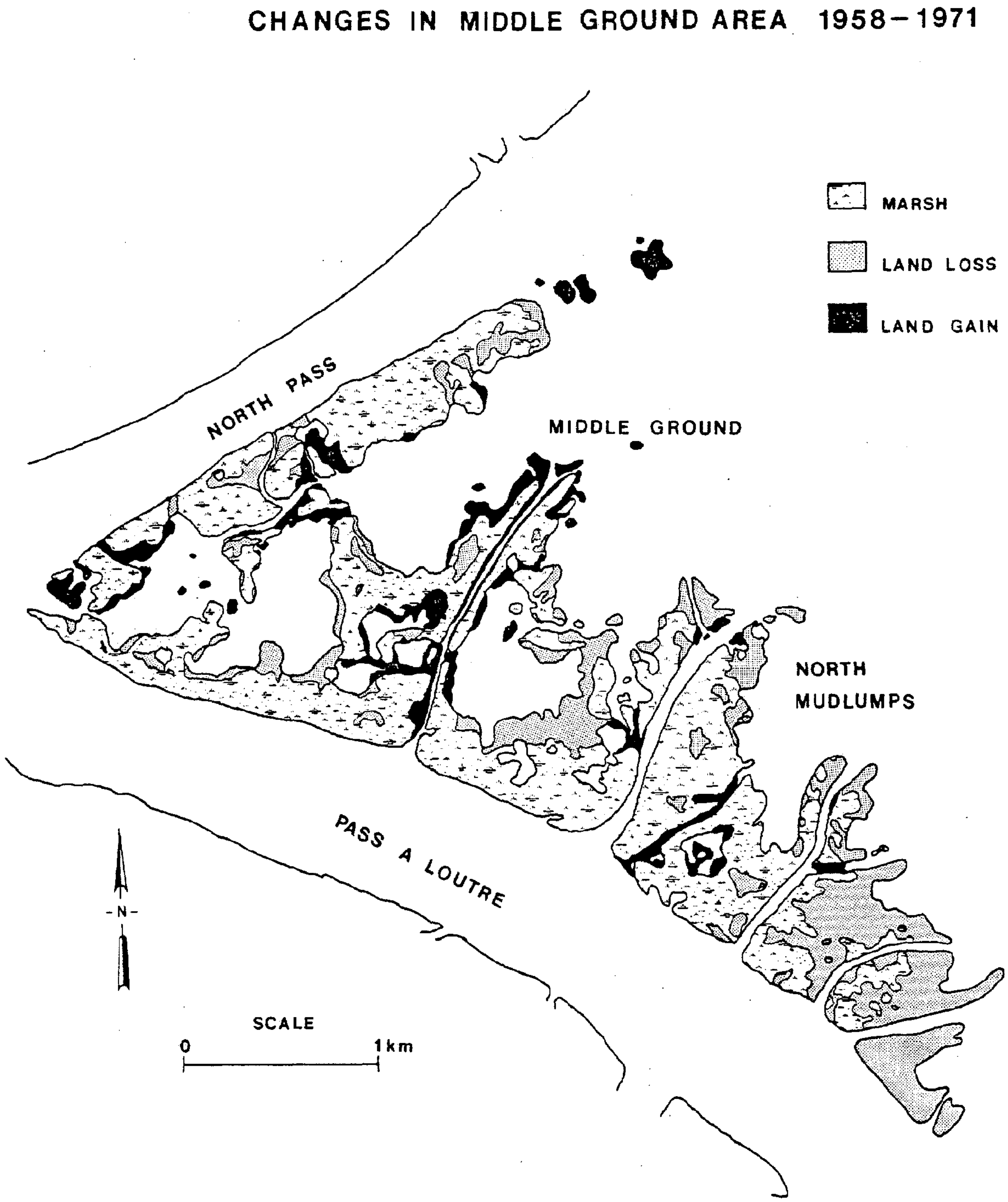


Figure 5. Land changes in the Middle Ground area 1958-1971.

Table 7

Erosion Rates for Sites Analyzed in the Mississippi Delta Management Unit

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr	or	% Land Loss
2	3	3	01	Middle Ground	Plaquemines	East Delta 15	USGS Quadrangle from 1958 photos	USGS Quadrangle from 1971 photos			1.67

The only accurate method of evaluating rates of change in the delta would be to prepare areal comparison (e.g., Fig. 5) of tide-control photography for the entire delta; however, such an endeavor would be excessively time consuming. The example deliniated in Fig. 5 had a net loss of 1.67 percent per year from 1958 to 1971 but as can be seen from this figure, the total change in the form of actual loss and gain was considerably greater. This is an important management consideration, and net loss or gain should not be used when evaluating active deltaic areas.

Management Unit III--Barataria

Coastline Erosion. The present coastline of the Barataria Basin Management Unit is the result of a complex series of events involving delta building and subsequent deterioration. No fewer than four delta complexes have contributed sediment to the area. They are (from oldest to youngest): St. Bernard, Lafourche, Plaquemines, and Modern. This long and complex history of sedimentation and deterioration is reflected in both substrate characteristics and surface expressions. Consequently, the coastline of this unit is represented by a number of features: barrier islands, cheniers, bays, distributary mouths.

The artificial closing of the Bayou Lafourche distributary in 1904 and the creation of the man-made levee system along the Mississippi River have effectively severed sediment supply to the area (Adams et al. 1976). Thus, except for small amounts of water coming in through the locks on the Gulf Intracoastal Waterway and seepage through the Mississippi levees, the Barataria Basin is a true hydrologic basin.

The nourishment of beaches along this coastline is dependent upon littoral drift. Although most of coastal Louisiana experiences a dominantly westerly drift, this area experiences seasonal shifts in the direction of littoral drift. Suhayda (1976) and Murray (1976) discuss the processes associated with waves and nearshore currents, respectively, offshore of the Barataria unit, and Harper (1975) and Conatser (1971) have examined those processes involved in producing an easterly drift from Belle Pass to Barataria Pass.

The variability in littoral drift, waves, age of sediments, and morphology has led to a corresponding variability in erosion rates along the coastline of the Barataria unit.

In Lafourche Parish the coastline has retreated an average of 14 meters per year (1954-1969).

This area has experienced the highest rate of coastline retreat. This retreat rate is attributed to several factors:

1) The sediments are relatively young, with Bayou Lafourche representing the most recently abandoned course of the Mississippi River.
2) There is wide exposure to wave attack from the south.
3) The presence of coarser-grained and unconsolidated sediments of the east-west trending cheniers, which are easily eroded by mechanical action.
4) Landward drifting gulf currents approach the coast in the vicinity of Belle Pass and then divide into easterly and westerly drifts. Therefore, longshore drift carries sediments away but not toward the area.

The Grand Isle area has been eroding at its western end and accreting at its eastern end in response to the easterly drift during the period from 1954 to 1969. The construction of the west end jetty in 1972 appears to have stabilized erosion in this area. Because of the extensive development of Grand Isle, various engineering solutions have been employed, and these are presented in Chapter 4.

A detailed analysis of the erosion occurring along the Grand Terre Islands is provided by Adams et al. (1976). That analysis indicates that erosion on Grand Terre proper is occurring along most of the island, which has been reduced in size from 385 hectares in 1956 to 318 hectares in 1972. Erosion is occurring along both the eastern and western ends (Pass Abel and Barataria Pass) as well as on the shorefront, particularly along the western end.

Although for some time erosion has dominated along the Grand Terre Islands, the construction of groins and the east-end rock jetty on Grand Isle have served as barriers to easterly moving sediments that nourished Grand Terre beaches periodically during the fall and winter months. Thus the tradeoff for increased stability of Grand Isle is, in part, the increased erosion of the Grand Terre Islands. The westerly drift of sediments predominates during the rest of the year, but the leeward position of this area in relation to the Mississippi Delta reduces the strength of the westerly drift in comparison to other areas along the Louisiana coast (Adams et al. 1976).

East of Cheniere Ronquille, the coastline has retreated at an average rate of 6.3 m/yr. The variability for the twenty-two examples examined is significant, with retreat rates ranging from 0 to 14.1 m/yr. Whereas the erosion rates for this area are generally high, they are less than the rates for the somewhat older Lafourche sediments to the west. This is attributed to the mitigating effects of limited amounts of Mississippi River sediments that are deposited via the weak westerly drift and to the leeward location of the area in relation to the seaward protruding delta, which reduces wave energies.

Well-Defined Lakeshores and Bays. A total of eleven lakes and bays were examined which, combined with examples examined by Adams et al. (1976), provide us with the most complete coverage of any management unit.

Despite the more inclusive coverage for this unit, there remains a high degree of variability, with expected patterns of erosion often being masked by other factors. The impact of man's activities is particularly evident in this unit, and this in turn adds more variables to a situation already difficult to understand.

An examination of examples that are considered to have been the least affected by man reveals that erosion rates of lakeshores and bays are generally higher than for other units except for Terrebonne, which has comparable rates. Shorelines around saline lakes and bays generally have lower rates than their brackish or fresh couterparts. The relatively high erosion rates for brackish areas is consistent with other units in the Deltaic Plain and is in agreement with Gagliano and van Beek (1970).

Fresh marsh lakeshores and bays have experienced the highest rate of erosion (4.67 m/yr) compared to saline (1.48 m/yr) and brackish (2.91 m/yr) for examples examined in the Barataria Management Unit. This is not consistent with the work of Gagliano and van Beek (1970), but it compares favorably with results obtained in this study for Southwest Louisiana and the Terrebonne unit in the Deltaic Plain. Fresh marsh shorelines along Lakes Cataouatche, des Allemands, and Salvador have undergone severe erosion, particularly along their southern and southeastern shores. This indicates that the stronger northerly components of wind-induced may be the responsible agents, and the fact that the larger lakes have higher rates of erosion further supports the hypothesis of wind-induced erosion. These same winds, however, also affect brackish and saline shorelines, but erosion rates there are considerably less. The high rates of erosion along sections of fresh marsh lakeshores is attributed to the unstable nature of the sediments comprising the marshes. These areas are typically floating marshes (flotant) consisting almost entirely of organics and are particularly susceptible to breaking up in response to high energy conditions such as in the case of cold front passages and tropical disturbances.

Inner Marsh Land Loss. Land loss in the Barataria unit is high relative to other units, with most examples being either in the above average or excessive category (0.3 to 1.0 percent/yr and greater than 1.0 percent/yr, respectively). The relatively high rates are to be expected when one considers the relative age and depth of sediments, the lack of continued inorganic sediment supply, and the degree of cultural activities in the area.

Although the number of examples used are few, saline marshes appear to be the most stable marsh type and are the least variable with respect to loss rates from site to site. This is consistent with values determined for lakeshores and bays and for saline marshes in general throughout the Deltaic Plain. As pointed out by Saucier (1963), saline marshes represent an advanced stage of deterioration that has already passed the stage of maximum land loss rate. In a sense, saline marshes are remnants, and these remnants are either more resistant to erosion or have experienced more favorable conditions for remaining in existence than their eroded counterparts.

Brackish marshes in the Barataria unit have experienced above average land loss rates (mean = 0.8 percent/yr). Rates are highest near the levees of Bayou Lafourche and associated distributaries and the present Mississippi River. The weight of the levees increases the instability of the marsh sediments, which is translated into localized subsidence and depicted as land loss.

Fresh marsh areas have experienced land loss rates similar to brackish marsh areas (mean = 0.8 percent/yr). The variability for fresh marsh areas is high, and examples range from stable to excessive losses. The variability in substrate is high and ranges from floating mats to low lying levees with little or no surface expression. These areas are close to population centers, which may cause indirect land loss through the discharge of various waste materials via canals and natural waterways. Swamp forest areas generally appear stable, showing little or no change.

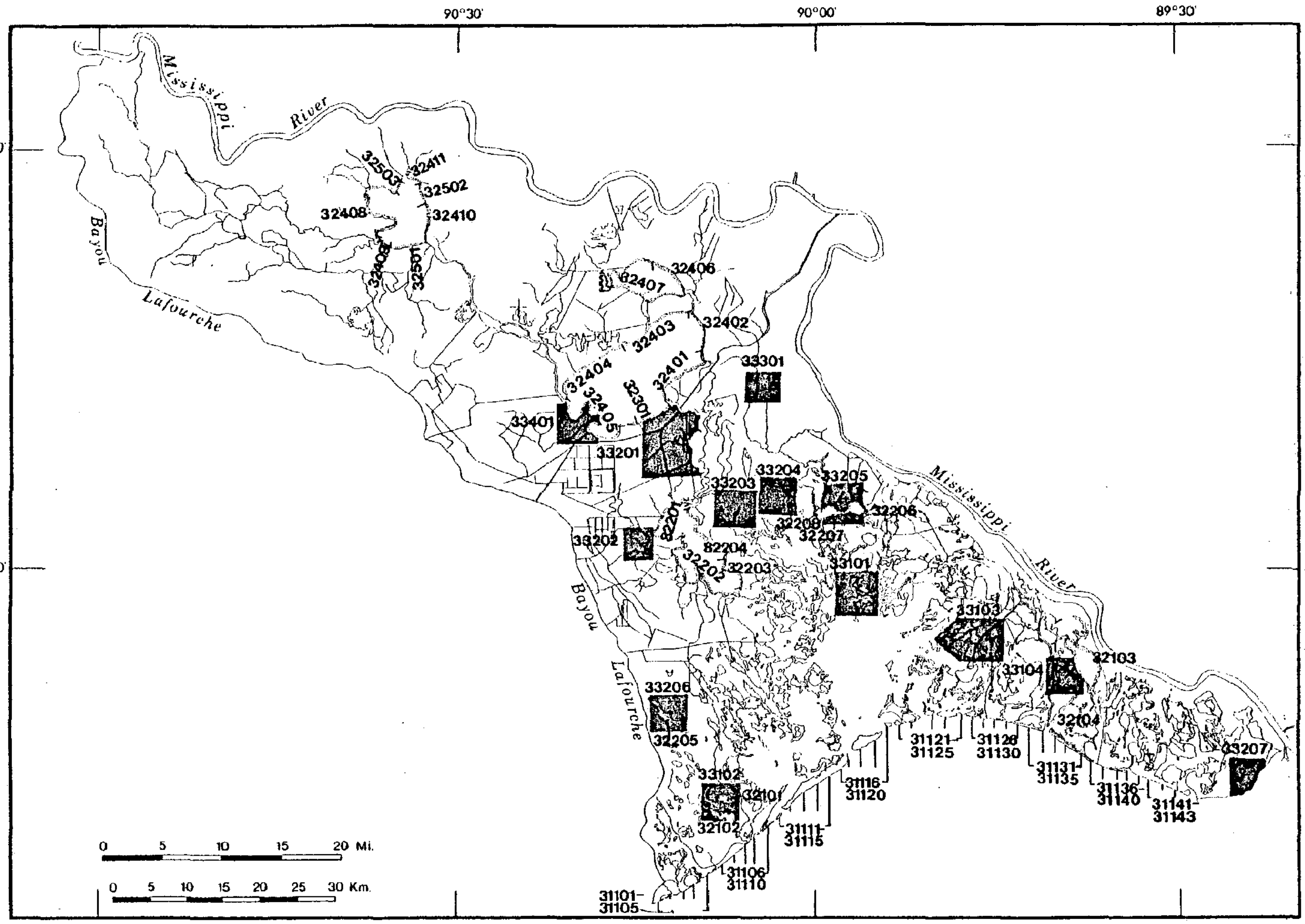


Figure 6. Site locations in the Barataria Management Unit.

Table 8

Erosion Rates for Sites Analyzed in the Barataria Management Unit

Management Unit / Shoreline Type / Vegetation Type / Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr	or	% Land Loss
3 1 1 01	Long. 90° 13'	Lafourche	Belle Pass 15	1954 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	8.1		
3 1 1 02	Long. 90° 12'	"	"	"	"	14.1		
3 1 1 03	Long. 90° 11'	"	"	"	"	24.0		
3 1 1 04	Long. 90° 10'	"	"	"	"	21.9		
3 1 1 05	Long. 90° 09'	"	"	"	"	20.1		
3 1 1 06	Long. 90° 08'	"	Leeville 7-1/2	"	"	14.1		
3 1 1 07	Long. 90° 07'	"	Caminada Pass 7-1/2	"	"	14.1		
3 1 1 08	Long. 90° 06'	"	"	"	"	12.0		
3 1 1 09	Long. 90° 05'	Jefferson	"	"	"	9.9		
3 1 1 10	Long. 90° 04'	"	"	"	"	9.9		
3 1 1 11	Long. 90° 03'	"	"	"	"	3.9		
3 1 1 12	Grand Isle Long. 90° 02'	"	"	"	"	8.1		
3 1 1 13	Grand Isle Long. 90° 01'	"	"	"	"	3.9		
3 1 1 14	Grand Isle Long. 90° 00'	"	"	"	"	3.9		
3 1 1 15	Grand Isle Long. 89° 59'	"	"	"	"	0		
3 1 1 16	Grand Isle Long. 89° 58'	"	Grand Isle 7-1/2	"	"	0		
3 1 1 17	Grand Isle Long. 89° 57'	"	Ft. Livingston 15	"	"	Adv.		
3 1 1 18	Grand Terre Long. 89° 56'	"	"	"	"	6.0		
3 1 1 19	Grand Terre Long. 89° 55'	"	"	"	"	0		
3 1 1 20	Long. 89° 54'	Jefferson	Ft. Livingston 15	1954 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	12.0		
3 1 1 21	Long. 89° 53'	"	"	"	"	9.9		
3 1 1 22	Long. 89° 52'	"	"	"	"	9.9		
3 1 1 23	Long. 89° 50'	Plaquemines	"	"	"	12.0		
3 1 1 24	Long. 89° 49'	"	"	"	"	8.1		
3 1 1 25	Long. 89° 48'	"	"	"	"	8.1		
3 1 1 26	Long. 89° 47'	"	"	"	"	14.1		
3 1 1 27	Long. 89° 46'	"	"	"	"	8.1		
3 1 1 28	Long. 89° 45'	"	Empire 15	"	"	3.9		
3 1 1 29	Long. 89° 44'	"	"	"	"	3.9		

Table 8 continued

Management Unit / Shoreline Type / Vegetation Type / Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr	or	% Land Loss
3 1 1 30	Long. 89° 43'	"	"	"	"	0		
3 1 1 31	Long. 89° 42'	"	"	"	"	0		
3 1 1 32	Long. 89° 41'	"	"	"	"	0		
3 1 1 33	Long. 89° 40'	"	"	"	"	2.1		
3 1 1 34	Long. 89° 39'	"	"	"	"	6.0		
3 1 1 35	Long. 89° 38'	"	"	"	"	12.0		
3 1 1 36	Long. 89° 37'	"	"	"	"	9.9		
3 1 1 37	Long. 89° 36'	"	"	"	"	6.0		
3 1 1 38	Long. 89° 35'	"	Bay Coquette 7-1/2	"	"	8.1		
3 1 1 39	Long. 89° 34'	"	"	"	"	2.1		
3 1 1 40	Long. 89° 33'	"	"	"	"	3.9		
3 1 1 41	Long. 89° 32'	"	"	"	"	3.9		
3 1 1 42	Long. 89° 31'	Plaquemines	Bay Coquette 7-1/2	1954 air photos Jack Ammann Corp.	1969 USCE Uncontrolled photomosaics	9.9		
3 1 1 43	Long. 89° 30'	"	"	"	"	9.9		
3 2 1 01	L. Palourde	Lafourche	Leeville & Caminada Pass 15	USGS Quadrangle from 1952 photos	1974 NASA MX293	2.6		
3 2 1 02	L. Laurier	"	"	"	"	1.0		
3 2 1 03	Adams Bay	Plaquemines	Empire 15	USGS Quadrangle from 1946 photos	"	1.8		
3 2 1 04	Bastian Bay	"	"	"	"	0.5		
3 2 2 01	Little Lake	Lafourche	Barataria 15	USGS Quadrangle from 1945 photos	"	2.1		
3 2 2 02	Little Lake	"	Bay Dosgris 15	USGS Quadrangle from 1952 photos	"	3.3		
3 2 2 03	Little Lake	Jefferson	"	"	"	1.6		
3 2 2 04	Little Lake	"	Barataria 15	USGS Quadrangle from 1945 photos	"	5.6		
3 2 2 05	Unnamed Lake	Lafourche	Mink Bayou 15	USGS Quadrangle from 1952 photos	"	2.0		
3 2 2 06	E L. Laurier	Plaquemines	Pointe a la Hache 15	USGS Quadrangle from 1946 photos	"	2.0		
3 2 2 07	Round L.	"	"	"	"	4.5		
3 2 2 08	Round L.	Jefferson	"	"	"	2.2		
3 2 3 01	SE L. Salvador	Lafourche	Barataria 15	USGS Quadrangle from 1945 photos	"	8.7		
3 2 4 01	E L. Salvador	Jefferson	"	"	"	13.2		
3 2 4 02	NE L. Salvador	Jefferson	New Orleans 15	USGS Quadrangle from 1950 photos	"	6.8		

Table 8 continued

Management Unit / Shoreline Type / Vegetation Type / Site No.	Site Area	Parish	Quadrangle & Size (minutes)	Data Sources & Dates		Retreat Rate m/yr	or	% Land Loss
3 2 4 03	NW L. Salvador	St. Charles	N.O.& Hahnville 15	USGS Quadrangle from 1950 photos	1974 NASA MX293	5.6		
3 2 4 04	SW L. Salvador	"	Cutoff 15	USGS Quadrangle (1939) no photo date	"	2.9		
3 2 4 05	SW L. Salvador	Lafourche	"	"	"	1.7		
3 2 4 06	L. Cataouatche	Jefferson	New Orleans 15	USGS Quadrangle from 1950 photos	"	2.2		
3 2 4 07	L. Cataouatche	St. Charles	N.O.& Hahnville 15	"	"	0.8		
3 2 4 08	Lac des Allemands	St. John the Baptist	Lac des Allemands 15	USGS Quadrangle from 1945 photos	"	0.9		
3 2 4 09	"	Lafourche	"	"	"	5.0		
3 2 4 10	"	"	"	"	"	0.9		
3 2 4 11	"	St. John the Baptist	"	"	"	0.9		
3 2 5 01	"	Lafourche	"	"	"	0.9		
3 2 5 02	"	St. John the Baptist	"	"	"	0		
3 2 5 03	"	"	"	"	"	0		
3 3 1 01	St. Mary's Point	Plaquemines	Ft. Livingston 15	USGS Quadrangle from 1960 photos	"			0.37
3 3 1 02	L. Palourde	Lafourche	Leeville & Caminada Pass 15	USGS Quadrangle from 1952 photos	"			0.09
3 3 1 03	L. Grande E. Ecaille	Plaquemines	Ft. Livingston 15	USGS Quadrangle from 1960 photos	"			0.33
3 3 1 04	Bay Adams	Plaquemines	Empire 15	USGS Quadrangle from 1960 photos	"			0.28
3 3 2 01	Bayou Perot	Lafourche	Barataria 15	USGS Quadrangle from 1961 photos	1974 NASA MX273			.35
3 3 2 02	Bay l'Ours	Lafourche	Barataria & Cutoff 15	"	"			0.26
3 3 2 03	Turtle Bay	Jefferson	Barataria 15	"	"			0.76
3 3 2 04	Dupre Cut	Jefferson	"	"	"			0.48
3 3 2 05	Round Lake	Plaquemines	Pointe a la Hache 15	"	"			0.32
3 3 2 06	Unnamed Lake	Lafourche	Mink Bayou 15	USGS Quadrangle from 1952 photos	"			1.25
3 3 2 07	Venice Oil Field	Plaquemines	W. Delta & Venice	USGS Quadrangles from 1958 photos	"			0.90
3 3 3 01	The Pen	Jefferson	Barataria 15	USGS Quadrangle from 1961 photos	"			0.53
3 3 4 01	SW L. Salvador	Lafourche	Catahoula Bay 15	USGS Quadrangle from 1962 photos	"			1.20

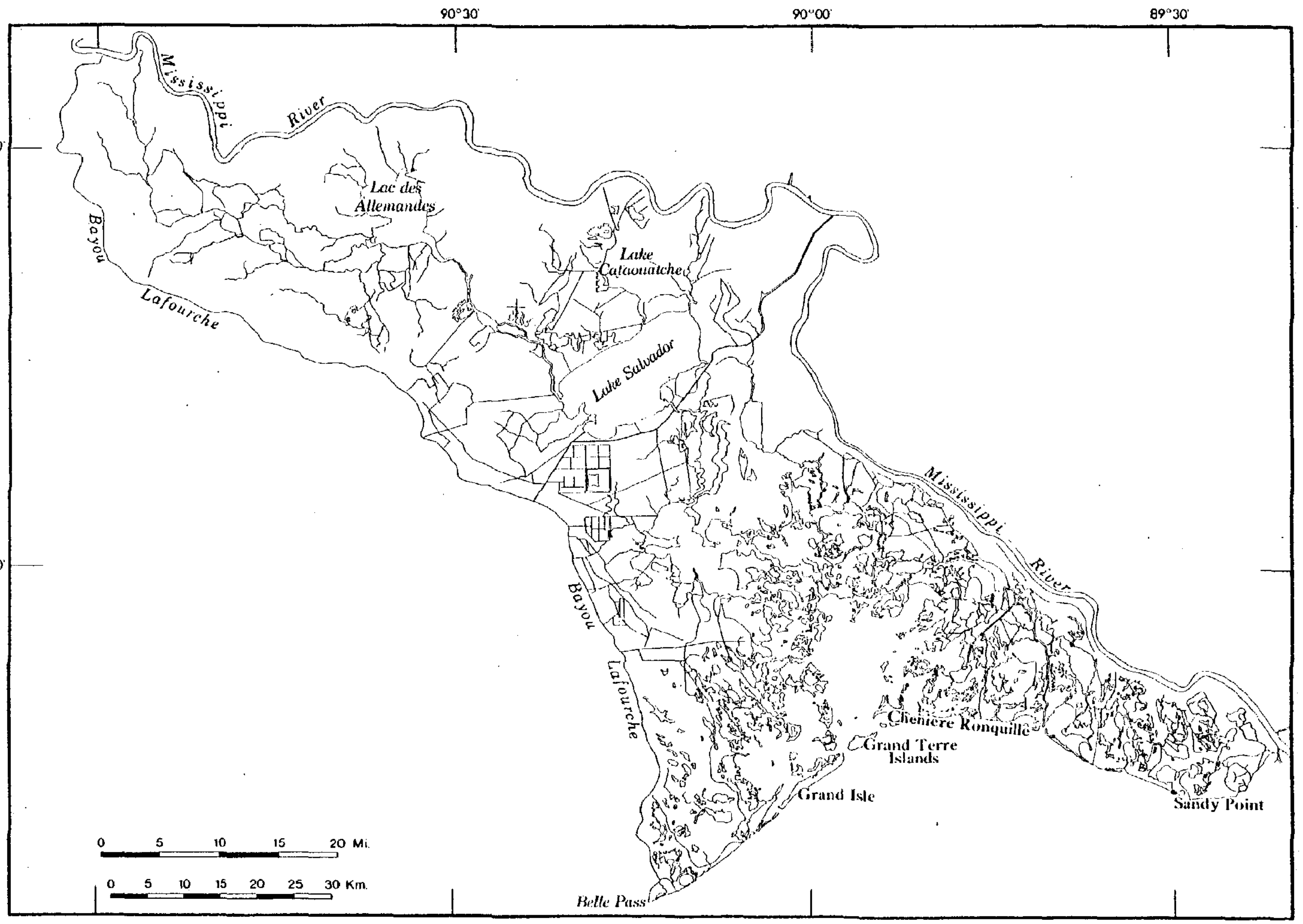


Figure 7. Place names in the Barataria Management Unit.

Management Unit IV--Terrebonne

Coastline Erosion. The Terrebonne Management Unit's coastline extends east from 91°15' west longitude on Point Au Fer Island to the mouth of Bayou Lafourche at Belle Pass (Fig. 9). This section of coastline is disjointed into two natural units. The western portion is a more-or-less continuous shoreline extending from 91°15' west longitude to the mouth of Bayou Grand Caillou at Caillou Bay. The eastern portion is more seaward and consists of a discontinuous series of barrier islands. The erosion rates of these two portions are considerably different, with the barrier island segment experiencing higher rates.

Along the western part of the unit, erosion is occurring at a rate of 5.3 meters per year (1954-1969). This rate is similar to the rate of coastline erosion for the Atchafalaya Management Unit's coastline along Point Au Fer Island. As both areas are largely composed of Teche-Mississippi sediments, this similarity is expected.

In contrast, the eastern part of the unit is eroding at a rate of 8.5 meters per year. The barrier islands that characterize this section are comprised of somewhat younger Lafourche-Mississippi sediments and are located in a more seaward position (receive more wave energy). Therefore this higher rate is to be expected.

In contrast to the more continuous coastline west of Caillou Bay, the barrier islands have highly variable erosion rates with erosion dominating the eastern end and the gulfward-facing shore, and accretion is commonplace on the downdrift end of these islands. Thus, these barrier islands (Isles Derniers and West and East Timbalier) are not only experiencing net retreat but are moving laterally along the coast because of the littoral transport of sediment.

Well-Defined Lakeshores and Bays. A total of ten lakes and bays were examined for analysis (see Table 9) and all, with the exception of Lake Verret, were undergoing erosion to some degree. As is typical of the Deltaic Plain, erosion is dominant but highly variable in the Terrebonne Management Unit. This unit and the Barataria Management Unit are experiencing the highest basin-wide erosion rates in coastal Louisiana.

Patterns of erosion are more complex than in the Chenier Plain in Southwest Louisiana. Lakes and bays that have not been modified to any great extent by man and are not close to natural ridges (e.g., levees) generally experience the same pattern of erosion as in the Chenier Plain, with southern shorelines exhibiting greater rates of erosion than northern shorelines. This, as outlined in the Calcasieu-Sabine and Mermentau Management Unit discussions, is regarded as being related to the stronger northerly winds and differences in sediment depth. The rate of erosion, however, is far greater for the Terrebonne area than Southwest Louisiana, and this difference may be related to the overall greater instability of sediments in the Terrebonne Unit. In addition, no clear-cut relationship was found between the size of the waterbody and the rate of erosion for Terrebonne as was the case in the Chenier Plain.

No relationship could be determined between vegetation type and rate of erosion except that the highest rates tended to be associated with brackish marshes.

One pattern of erosion seems to consistenly emerge both in this unit and in the Barataria unit. All lakes examined that were located in a depressed area between natural levees of small distributaries or located parallel and close to large former distributaries (e.g., Bayou Lafourche) exhibited high erosion rates, and in many cases these rates were comparable to or even greater than rates found at the coastline. This pattern has no relationship to vegetative type. The high rate of erosion in these examples is probably related to subsidence induced by the weight of the natural levees, which cause the unstable sediments to consolidate. In many cases the long axis of these lakes parallel the ridge, probably reflecting the axis of maximum depression.

Inner Marsh Land Loss. Six inner marsh areas representing all marsh types were analyzed. All the examples exhibited above average losses (0.3 to 1.0%/yr). Further examination of this category does not reveal any relationship between vegetative type and landloss rate. One notable exception is that the fresh marshes in the northwest part of Terrebonne Parish have lower land loss rates than fresh or other marsh types throughout the remaining parts of the management unit. This may be related to the influence of Atchafalaya River sediments.

The high rate of land loss throughout the unit is consistent with the high rates of erosion for the coastline and well-defined lakeshores and bays. Overall, the rates determined for the Terrebonne Management Unit compared to other units support previous geologic evidence associated with land loss; namely, areas of geologically younger deltaic sediments and areas containing thicker sequences of these sediments will have higher erosion rates.

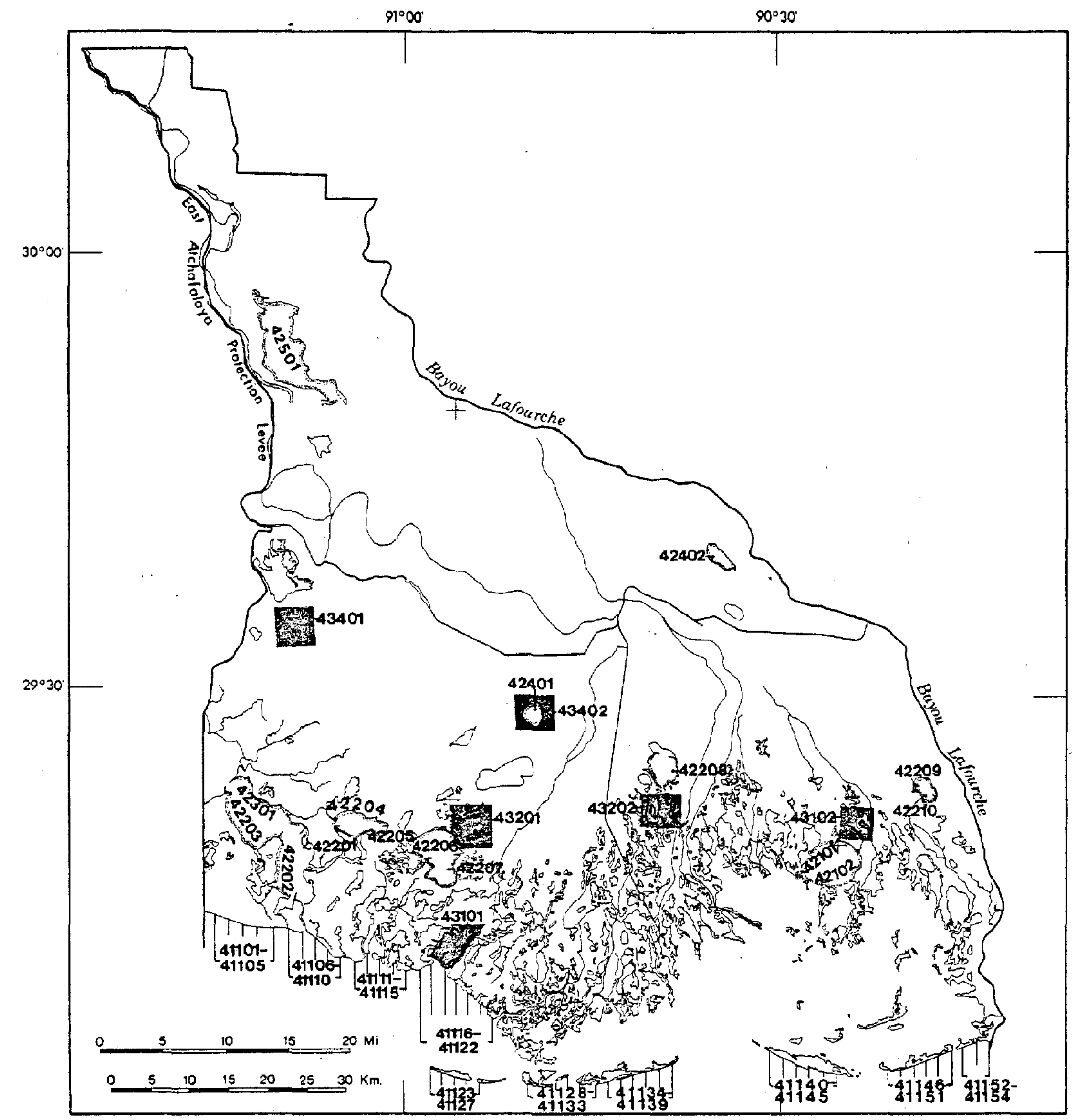


Figure 8. Site locations in the Terrebonne Management Unit.

Table 9

Erosion Rates for Sites Analyzed in the Terrebonne Management Unit

Management Unit / Shoreline Type / Vegetation Type / Site No.	Site Area	Parish	Quadrangle & Size(minutes	Data Sources & Dates		Retreat Rate m/yr	or	% Land Loss
4 1 1 01	Long. 91° 14'	Terrebonne	Oyster Bayou 15	1954 Air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	6.0		
4 1 1 02	Long. 91° 13'	"	"	"	"	8.1		
4 1 1 03	Long. 91° 12'	"	"	"	"	6.0		
4 1 1 04	Long. 91° 11'	"	"	"	"	6.0		
4 1 1 05	Long. 91° 10'	"	"	"	"	6.0		
4 1 1 06	Long. 91° 09'	"	"	"	"	3.9		
4 1 1 07	Long. 91° 08'	"	"	"	"	3.9		
4 1 1 08	Long. 91° 07'	"	"	"	"	3.9		
4 1 1 09	Long. 91° 06'	"	"	"	"	6.0		
4 1 1 10	Long. 91° 05'	"	"	"	"	6.0		
4 1 1 11	Long. 91° 04'	"	"	"	"	6.0		
4 1 1 12	Long. 91° 03'	"	"	"	"	6.0		
4 1 1 13	Long. 91° 02'	"	"	"	"	3.9		
4 1 1 14	Long. 91° 01'	"	"	"	"	2.1		
4 1 1 15	Long. 91° 00'	"	"	"	"	3.9		
4 1 1 16	Long. 90° 59'	"	Grand Bayou du Large 7-1/2	"	"	6.0		
4 1 1 17	Caillou Bay Long. 90° 58'	"	"	"	"	6.0		
4 1 1 18	Caillou Bay Long. 90° 57'	"	"	"	"	6.0		
4 1 1 19	Caillou Bay Long. 90° 56'	Terrebonne	Grand Bayou du Large 7-1/2	1954 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	3.9		
4 1 1 20	Caillou Bay Long. 90° 55'	"	Grand Bayou du Large 7-1/2	"	"	3.9		
4 1 1 21	Caillou Bay Long. 90° 54'	"	"	"	"	3.9		
4 1 1 22	Caillou Bay Long. 90° 53'	"	"	"	"	3.9		
4 1 1 23	Racoon Point Long. 90° 58'	"	Western Isles Dernieres 7-1/2	"	"	21.9		
4 1 1 24	Isles Dernieres Long. 90° 57'	"	"	"	"	6.0		
4 1 1 25	Long. 90° 56'	"	"	"	"	6.0		
4 1 1 26	Long. 90° 55'	"	"	"	"	Adv.		
4 1 1 27	Long. 90° 54'	"	"	"	"	15.9		
4 1 1 28	Long. 90° 50'	"	Central Isles Dernieres 7-1/2	"	"	6.0		
4 1 1 29	Long. 90° 49'	"	"	"	"	8.1		
4 1 1 30	Long. 90° 48'	"	"	"	"	14.1		
4 1 1 31	Long. 90° 47'	"	"	"	"	8.1		

Table 9 continued

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr	or	% Land Loss
4	1	1	32	Long. 90° 46'	"	"	"	"	12.0		
4	1	1	33	Long. 90° 45'	"	"	"	"	6.0		
4	1	1	34	Long. 90° 44'	"	Eastern Isles Dernieres 7-1/2	"	"	3.9		
4	1	1	35	Isles Dernieres Long. 90° 43'	"	"	"	"	8.1		
4	1	1	36	Long. 90° 42'	Terrebonne	Eastern Isles Dernieres 7-1/2	1954 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	8.1		
4	1	1	37	Long. 90° 41'	"	"	"	"	6.0		
4	1	1	38	Long. 90° 40'	"	"	"	"	6.0		
4	1	1	39	Long. 90° 39'	"	"	"	"	6.0		
4	1	1	40	Timbalier Is. Long. 90° 31'	"	Cat Island Pass 7-1/2	"	"	Adv.		
4	1	1	41	Timbalier Is. Long. 90° 30'	"	"	"	"	Adv.		
4	1	1	42	Timbalier Is. Long. 90° 29'	"	Timbalier Is. 7-1/2	"	"	3.9		
4	1	1	43	Timbalier Is. Long. 90° 28'	"	"	"	"	12.0		
4	1	1	44	Timbalier Is. Long. 90° 27'	"	"	"	"	9.9		
4	1	1	45	Timbalier Is. Long. 90° 26'	"	"	"	"	6.0		
4	1	1	46	E. Timbalier Is. Long. 90° 22'	Lafourche	Calumet Is. 7-1/2	"	"	0		
4	1	1	47	E. Timbalier Is. Long. 90° 21'	"	"	"	"	27.9		
4	1	1	48	E. Timbalier Is. Long. 90° 20'	"	"	"	"	15.9		
4	1	1	49	E. Timbalier Is. Long. 90° 19'	"	"	"	"	14.1		
4	1	1	50	E. Timbalier Is. Long. 90° 18'	"	"	"	"	120		
4	1	1	51	E Timbalier Is. Long. 90° 17'	Lafourche	Calumet Is. 7-1/2	1954 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	8.1		
4	1	1	52	Long. 90° 16'	"	"	"	"	20.1		
4	1	1	53	Long. 90° 15'	"	"	"	"	8.1		
4	1	1	54	Belle Pass Long. 90° 14'	"	Belle Pass 7-1/2	"	"	8.1		
4	2	1	01	Lake Felicity	Terrebonne	Lake Felicity 15	USGS Quadrangle (1944) no photo date	1974 NASA MX293	0.3		
4	2	1	02	"	"	"	"	"	7.1		
4	2	2	01	SE Four League Bay	"	Lake Decade 15	USGS Quadrangle from 1955 photos	"	2.3		
4	2	2	02	SW Four League Bay	"	"	"	"	0.9		
4	2	2	03	NW Four League Bay	"	"	"	"	2.2		

Table 9 continued

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr	or	% Land Loss
4	2	2	04	Lost Lake	"	"	"	"	0.8		
4	2	2	05	Lost Lake	"	"	"	"	2.6		
4	2	2	06	N L. Mechant	"	Bayou du Large 15	USGS Quadrangle from 1940 photos	"	2.3		
4	2	2	07	S L. Mechant	"	"	"	"	1.3		
4	2	2	08	L Boudreaux	"	Dulac 15	USGS Quadrangle (1944) no photo date	"	6.3		
4	2	2	09	N & E Catfish Lake	Lafourche	Lake Felicity 15	"	"	2.5		
4	2	2	10	S&W Catfish Lake	"	"	"	"	6.3		
4	2	3	01	NE Four League Bay	Terrebonne	Lake Decade 15	USGS Quadrangle from 1955 photos	"	2.8		
4	2	4	01	Lake Theriot	Terrebonne	Bayou du Large 15	USGS Quadrangle from 1940 photos	1974 NASA MX293	3.4		
4	2	4	02	Lake Fields	Lafourche	Houma 15	USGS Quadrangle (1944) no photo date	"	5.2		
4	2	5	01	Lake Verret	Assumption	Napoleonville 15	USGS Quadrangle from 1950 photos	"	0		
4	3	1	01	S Caillou Lake	Terrebonne	Grand Bayou 15	USGS Quadrangle from 1952 photos	"			0.52
4	3	1	02	E Lake Chien	"	Lake Felicity 15	USGS Quadrangle from 1963 photos	"			0.55
4	3	2	01	N Lake Mechant	"	Lake Mechant 15	"	"			0.68
4	3	2	02	Lake Quitman	"	Lake Quitman 15	"	"			0.93
4	3	4	01	Bayou Penchant	"	Morgan City SW 15	USGS Quadrangle from 1964 photos	"			0.33
4	3	4	02	Lake Theriot	"	Lake Theriot 15	USGS Quadrangle from 1963 photos	"			0.97

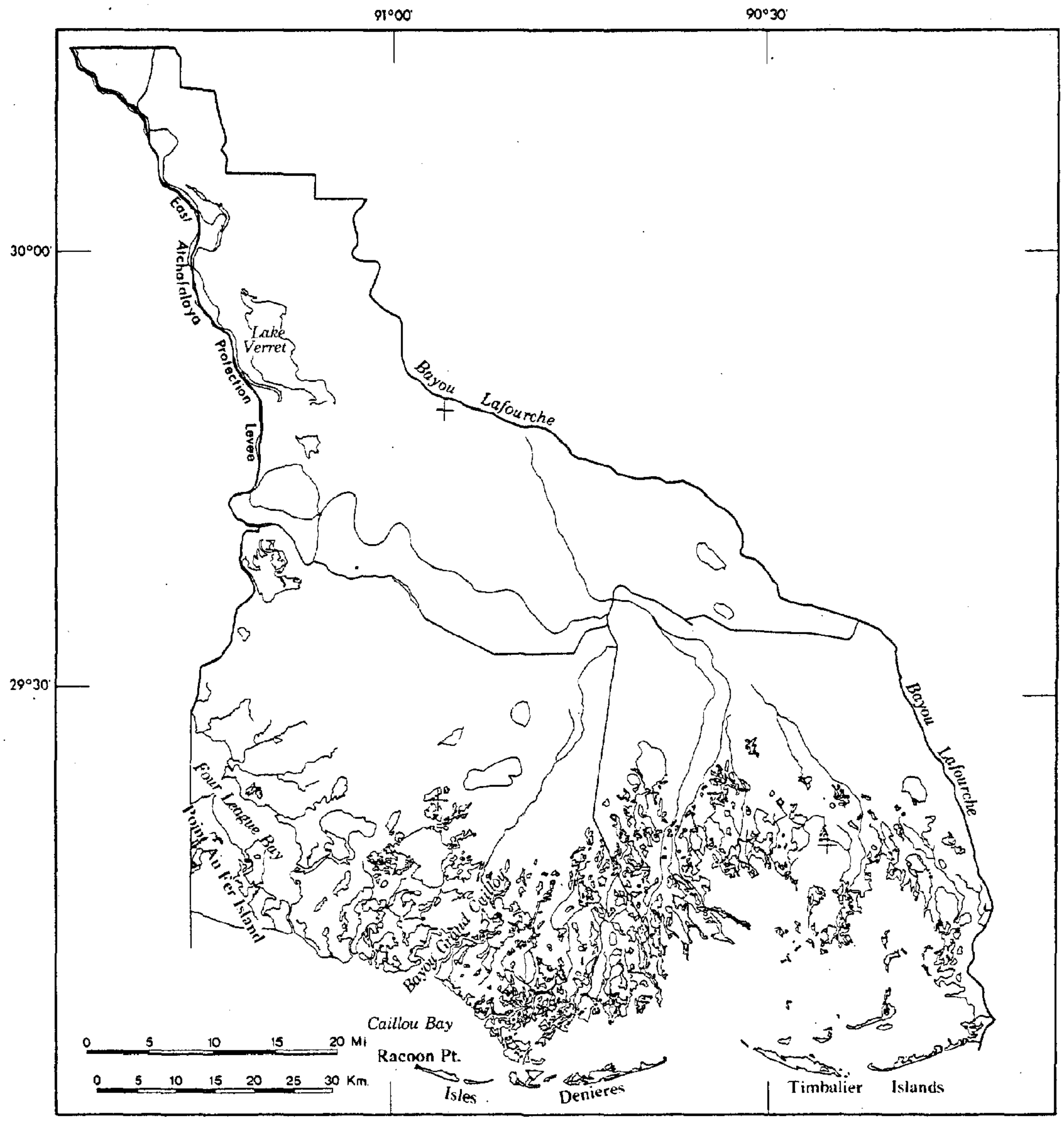


Figure 9. Place names in the Terrebonne Management Unit.

Management Unit V--Atchafalaya

Coastline Erosion. The coastline of the Atchafalaya Management Unit extends from South Point on Marsh Island to 91° 15' west longitude on Point Au Fer Island (Fig. 11). The section of coastline from South Point to North Point (Point Au Fer Island) consists of discontinuous near sea level oyster reefs. The latter set of aerial photography used (1969) was not tide controlled; therefore, changes in these reefs cannot be analyzed. Field checks of these reefs, however, following cold front passages during the winter of 1975-1976 indicated that fine-grain sediments were deposited over portions of them. The source of sediments are obviously associated with the Atchafalaya River. General field observations indicated that much of these deposits were currently being eroded; therefore, no conclusions were made as to their permanence.

From North Point to 91°15' west longitude (11 km), the coastline is bordered by brackish and saline marshes. Most of this section of coastline is undergoing erosion at an annual rate of 5.8 m (1954-1969). A 3 km section, however, has experienced a considerable advance of 7.7 m/yr. The advance of this small section is attributed to the reworking and redepositing of eroded sections further east along the shoreline rather than an influx of new sediments.

USCE 1975 uncontrolled photomosaics indicate that the trend may have reversed with the accretion now occurring along the coastline at the western end of Point Au Fer Island. The continued seaward advance of the Atchafalaya Delta should result in the further progradation of this part of the coastline.

Well-Defined Lakeshores and Bays. Virtually the entire length of shoreline around Atchafalaya Bay has prograded between 1955 and 1975. Much of the new subaerial exposures appeared following the flood years of 1973-1975 (see Chapter 1). Continued progradation of the shorelines and growth of the delta is expected. The rate of growth cannot be predicted because it is largely dependent on the duration and peak of the spring floods.

Although net growth should continue around Atchafalaya Bay, erosion and reworking of sediments will occur between flood periods. Thus the new land formed following a flood period should not be thought of as permanent or stable land at this stage of delta development.

Inner Marsh Land Loss. The fresh marshes bordering the northern part of Atchafalaya Bay have experienced a net land gain from 1952 to 1975. These gains of inner marsh areas are in the form of pond filling and subsequent colonization. The high density of essentially natural waterways between Bayou Sale and east of the Lower Atchafalaya River facilitates the input of sediment over these marshes.

Dispersed throughout these fresh marshes and increasing in density as one progresses north towards Bayou Teche are areas of swamp forest. Although the total swamp forest area has remained stable, it has experienced the same influx of sediment as the fresh marshes. The responses to these changes are much slower for swamp forest species than for marsh grasses. Because our analysis of land loss/gain is based on changes in the amount of vegetated area over approximately twenty years, it is possible for us to detect changes in marsh areas but not in swamp forest, although both areas are influenced by the same processes.

In the Atchafalaya Management Unit, brackish marsh is limited to the western part of Point Au Fer Island. Losses in this area are comparable to those determined for brackish marshes in the southwest part of the neighboring Terrebone Management Unit. As both of these areas are largely comprised of Teche-Mississippi age sediments, their rates of loss are expected to be similar. Apparently modern Atchafalaya sediments have not influenced the brackish marshes on Point Au Fer Island to the extent of reversing or even retarding land loss rates. The continued growth of the Atchafalaya Delta towards Point Au Fer Island, however, should result in a future slowdown of the rate of land loss.

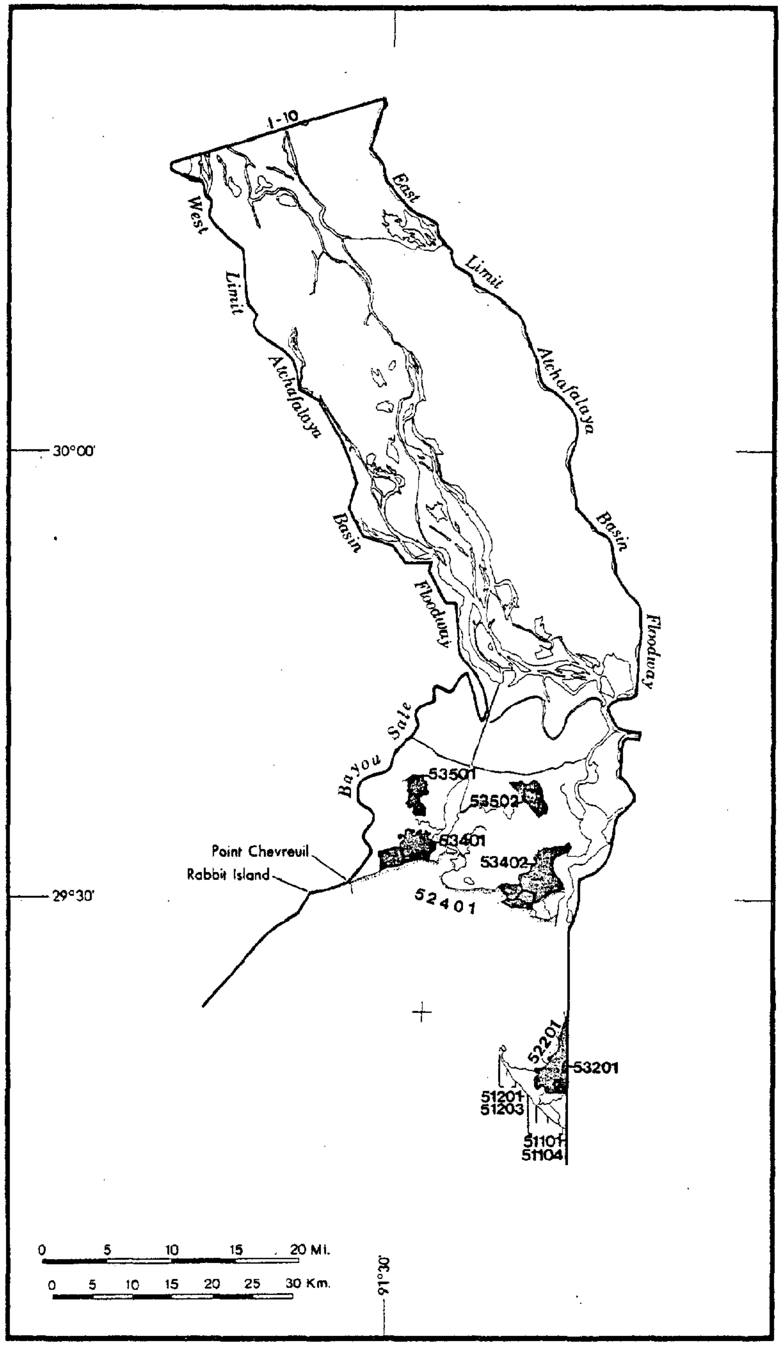


Figure 10. Site locations in the Atchafalaya Management Unit.

Table 10

Erosion Rates for Sites Analyzed in the Atchafalaya Management Unit

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size (minutes)	Data Sources & Dates		Retreat Rate m/yr	or % Land Loss
5	1	1	01	Long. 91° 18'	Terrebonne	Point Au Fer 15	1954 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	Adv.	
5	1	1	02	Long. 91° 17'	"	"	"	"	3.9	
5	1	1	03	Long. 91° 16'	"	"	"	"	9.9	
5	1	1	04	Long. 91° 15'	"	"	"	"	6.0	
5	1	2	01	North Point Long. 91° 21'	"	"	"	"	2.1	
5	1	2	02	Long. 91° 20'	"	"	"	"	8.1	
5	1	2	03	Long. 91° 19'	"	"	"	"	Adv.	
5	2	2	01	So. Point to Fishing Point	"	Point Au Fer 15 & Lost Lake 15	1952 USN air photos	1975 USCE uncontrolled photomosaics	Adv.	
5	2	4	01	Pt. Chevreuil to Shell Is.	St. Mary	Bayou Sale, Belle Isle 15 & Pt. Au Fer	"	"	Adv.	
5	3	2	01	Pt. Au Fer Is.	Terrebonne	Point Au Fer 15	"	"		0.50
5	3	4	01	Hog Bayou	St. Mary	Belle Isle 15	USGS Quadrangle from 1964 photos	"		Gain
5	3	4	02	Little Hog Bayou	"	Point Au Fer & Belle Isle 15	1952 USN air photos	"		Gain
5	3	5	01	Bayou Blue	"	Belle Isle 15	USGS Quadrangle from 1964 photos	1972 NASA MX194		0
5	3	5	02	Cross Bayou	"	"	"	"		0

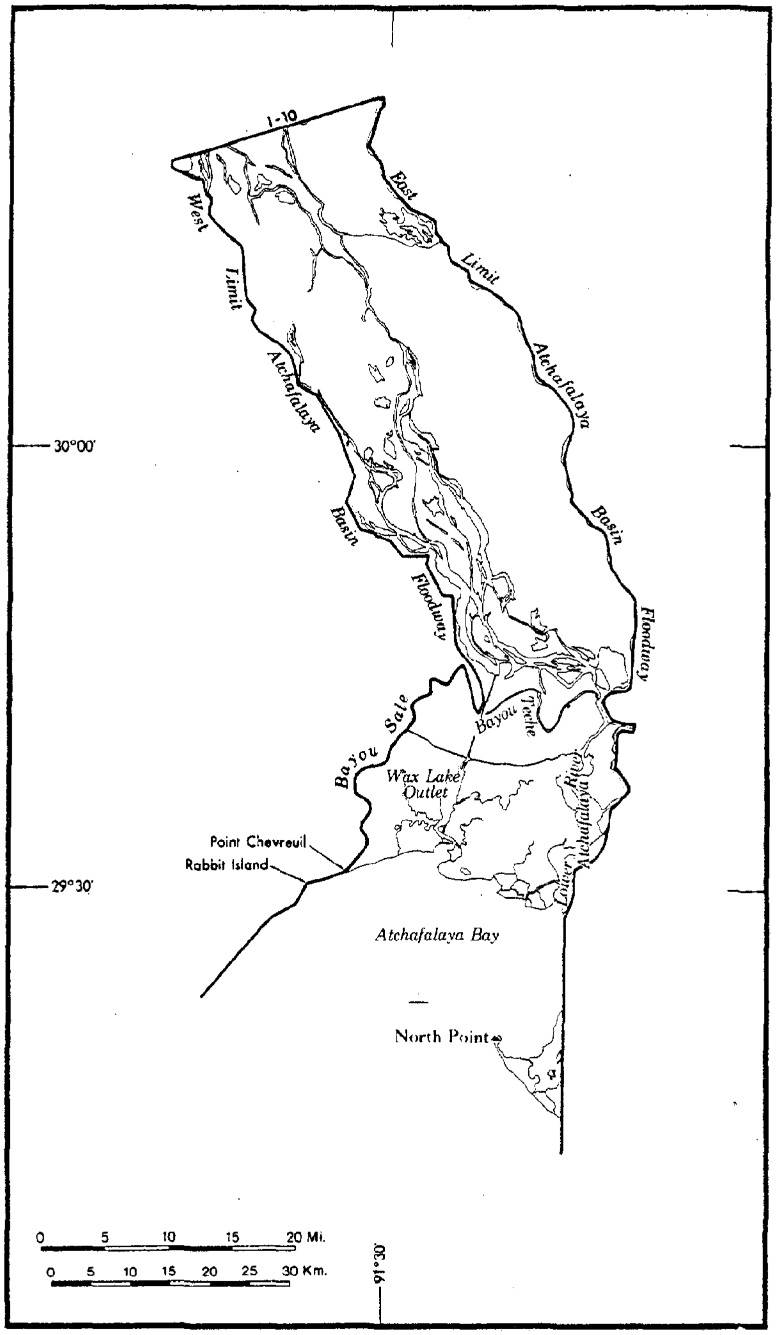


Figure 11. Place names in the Atchafalaya Management Unit.

Management Unit VI--Vermilion

Coastline Erosion. The coastline of the Vermilion Management Unit extends east from Freshwater Bayou Canal to South Point on the eastern end of Marsh Island (Fig. 13). The area is naturally divided into two sections, east and west of Southwest Pass. The coastline along Marsh Island has been relatively stable from 1954 to 1969. Morgan and Larimore (1957) report similar findings for the period from 1932 to 1954. The stability along this section is caused by the effectiveness of the offshore oyster reefs in reducing wave energies. At the eastern and western margins of Marsh Island, where no reefs are located in the nearshore area, erosion is occurring at a rate of 5 m/yr.

From Freshwater Bayou Canal to Southwest Pass, the coastline is eroding at variable rates, except for a 3 km section along Chenier Au Tigre, which has prograded 3 m/yr from 1954 to 1969. West of Chenier Au Tigre to Freshwater Bayou Canal, erosion is occurring at a rate of 5 m/yr. East of Chenier Au Tigre to Southwest Pass, the erosion rate is variable, from 3 m/yr to 9 m/yr, and averages 7.5 m/yr. As in the case of the Mermentau Management Unit, these erosion rates are significantly greater than those reported by Morgan and Larimore (1957) for the period from 1932 to 1954.

Well-Defined Lakeshores and Bays. A total of three lakes plus the shoreline around Vermilion and East and West Cote Blanche Bays were examined. The three lakes chosen--Portage, Fearman and Onion--are all located on the western side of Vermilion Bay in brackish marshes.

Portage and Onion Lakes show essentially the same pattern, with erosion occurring along the north shore at a rate of approximately 0.4 m/yr and the remaining shoreline being essentially stable. Both lakes are similar in size and are directly connected to Vermilion Bay via a tidal channel. A spoil bank resulting from the dredging of an oil access canal through Onion Lake has divided the lake in half and may have had an effect on shoreline changes.

Fearman Lake is considerably larger than the above lakes and is connected to Vermilion Bay at either end via tidal channels. No detectable erosion occurred between 1952 and 1974. Some minor accretion occurred along its eastern shoreline where Fearman Bayou connects the lake with Vermilion Bay.

Shorelines around Vermilion and West and East Cote Blanche Bays have either remained stable or have experienced minor erosion. The only section of shoreline that has eroded at a rate greater than 1 m/yr is located between Southwest Point and Deadman Island along Southwest Pass. Erosion here (3.5 m/yr) is related to tidal scour. Southwest Pass reaches a maximum depth of 50 m, which indicates that tidal currents are relatively strong and capable of considerable mechanical erosion.

Comparison of erosion rates of Vermilion and West and East Cote Blanche Bays with other bays and large lakes across Louisiana shows that the Vermilion Bay complex area has experienced considerably less erosion than one would expect on the basis of fetch alone. The reduced erosion rates must be due to the role of the lower Atchafalaya River.

Based on the recent subaerial growth rates of the deltas forming at the Lower Atchafalaya River Outlet and Wax Lake Outlet and the changing bathymetry in the surrounding bays, the shorelines around Vermilion and West and East Cote Blanche Bays should stabilize and may experience significant progradation.

Inner Marsh Land Loss. The marshes within the Vermilion Management Unit generally have experienced lower loss rates than the state average in areas that have experienced little modification by man. Areas of intensive man-related activities have faired poorly regardless of wetland type.

Salt marsh in this unit is limited to a small area on the east side of Southwest Pass (Chabreck 1972). Analysis of sample sites on the west side of Southwest Pass indicates that the percent of vegetation cover has remained stable in this area.

Brackish marsh north of Chenier Au Tigre and immediately east of Freshwater Bayou Canal has experienced above average land loss rates. This marsh was originally part of the area west of Freshwater Bayou Canal, which is discussed in more detail in the Mermentau Management Unit section.

The remaining brackish marsh areas have all experienced average or below average land loss rates. Losses are probably largely attributable to natural processes of erosion and subsidence. Atchafalaya River sediments apparently have not yet contributed enough sediments to these inner marsh areas surrounding Vermilion and East and West Cote Blanche Bays to reverse the trend. Loss rates determined for these areas between 1951 and 1974 are similar to those determined by Gagliano and van Beek (1970) for the period from the early 1930s to 1951.

The area from Cote Blanche Island to Jaws [also known as Little Bay] was the only intermediate marsh site analyzed. Land loss there did not differ from those rates determined for neighboring brackish marshes.

The only fresh marsh area where there was adequate aerial coverage for analysis is east of Forked Island. This area, however, is rapidly becoming reclaimed for agriculture primarily for rice and pasture. The deliberate modification of these wetlands precludes any meaningful analysis of natural processes.

Two different types of swamp forest were chosen for analysis: a swamp on the Vermilion River north of Intracoastal City and an interdistributary swamp west of Charenton Canal. Both types of swamp have remained stable with respect to percent cover.

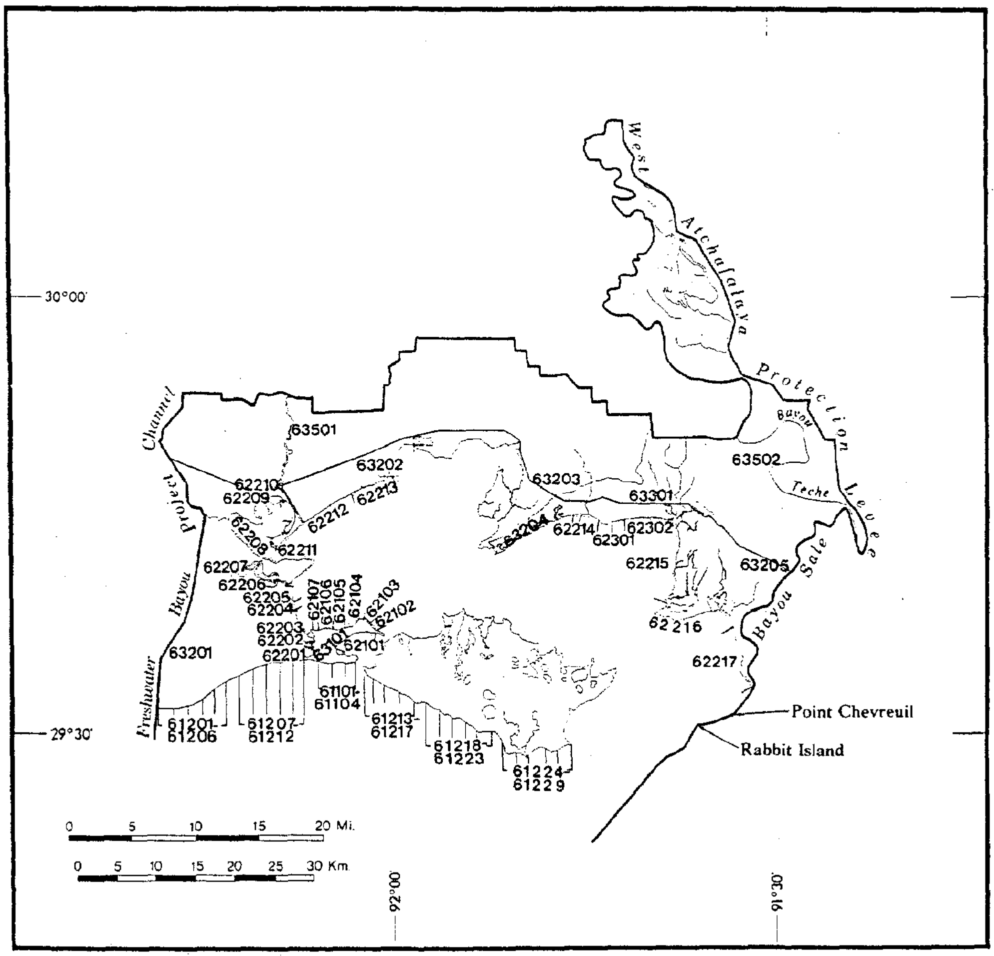


Figure 12. Site locations in the Vermilion Management Unit.

Table 11

Erosion Rates for Sites Analyzed in the Vermilion Management Unit

Management Unit	Shoreline Type	*Vegetation Type*	Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr	or % Land Loss
6	1	1	01	Long. 92° 06'	Vermilion	Cheniere au Tigre	1954 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	6.0	
6	1	1	02	Long. 92° 05'	"	"	"	"	6.0	
6	1	1	03	Long. 92° 04'	"	Cheniere au Tigre 15'	"	"	6.0	
6	1	1	04	Southwest Pass Long. 92° 03'	"	"	"	"	6.0	
6	1	2	01	Freshwater Bayou Canal Long. 92° 18'	"	Pecan Island 15'	"	"	3.9	
6	1	2	02	Long. 92° 17'	"	"	"	"	3.9	
6	1	2	03	Long. 92° 16'	"	"	"	"	6.0	
6	1	2	04	Long. 92° 15'	"	"	"	"	6.0	
6	1	2	05	Long 92° 14'	"	Cheniere au Tigre 15'	"	"	0	
6	1	2	06	Cheniere au Tigre Long. 92° 13'	"	"	"	"	Adv.	
6	1	2	07	Long. 92° 12'	"	"	"	"	3.9	
6	1	2	08	Long. 92° 11'	"	"	"	"	8.1	
6	1	2	09	Long. 92° 10'	"	"	"	"	9.9	
6	1	2	10	Long. 92° 09'	"	"	"	"	9.9	
6	1	2	11	Long. 92° 08'	"	"	"	"	12.0	
6	1	2	12	Long. 92° 07'	"	"	"	"	6.0	
6	1	2	13	Southwest Pass-Marsh Is. Long. 92° 02'	Iberia	"	1960 air photos Jack Ammann Corp.	"	6.6	
6	1	2	14	Long. 92° 01'	Iberia	Cheniere au Tigre 15	1960 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	3.0	
6	1	2	15	Long. 92° 00'	"	Marsh Island 15	"	"	0	
6	1	2	16	Long. 91° 59'	"	"	"	"	0	
6	1	2	17	Long. 91° 58'	"	"	"	"	0	
6	1	2	18	Long. 91° 57'	"	"	"	"	0	
6	1	2	19	Long. 91° 56'	"	"	"	"	0	
6	1	2	20	Long. 91° 55'	"	"	"	"	Adv.	
6	1	2	21	Long. 91° 54'	"	"	"	"	Adv.	
6	1	2	22	Long. 91° 53'	"	"	"	"	0	

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size (minutes)	Data Sources & Dates		Retreat Rate m/yr	or	% Land Los
6	1	2	23	Long. 91° 52'	"	"	"	"	0		
6	1	2	24	Long. 91° 51'	"	Mount Point 7-1/2	"	"	3.3		
6	1	2	25	Long. 91° 50'	"	"	"	"	0		
6	1	2	26	Mound Pt. Long. 91° 49'	"	"	"	"	6.6		
6	1	2	27	Long. 91° 48'	"	"	"	"	6.6		
6	1	2	28	Long. 91° 47'	"	"	"	"	0		
6	1	2	29	South Pt. Long. 91° 46'	"	"	"	"	9.9		
6	2	1	01	Southwest Pt.	Vermilion	Cheniere Au Tigre 15	USGS Quadrangle from 1948 photos	1972 NASA MX194	3.9		
6	2	1	02	"	"	"	"	"	0		
6	2	1	03	Indian Point	Vermilion	Cheniere Au Tigre 15	USGS Quadrangle from 1948 photos	1969 USCE uncontrolled photomosaics	0.9		
6	2	1	04	"	"	"	"	"	0		
6	2	1	05	S Vermilion Bay	"	"	"	"	0.6		
6	2	1	06	"	"	"	"	"	0		
6	2	1	07	Hell Hole	"	"	"	"	0.9		
6	2	2	01	Portage Lake	"	"	"	"	0		
6	2	2	02	"	"	"	"	"	0.2		
6	2	2	03	SW Vermilion Bay	"	"	"	"	0.8		
6	2	2	04	"	"	"	"	"	0		
6	2	2	05	"	"	"	"	"	0.8		
6	2	2	06	Fearman Lake	"	"	"	"	Adv.		
6	2	2	07	"	"	"	"	"	0		
6	2	2	08	Redfish Pt. to Buck Pt. to Little White Lake	"	Cheniere Au Tigre & Abbeville 15	"	1972 NASA MX194	0		
6	2	2	09	Vermilion Bay near Onion Bayou	"	Abbeville 15	"	"	0.5		
6	2	2	10	Vermilion Cutoff to Mud Pt.	"	Cheniere Au Tigre 15	"	"	0		
6	2	2	11	Mud Pt.	"	"	"	"	Adv.		

Table 11 continued

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr.	or	% Land Loss
6	2	2	12	Vermilion Bay (Mud Pt. to Lake Cleodis)	Vermilion	Cheniere Au Tigre & Abbeville 15	USGS Quadrangle from 1948 photos	1972 NASA MX194	0.8		
6	2	2	13	Vermilion Bay (Lake Cleodis to Lake Cock)	"	Abbeville & Derouen 15	"	"	0		
6	2	2	14	W Cote Blanche Bay	St. Mary	Bayou Sale 15	USGS Quadrangle from 1955 photos	"	0.4		
6	2	2	15	W Cote Blanche Bay (Jaws to Marone Pt.)	"	"	"	"	0		
6	2	2	16	E Cote Blanche Bay (Marone Pt. to Yellow Bayou)	"	"	"	"	0.6		
6	2	2	17	E Cote Blanche Bay (Yellow Bayou to Bayou Sale Bay)	"	"	"	"	0		
6	2	3	01	Cote Blanche Is.	"	"	"	"	0		
6	2	3	02	Cote Blanche Is. to Jaws	"	"	"	"	0.6		
6	3	1	01	Southwest Pass	Vermilion	Cheniere Au Tigre 15	USGS Quadrangle from 1948 photos	USGS Orthophoto Quadrangle 1974 photos			0
6	3	2	01	Freshwater Bayou Canal	"	Pecan Island 15	1952 USN photos	"			0.54
6	3	2	02	Green Is. Bayou	"	Abbeville 15	USGS Quadrangle from 1948 photos	1972 NASA MX194			0.24
6	3	2	03	Shark Island	Iberia	Derouen 15	1952 USN photos	1972 NASA MX194			0.08
6	3	2	04	Cypremort	St. Mary	"	"	"			0.20
6	3	2	05	Freshwater Lake Bayou Carlin	"	Bayou Sale 15	USGS Quadrangle from 1955 photos	"			0.07
6	3	3	01	Hackberry Lake	"	Bayou Sale & Jeanerette 15	1952 USN photos	"			0.27
6	3	5	01	Vermilion River below Bancher	Vermilion	Abbeville 15	"	USGS Orthophoto Quadrangle from 1974 photos			0
6	3	5	02	Bayou Choupique	St. Mary	Jeanerette 15	USGS Quadrangle from 1962 photos	1972 NASA MX194			0

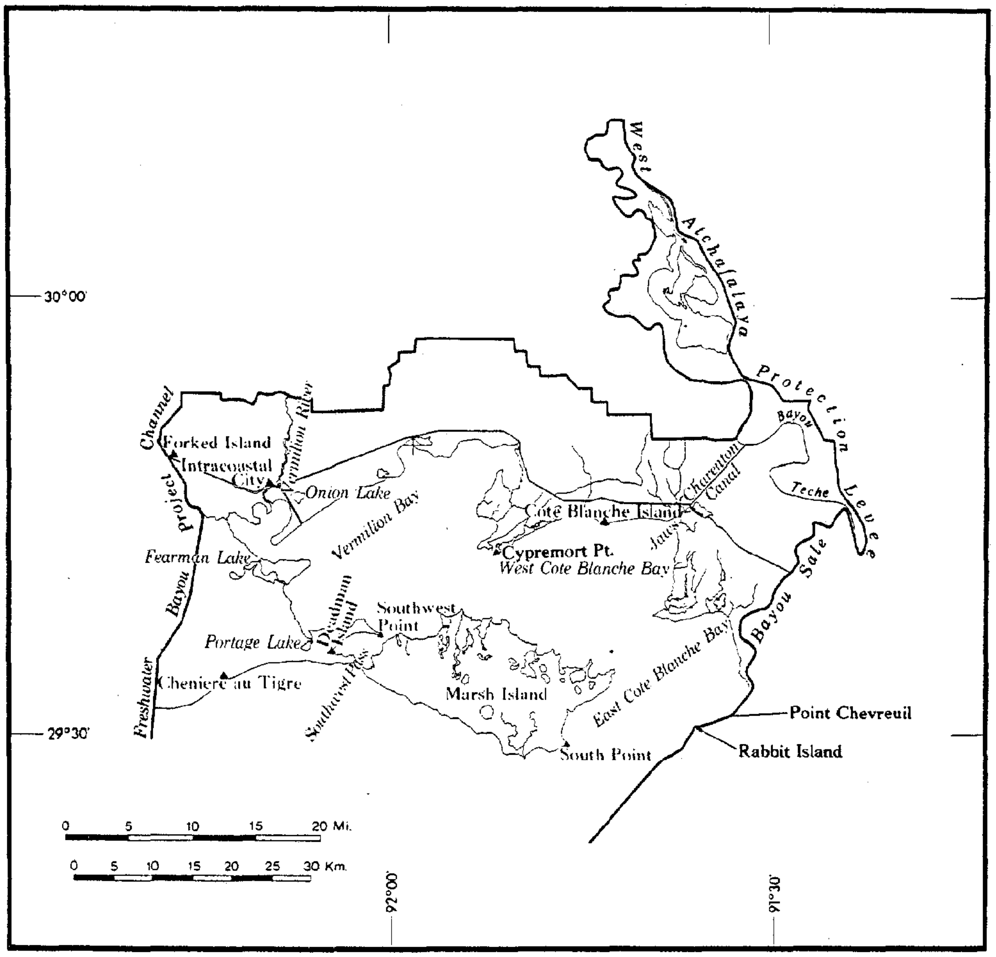


Figure 13. Place names in the Vermilion Management Unit.

Management Unit VII--Mermentau

Coastline Erosion. The Mermentau Management Unit's coastline extends east from the natural mouth of the Mermentau River to the entrance of the Freshwater Bayou-Belle Isle Canal System (Fig. 16). Beginning at the natural mouth of the Mermentau River and moving east along Hackberry Beach for seven kilometers to State Cut, the coastline is eroding at a rate of 1.5 m/yr. This is a reversal of the trend occurring to the immediate west of the Mermentau River, where accretion is 3.2 m/yr. East of the State Cut for a distance of 60 kilometers to Dewitt Canal, the coast is eroding at a rate of 11.7 m/yr. This represents the highest rate of coastline erosion west of the Isles Derniers in Terrebonne Parish. The 11.7 m/yr retreat rate for 1954 to 1969 is slightly greater than the 9.1 m/yr of retreat for 1932 to 1954 (Morgan and Larimore 1957). This difference is not felt to be indicative of a significant trend because the increase probably reflects the effects of Hurricane Audrey. This section of coastline is undeveloped and much of the land is in public ownership.

East of Dewitt Canal the coastline is prograding at a rate of 9 m/yr for a distance of 3 km. Beyond this section to Freshwater Bayou Canal, erosion is occurring at a rate of 4 m/yr. During the period from 1932 to 1954, both of these sections experienced accretion at a rate of 6.3 m/yr due to mudflat deposition. Thus it appears that the increase in accretion east of Dewitt Canal (6.3 m/yr from 1932 to 1954 to 9 m/yr from 1954 to 1969) is the result of the displacement of reworked sedimentfrom the east.

Well-Defined Lakeshores. A total of ten lakes were examined in the Mermentau Management Unit (Figs. 15 and 16). Lower Mud, Miller [also shown as Tolan Lake on some maps], and Flat Lakes are saline to brackish. The remaining lakes are all dominated by fresh marshes along their shorelines except for the southwest shore of Grand Lake, which contains intermediate marsh, and Lake Arthur, which borders on the Pleistocene terrace.

Lake Arthur represents the only known stable lake north of Grand Chenier in this management unit. Most of its shoreline consists of subaerial Pleistocene sediments, which account for its stability. The Mermentau River flows into Lake Arthur from the northeast. At this point, swamp vegetation borders the lake and this section has also remained stable. At the southwest portion of the lake just above Lowry, a small pocket of fresh marsh dominates the shoreline. This area has been undergoing shoreline advance.

The remaining lakes north of Grand Chenier, which include Catfish, Grand, Misere, Sweet, White, and Willow, all exhibit similar erosion patterns. Southern and southeastern shorelines generally have higher erosion rates than their northern counterparts and usually the larger the lake, the greater the erosion rates. Insofar as all these lakes are approximately the same depth, the above erosion pattern appears to be related to wind speed and direction as discussed elsewhere (see Calcasieu-Sabine Management Unit discussion).

Based on size, Grand and White Lakes should have erosion rates similar to Sabine and Calcasieu Lakes. Although the pattern of erosion is similar, Grand and White Lakes have been eroding at a rate several times greater than Calcasieu or Sabine Lakes, and they have eroded at a greater rate than lakes in similar vegetation zones in the Deltaic Plain where Recent sediments are considerably thicker. This high rate of erosion has led to the construction of levees along much of White Lake and sections of Grand Lake. Many of these levees have been set back from the present shoreline; therefore, it is not yet possible to analyze their effectiveness in retarding erosion. Case studies of the effect of lake ridges and spoil deposits from neighboring lakes may provide some insight into the future effectiveness of these levees.

Cheniere Du Fond is a lakeshore ridge located on the southeast shore of Grand Lake (Fig.14). From 1932 to 1951 it retreated back over the marsh at a rate of less than 1 m/yr. From 1951-1974 it has retreated 2.5 m/yr and has all but disappeared. Without the presence of this ridge, shoreline erosion will probably accelerate. Based on the above erosion rates, two questions arise:

1) Why have they accelerated?
2) Why has Cheniere Du Fond all but disappeared as opposed to being thrown back over the marsh as it was in the past?

A brief examination of other areas along Grand and White Lakes indicates that erosion rates there have also accelerated by as much as an order of magnitude. Erosion of lake shorelines south of Grand Chenier, however, has not accelerated. Examination of pre- and post-Hurricane Audrey air photos indicates that whereas Hurricane Audrey caused some detectable erosion, it only accounts for a small portion of the total accelerated rate.

To this point we have eliminated several possible causes (hurricanes, depth of sediment, and fetch) but have not documented the cause. We believe it is significant that the lakes that are experiencing high erosion rates are all within the Mermentau water management area. The

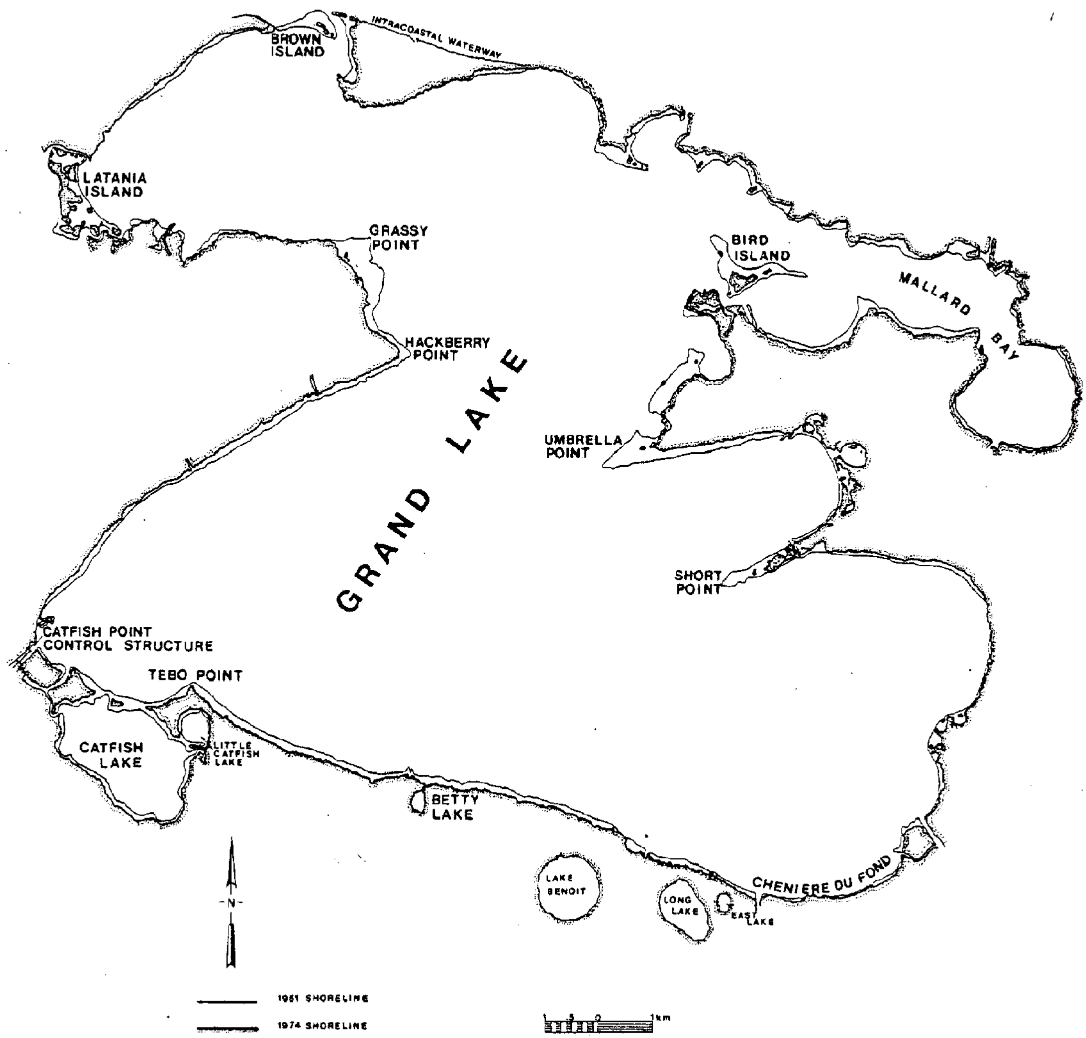


Figure 14. Shoreline erosion along Grand Lake 1951-1974.

Mermentau water management area is a man-made holding area for water to be used for rice irrigation. A series of control structures completed in 1951 prevent saltwater intrusion into the area and hold fresh water in. The structures have artificially raised water levels within the system. This increase in water level may have been sufficient to raise the height of wind induced waves from breaking onshore to breaking over the shore and could explain why Cheniere du Fond has all but disappeared instead of just being displaced further back over the marsh.

As exemplified by Grand Lake, the larger lakes in this area have a tendency to round themselves. This is illustrated by the fact that points (e.g., Umbrella Point, Short Point) along the lakeshore have the highest erosion rates. Through erosion Grand Lake has incorporated several other lakes (e.g., Catfish Lake). If the present trends continue, it is expected that coalescing will continue until the area between Lake Misere and White Lake becomes one lake.

Levees along the southwest shore of White Lake have successfully retarded erosion. These levees combined with other levee systems, however, have impounded those marshes south and southwest of White Lake and have consequently removed those areas as nursery grounds.

Saline to brackish lakes just inland from the coastline have either remained fairly stable or have accreted. Miller's Lake has undergone major accretion, and Flat Lake has remained stable except for a small segment of shoreline that has accreted. The amount of accretion that occurs in these saline lakes appears to be directly related to their proximity to the coastline. Consequently, it is believed that the accretion occurs infrequently and results from storm waves that wash beach deposits back into these lakes. The dominant vegetation on these accreting areas is oyster grass (*Spartina alterniflora*).

Lower Mud Lake, which is predominantly saline despite being part of the Mermentau River system, has experienced a complex interaction of erosion and accretion that is probably due to man's intervention. The natural mouth of the Mermentau River is now silting in. Farther east along the southern shoreline, erosion is occurring and is greatest in the vicinity of the State Cut (a man-made channel exiting to the gulf, see Fig. 16). Other shorelines of this lake could not be assessed because of cultural modification.

Inner Marsh Land Loss. Although coastline and lake shoreline erosion rates are relatively high, inner marsh loss has been generally below the state average. This is particularly true for the fresher marshes within the Mermentau water management area. These findings of low inner marsh loss rates are, however, somewhat misleading. Approximately forty percent of the marshes in this area are impounded (Gosselink, in press). This includes wildlife impoundments and agricultural impoundments where marsh vegetation has been replaced by other species. Our analysis of inner marsh areas that change to open water does not include these impounded areas. In addition, it could be argued that the entire Mermentau water management area is a type of impoundment. Whereas we recognize that this area is impounded periodically every year, water exchange does occur during periods when the control structures remain open. Thus although natural water exchange has been substantially modified, we have included sample sites from within the Mermentau water management area with the understanding that we are dealing with different circumstances.

There are no major areas of swamp forest in the Mermentau area. Patches of swamp forest vegetation are present on the flood plains of the Mermentau River, Bayou Lacassine, and Bayou Queue de Tortue, but these are primarily located north of the confines of the study area. Based on the examination of a small area on the Mermentau River just north of Lake Arthur, swamp forest appears to be stable with no detectable areas of loss or gain found.

Fresh marsh areas have generally experienced average to below average losses. Much of the sawgrass (Cladium jamaicense) marsh that was lost following Hurricane Audrey in 1957 has been revegetated but largely by other species (see also Calcasieu-Sabine Management Unit). The only fresh marsh area examined having above average loss rates was the area between the road to Little Chenier and the Gulf Intracoastal Waterway (GIWW). Known as part of the "Great Burn Area" by some of the older local residents, it is bounded by the GIWW on the north, Highway 27 on the west, and Little Chenier Ridge and road on the south. Thus the area is semienclosed by ridges, which may serve to reduce overland flow and sedimentation and thereby contribute to land loss. This area, however, has had a history of land loss predating the earliest aerial photography and USGS quadrangle maps of the area. Lynch (1941) reports that marsh fires occurring during the 1924-25 drought burned deeply into the peat and destroyed the root system. Valentine (unpublished ms.) reports that this area experienced prolonged flooding during 1940 with die-offs subsequently occurring. The presence of ridges on three sides may have lessened the ability of the waters to recede and thereby have contributed to the excessive flooding. O'Neil (1949) states that this area had recovered to a great extent although a species change was evident. Valentine (unpublished ms.) reports that this area once again opened up following Hurricane Audrey.

In summary, this area has had a complex history of die-offs and revegetation with no single cause being evident. The documentation of this area is better than for most of coastal Louisiana. Thus, it serves to indicate that marsh loss throughout coastal Louisiana may be the result of the interaction of several factors rather than single cause-effect relationships.

Brackish marsh areas have experienced higher loss rates than fresh marsh in the Mermentau area, but these rates are generally less than for brackish marshes in the Deltaic Plain. The only area of brackish marsh with an above-average erosion rate is located in the southeast portion of the management area near Freshwater Bayou Canal. The paralleling linear ponds that are forming here and on the east side of Freshwater Bayou are believed to be caused by the loss of circulation due to the spoil banks of Freshwater Bayou Canal, numerous oil access canals, and the natural cheniers bordering these ponds. Prior to the dredging of these canals, water drained through the swales into Freshwater Bayou. The spoil banks of these canals have effectively blocked the natural drainage flow thus causing water to accumulate in these swales.

Except for some areas where natural bayous drain into the gulf, the salt marsh is limited to a narrow zone immediately landward of the beach. No major losses are associated with this small area although the salt marsh appears to migrate inland as the coastline erodes.

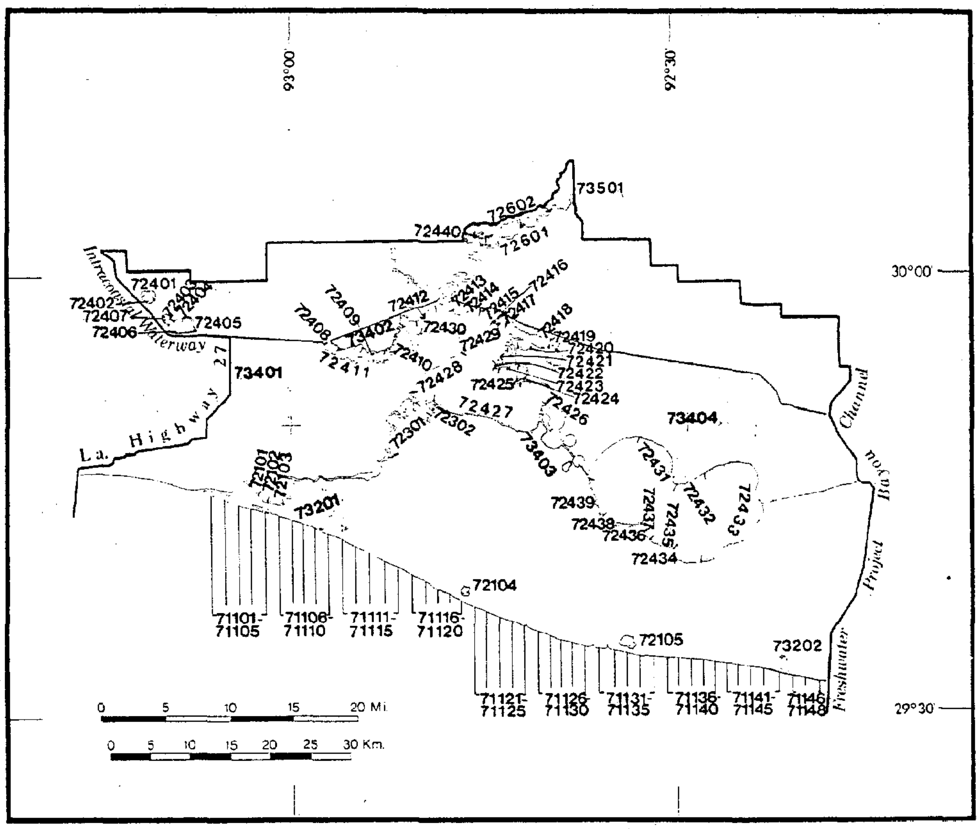


Figure 15. Site locations in the Mermentau Management Unit.

Table 12

Erosion Rates for Sites Analyzed in the Mermentau Management Unit

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr	or	% Land Loss
7	1	1	01	Mermentau River Long. 93° 06'	Cameron	Sweet Lake 15	1954 photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	0		
7	1	1	02	Long. 93° 05'	"	"	"	"	0		
7	1	1	03	Long. 93° 04'	"	"	"	"	2.1		
7	1	1	04	Long. 93° 03'	"	"	"	"	9.9		
7	1	1	05	Long. 93° 02'	"	"	"	"	9.9		
7	1	1	06	Long. 93° 01'	"	"	"	"	8.1		
7	1	1	07	Long. 93° 00'	"	Hog Bayou 15	"	"	6.0		
7	1	1	08	Long. 92° 59'	"	"	"	"	9.9		
7	1	1	09	Long. 92° 58'	Cameron	Hog Bayou 15	"	"	14.1		
7	1	1	10	Long. 92° 57'	"	"	"	"	9.9		
7	1	1	11	Club Canal Long. 92° 56'	"	"	"	"	14.1		
7	1	1	12	Long. 92° 55'	"	"	"	"	9.9		
7	1	1	13	Long. 92° 54'	"	"	"	"	12.0		
7	1	1	14	Long. 92° 53'	"	"	"	"	9.9		
7	1	1	15	Long. 92° 52'	"	"	"	"	12.0		
7	1	1	16	Long. 92° 51'	"	"	"	"	12.0		
7	1	1	17	Long. 92° 50'	"	"	"	"	12.0		
7	1	1	18	Long. 92° 49'	"	"	"	"	12.0		
7	1	1	19	Long. 92° 48'	"	"	"	"	9.9		
7	1	1	20	Long. 92° 47'	Cameron	Hog Bayou 15	1954 photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	9.9		
7	1	1	21	Long. 92° 46'	"	"	"	"	12.0		
7	1	1	22	Long. 92° 45'	"	Constance Bayou 15	"	"	12.0		
7	1	1	23	Long. 92° 44'	"	"	"	"	12.0		
7	1	1	24	Long. 92° 43'	"	"	"	"	14.1		
7	1	1	25	Constance Bayou Long. 92° 42'	"	"	"	"	14.1		
7	1	1	26	Long. 92° 41'	"	"	"	"	14.1		
7	1	1	27	Long. 92° 40'	"	"	"	"	12.0		
7	1	1	28	Long. 92° 39'	"	"	"	"	12.0		
7	1	1	29	Long. 92° 38'	"	"	"	"	12.0		
7	1	1	30	Long. 92° 37'	Vermilion	"	"	"	12.0		
7	1	1	31	Long. 92° 36'	"	"	"	"	12.0		
7	1	1	32	Long. 92° 35'	"	"	"	"	12.0		
7	1	1	33	Long. 92° 34'	"	"	"	"	14.1		

Table 12 continued

Management Unit / Shoreline Type / Vegetation Type / Site No.	Site Area	Parish	Quadrangle & Size (minutes)	Data Sources & Dates		Retreat Rate m/yr or % Land Loss
7 1 1 34	Long 92° 33'	"	"	"	"	15.9
7 1 1 35	Near Rollover Bayou Long. 92° 32'	"	"	"	"	15.9
7 1 1 36	Long. 92° 31'	"	"	"	"	15.9
7 1 1 37	Long. 92° 30'	"	Pecan Island 15	"	"	12.0
7 1 1 38	Long. 92° 29'	"	"	"	"	14.1
7 1 1 39	Long. 92° 28'	Vermilion	Pecan Island 15	1954 photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	14.1
7 1 1 40	Long. 92° 27'	"	"	"	"	12.0
7 1 1 41	Long. 92° 26'	"	"	"	"	8.1
7 1 1 42	Long. 92° 25'	"	"	"	"	9.9
7 1 1 43	Long. 92° 24'	"	"	"	"	Adv.
7 1 1 44	Long. 92° 23'	"	"	"	"	Adv.
7 1 1 45	Long. 92° 22'	"	"	"	"	9.9
7 1 1 46	Long. 92° 21'	"	"	"	"	9.9
7 1 1 47	Long. 92° 20'	"	"	"	"	2.1
7 1 1 48	Near Freshwater Bayou Canal Long. 92° 19'	"	"	"	"	6.0
7 2 1 01	Lower Mud Lake	Cameron	Sweet Lake 15	1952 USN photos	1974 NASA MX294	Adv.
7 2 1 02	"	"	"	"		0
7 2 1 03	"	"	"	"		0.4
7 2 1 04	Miller Lane	"	Hog Bayou 15	"		Adv.
7 2 1 05	Flat Lake	Vermilion	Constance Bayou 15	"	1974 NASA MX293	0
7 2 3 01	Catfish Lake	Cameron	Grand Lake West 15	"	USGS orthophoto Quadrangle from 1974 photos	3.7
7 2 3 02	"	"	"	"	"	0.6
7 2 4 01	Willow Lake	Cameron	Sweet Lake 15	1952 USN photos	USGS orthophoto quadrangle from 1975 photos	0.4
7 2 4 02	"	"	"	"	"	1.9
7 2 4 03	Sweet Lake	"	"	"	"	0.4
7 2 4 04	"	"	"	"	"	1.1
7 2 4 05	"	"	"	"	"	0.5
7 2 4 06	"	"	"	"	"	2.0
7 2 4 07	"	"	"	"	"	0

Table 12 continued

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr.	or	% Land Loss
7	2	4	08	Lake Misere	"	Grand Lake West 15	"	USGS orthophoto quadrangle from 1974 photos	0.6		
7	2	4	09	"	"	"	"	"	1.2		
7	2	4	10	"	"	Grand Lake East Grand Lake West	"	"	0.8		
7	2	4	11	"	"	"	"	"	1.8		
7	2	4	12	NW Grand Lake	"	Grand Lake West 15	"	"	0.8		
7	2	4	13	Grand Lake Negro Island	"	"	"	"	1.1		
7	2	4	14	"	"	"	"	"	0 7		
7	2	4	15	N Grand Lake	"	Grand Lake East 15	"	"	0.8		
7	2	4	16	Grand Lake Rabbit Island	"	"	"	"	8.4		
7	2	4	17	Grand Lake Mallard Bay Is.	Cameron	Grand Lake East 15	1952 USN photos	USGS orthophoto quadrangle from 1974 photos	0.8		
7	2	4	18	Mallard Bay	"	"	"	"	3.6		
7	2	4	19	"	"	"	"	"	0.7		
7	2	4	20	"	"	"	"	"	3.9		
7	2	4	21	E Grand Lake	"	"	"	"	9.4		
7	2	4	22	Grand Lake Umbrella Pt.	"	"	"	"	36.5		
7	2	4	23	Grand Lake Umbrella Bay	"	"	"	"	4.8		
7	2	4	24	"	"	"	"	"	0.9		
7	2	4	25	Grand Lake Short Pt.	"	"	"	"	9.8		
7	2	4	26	SE Grand Lake	"	"	"	"	0.9		
7	2	4	27	"	"	Grand Lake E&W 15	"	"	4.4		
7	2	4	28	SW Grand Lake	"	Grand Lake West 15	"	"	3.3		
7	2	4	29	Grand Lake Hackberry Pt.	"	"	"	"	9.2		
7	2	4	30	Grand Lake Cypress Is.	"	"	"	"	0.8		
7	2	4	31	NW White Lake	Vermilion	Grand Lake East 15	"	"	3.5		
7	2	4	32	N White Lake	"	Forked Is. 15	"	"	0.8		

Table 12 continued

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr.	or	% Land Loss
7	2	4	33	E White Lake	Vermilion	Forked Is. & Pecan Is.15	1952 USN Photos	USGS ortho-photo quadrangle from 1974 photos	4.5		
7	2	4	34	SE White Lake	"	Pecan Is. & Constance Bayou 15	"	"	0.9		
7	2	4	35	"	"	Constance Bayou 15	"	"	1.9		
7	2	4	36	"	"	"	"	"	0.8		
7	2	4	37	White Lake-Bear Lake	"	"	"	"	3.8		
7	2	4	38	SW White Lake	"	"	"	"	0.6		
7	2	4	39	"	"	Constance Bayou Grand Lake East 15	"	"	1.2		
7	2	4	40	SW Lake Arthur	Jefferson Davis	Welsh 15	"	"	Adv.		
7	2	6	01	Lake Arthur	Vermilion	Jennings 15	"	"	0		
7	2	6	02	"	Jefferson Davis	"	"	"	0		
7	3	2	01	Hog Bayou	Cameron	Hog Bayou 15	"	"			0.08
7	3	2	02	Freshwater Bayou Canal	Vermilion	Pecan Island 15	"	"			0.54
7	3	4	01	Little Cheniere	Cameron	Sweet Lake 15	"	USGS ortho-photo Quadrangle from 1975 photos			0.68
7	3	4	02	Lake Misere	"	Grand Lake West 15	"	USGS ortho-photo from 1974 photos			0
7	3	4	03	Grand Lac l'Huit	"	Grand Lake East 15	"	"			0.09
7	3	4	04	N of White Lake	Vermilion	Grand Lake East & Forked Is. 15	"	"			0.04
7	3	5	01	Lake Arthur	Jefferson Davis	Jennings 15	"	"			0

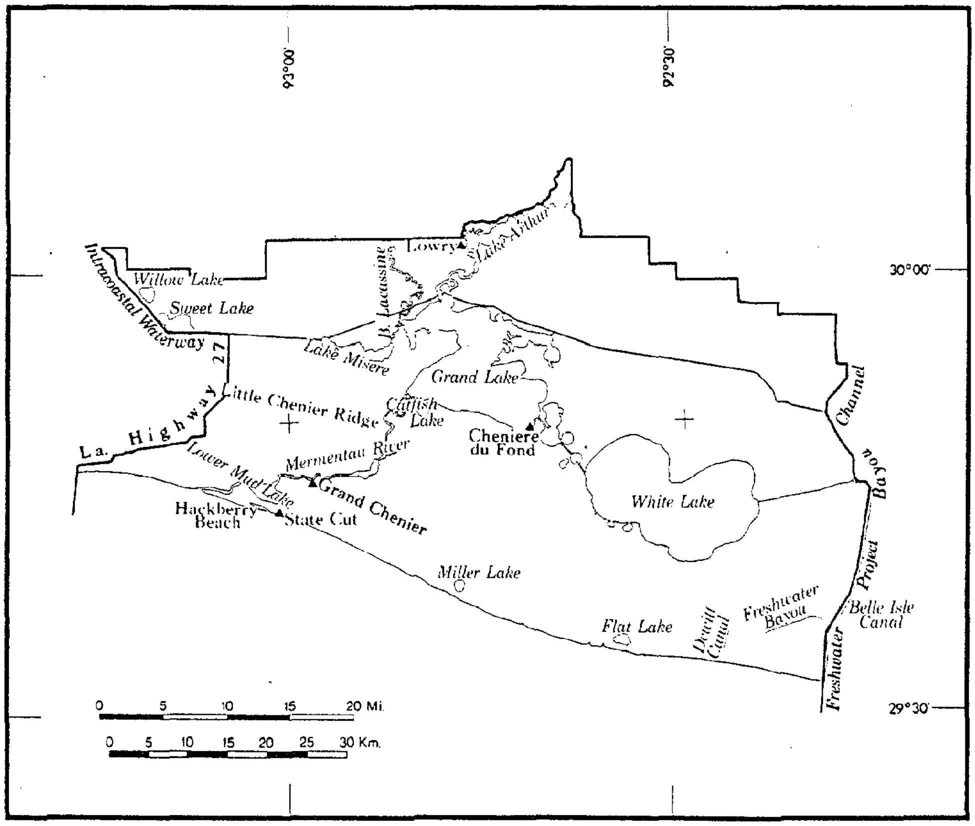


Figure 16. Place names in the Mermentau Management Unit.

Management Unit VIII--Calcasieu-Sabine

Coastline Erosion. Considered as a unit, the Calcasieu-Sabine Management Area's coastline has experienced slight net advance during the period from 1954 to 1969. A more refined examination of this segment of coastline reveals that the section from Sabine Pass to Calcasieu Pass has eroded at a rate of 3.3 m/yr, whereas the section east of Calcasieu Pass to the mouth of the Mermentau River has prograded 3.2 m/yr. Comparing these rates with those of Morgan and Larimore (1957) for the period from 1932 to 1954 shows that some significant changes have occurred. During the 1932 to 1954 period, the western section was relatively stable with some portions experiencing moderate accretion. Since 1954, the reverse has occurred, with moderate erosion dominating most of this section. Although predominantly rural, this section does contain the recreational communities of Holly, Peveto, and Ocean View Beaches, all of which are located at or close to the present beach line. The post-Hurricane Audrey (1957) reconstruction and growth of these communities took place largely within 100 meters of the shoreline. The past history of the area indicated that only the erosion that resulted from a direct hit by a tropical disturbance would be a significant problem. The present history indicates that there is cause for alarm even without the possibility of a tropical disturbance of the magnitude of "Audrey."

The section east of Calcasieu Pass has prograded at approximately the same rate as from 1932 to 1954. This section of coast is largely unsettled except for the small community of Rutherford Beach at the extreme eastern end of the section.

The dramatic change from accretion east of Calcasieu Pass to erosion west of the Pass is believed to be due to the jetties constructed at the mouth of the ship channel. The jetties trap sediment being carried by the dominant westerly littoral drift and build out areas to the east. At the same time, areas to the west are deprived of this sediment and consequently erode. The Sabine Pass Jetties, however, have not had the same effect. Areas immediately to the east are now undergoing erosion. Either these jetties are not effectively trapping sediment or there is little sediment to be trapped at this point along the coast. Morgan and Larimore (1957) point out that from 1932 to 1954, the Sabine Jetties were effective in trapping sediment; therefore, it would seem that the latter would be the case.

Although the Mermentau River and other smaller bayous that drain into the gulf undoubtedly contribute some sediment, the main source for the eastern prograding section of the Calcasieu-Sabine Basin is considered to be largely the result of the reworking and redepositing of sediments originating further east along the coastline. The beach along this section consists mainly of fine sands and shell hash, whereas the suspended load of the Mermentau River at its mouth contains mainly silts and clays (USCE 1961).

The history of sedimentation throughout the past several thousands of years and the future possibility of increased sedimentation from the Atchafalaya River along the Chenier Plain coast have been discussed in Chapter 1.

Well-Defined Lakeshores. Four lakes were examined in the Calcasieu-Sabine Management Unit, Black, Calcasieu, Mud, and Sabine Lakes (Fig. 18,19). All, except for a small segment of Calcasieu and Sabine Lakes that contain saline marshes, are dominated by brackish marshes along their shorelines. The only well-defined lakes in either fresh or intermediate marshes are those along the Calcasieu River. These, however, have undergone extensive cultural modification.

Both Calcasieu and Sabine Lakes are among the top twenty-five largest lakes in the United States. They are relatively shallow, as is typical in coastal Louisiana, averaging two meters (Barrett 1970). The considerable fetch of these lakes (approximately 40 km along the north-south axis has facilitated wave-induced erosion. The greatest amount of erosion occurs along the southern and southeastern shorelines. Although southerly components of wind occur with the greatest frequency in this area, northerly components are generally stronger and have a frequency percentage of sixteen from October through March (Murray 1976). These periodic northerly winds are thought to be the main cause of the higher erosion rates along the southern shorelines. Lakefront beaches composed of large amounts of shell and other debris average 0.7 m above marsh level along the southern shorelines and provide further evidence of wave attack.

Calcasieu Lake has experienced a slightly higher rate of erosion than Sabine Lake. Based on air photos taken six months prior to Hurricane Audrey (U.S. Dept. of Agriculture [USDA]) and one month after (U.S. Navy [USN]), the difference in the erosion rates of these two similar lakes can largely be attributed to this single event. The storm's center passed through the vicinity of Calcasieu Lake and did the most amount of damage in this area (Morgan et al. 1958). Over half of the total erosion of Calcasieu, Mud, and Sabine Lakes between 1952 and 1974 can be attributed to Hurricane Audrey.

Oyster reefs along the southeast section of Calcasieu Lake are effective in reducing wave action. Consequently, the shoreline leeward of these reefs has retreated at a rate of 0.38 m/yr. That portion of the southeast lakeshore that is not protected by these reefs has retreated at a rate of 1.1 m/yr. Oyster reefs have provided similar protection from wave erosion along the coastline of Marsh Island (see Vermilion Management Unit discussion).

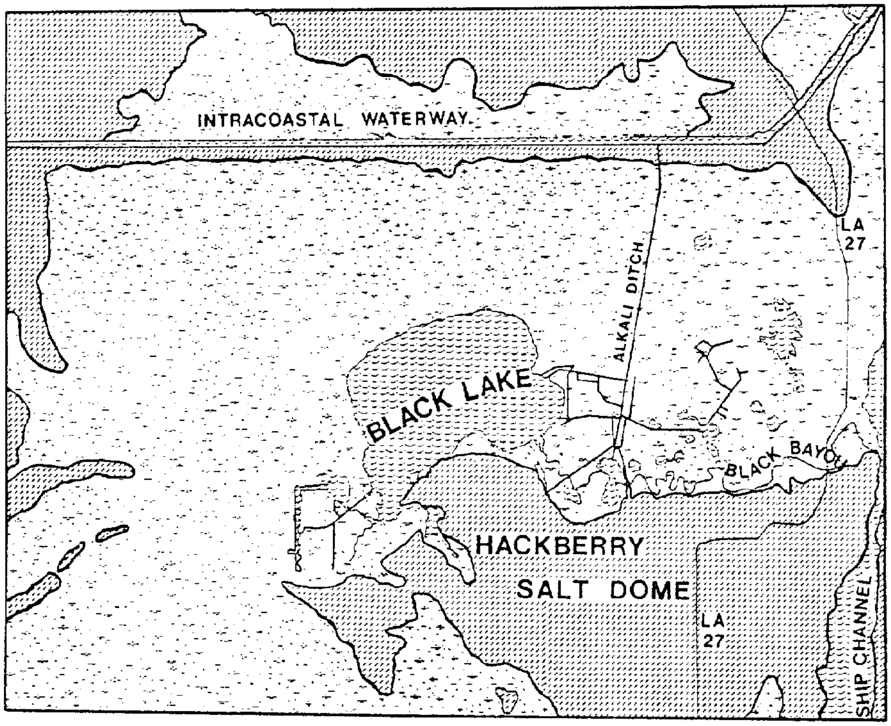
Mud Lake is an oxbow lake of a remnant Calcasieu River course. It's shoreline has remained fairly stable from 1952 to 1972, with only the smallest detectable erosion rate (0.25 m/yr) occurring along some portions of the shoreline. Of the erosion that has occurred, nearly all can be attributed to Hurricane Audrey. The presence of ridges (either levee remnants or transverse cheniers) located along much of the shoreline has probably helped as a stabilizing agent. This, combined with the lack of a long fetch and shallowness of the lake (0.4 m), has served to minimize erosion.

The Black Lake area northwest of the town of Hackberry is an unusual case of shoreline erosion. No absolute quantitative value of erosion can be assigned to much of the shoreline because of its disappearance. A tentative value of greater than 10 m/yr has been designated for the western, northern, and eastern shorelines. The southern shoreline has remained stable because of the presence of subaerial Pleistocene sediments that overlie the Hackberry salt dome. The tentative erosion value would place this lake in the highest designated category and, as such, would be the only example west of Terrebonne Parish. Black Lake has a fetch of approximately 3.5 km and an average depth of 1.2 m. Based on the size and erosion rates of other lakes in this and neighboring management units, it seems highly unlikely that such high erosion could be induced by wave action. The average depth of Recent material is less than 2 meters; therefore, the subsidence potential of the marsh sediments is relatively low. Consequently, the disappearance of the lake shoreline is felt to be related to additional factors. Some possibilities are outlined below.

Inner Marsh Land Loss. Marshes in the Black Lake area south of the Gulf Intracoastal Waterway, west of Alkali ditch, and east of Cameron Farms have experienced an 81 percent reduction from 1952 to 1974 (Fig. 17). This area may well have the highest intensity of marsh loss for any area of comparable size over a similar time period in coastal Louisiana and therefore warrants some discussion. These marshes, which were characterized as brackish by Chabreck (1972), were dominated by sawgrass (*Cladium jamaicense*) prior to Hurricane Audrey. Valentine (unpublished ms.) hypothesizes that these marshes were destroyed as a result of the combined effects of Hurricane Audrey in 1957 and subsequent drought periods extending through the mid 1960s. Whereas there is little doubt that these marshes were destroyed contemporaneously with these climatic events, that does not explain why other neighboring areas of sawgrass marsh in the Chenier Plain have been recolonized (largely by more salt tolerant species) and the Black Lake area has remained barren. Presently efforts are underway to return some of this area to marshland through the use of impoundments. Difficulties may arise because there has been extensive denudation since the loss of vegetation as is evidenced by the increased siltation in many neighboring canals where spoil banks are not continuous.

Although the exact cause(s) of this extensive loss cannot be documented, a list of activities and features on the landscape that have been documented as or are suspected of being associated with land loss in other areas may provide insight.

BLACK LAKE AND VICINITY-1952



BLACK LAKE AND VICINITY-1974

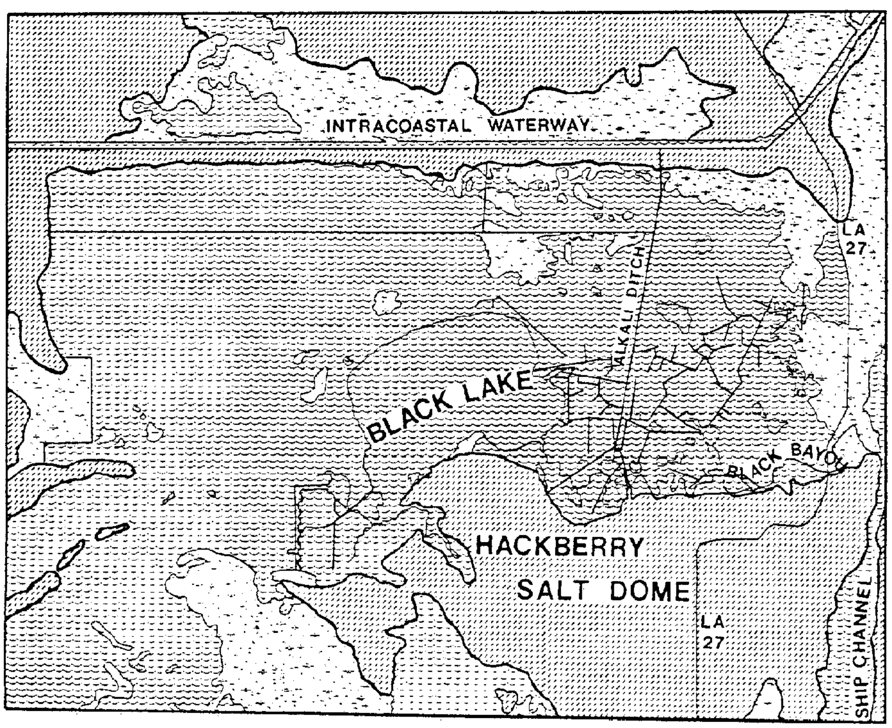


Figure 17. Land changes in the Black Lake Area 1952-1974.

The following occur in the vicinity of Black Lake:

1) Oil and gas extraction--numerous canals with associated spoil banks have been dredged throughout the extensive field surrounding the Hackberry salt dome. The extraction itself may have induced subsidence, as was the case in the Goose Creek Oil field in Texas (Weaver and Sheets 1962). Bench marks in the vicinity of Black Lake have subsided an average of 0.6 m since the early 1950s (La.Dept. of Public Works, unpublished data).

2) The dredging of the Calcasieu Ship Channel has led to increased salinities (Gosselink, in press). The Black Lake area is connected to the ship channel via Black Bayou.

3) Spoil banks associated with the Gulf Intracoastal Waterway, Alkali Ditch, Calcasieu Ship Channel, and Stark's North Canal combined with natural topographic highs of the Hackberry salt dome and the subaerial Pleistocene in the vicinity of Cameron Farms have left Black Bayou as the only drainage into and out of the Black Lake marshes. Consequently, natural drainage may be severely modified, reducing its ability to drain off saline waters associated with hurricane surges.

The Calcasieu-Sabine Basin as a whole has experienced the highest land loss rates in comparison with other areas in the Chenier Plain and has experienced rates comparable to management units in the Deltaic Plain. However, the highest losses appear to be associated with fresh and intermediate marshes. Brackish marshes, except for the Black Lake area, have experienced rates of land loss lower than the Deltaic Plain but similar to brackish marshes in other areas of the Chenier Plain.

Salt marsh does not comprise a significant amount of area in this unit; therefore, no conclusions can be drawn. The southernmost point of swamp forest on the Sabine River has experienced some minor losses. Marshes in the vicinity of the Black Bayou, which drains into Sabine Lake, have been highly variable in their loss rates. Those south of Black Bayou that have had little cultural modification have experienced below average losses; those located in the Black Bayou oil field extending north past the Gulf Intracoastal Waterway between the Vinton Drainage Canal and Big and Sassafras Islands as well as those west of these islands to the Sabine River have undergone above average or excessive losses. These areas have a high degree of ongoing cultural activities such as oil and gas extraction and agricultural drainage canals.

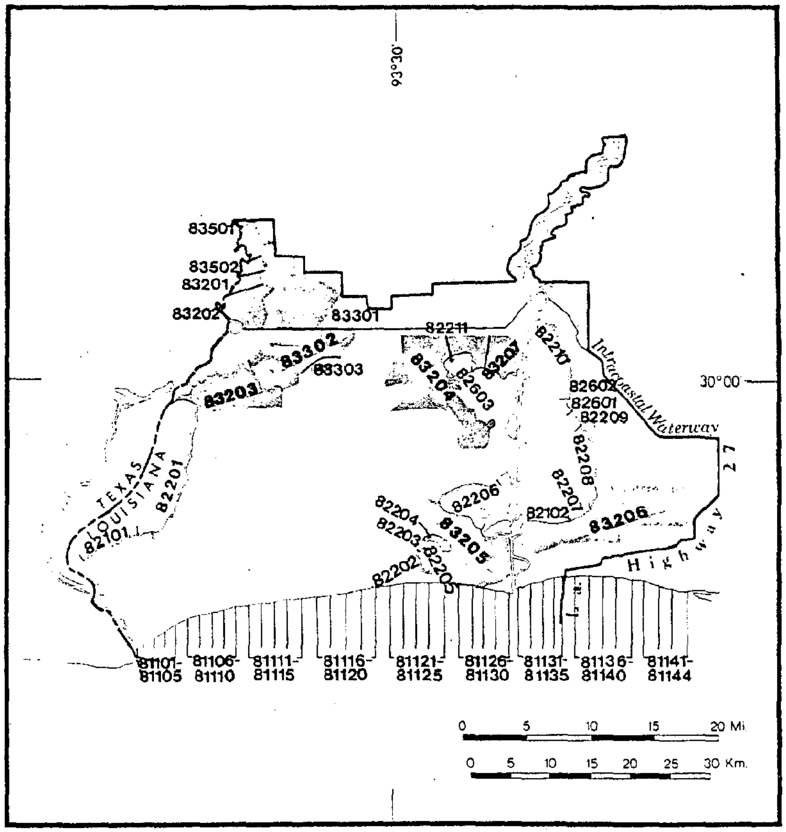


Figure 18. Site locations in the Calcasieu-Sabine Management Unit.

Table 13

Erosion Rates for Sites Analyzed in the Calcasieu-Sabine Management Unit

Management Unit / Shoreline Type / Vegetation Type / Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr	or	% Land Loss
8 1 1 01	Sabine Pass Long. 93° 50'	Cameron	Sabine Pass 15	1954 photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	14.1		
8 1 1 02	Long. 93° 49'	"	"	"	"	9.9		
8 1 1 03	Long. 93° 48'	"	"	"	"	9.9		
8 1 1 04	Long. 93° 47'	"	"	"	"	8.1		
8 1 1 05	Long. 93° 46'	"	"	"	"	0		
8 1 1 06	Long. 93° 45'	"	"	"	"	2.1		
8 1 1 07	Long. 93° 44'	"	Johnson's Bayou 15	"	"	0		
8 1 1 08	Long. 93° 43'	"	"	"	"	0		
8 1 1 09	Long. 93° 42'	"	"	"	"	0		
8 1 1 10	Long. 93° 41'	"	"	"	"	0		
8 1 1 11	Long. 93° 40'	"	"	"	"	0		
8 1 1 12	Long. 93° 39'	"	"	"	"	0		
8 1 1 13	Long. 93° 38'	"	"	"	"	3.9		
8 1 1 14	Ocean View Beach Long. 93° 37'	"	"	"	"	0		
8 1 1 15	Ocean View Beach Long. 93° 36'	"	"	"	"	0		
8 1 1 16	Ocean View Beach Long. 93° 35'	"	"	"	"	0		
8 1 1 17	Ocean View Beach Long. 93° 34'	Cameron	Johnson's Bayou 15	1954 photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	2.1		
8 1 1 18	Peveto Beach Long. 93° 33'	"	"	"	"	0		
8 1 1 19	Peveto Beach Long. 93° 32'	"	"	"	"	3.9		
8 1 1 20	Long. 93° 31'	"	"	"	"	3.9		
8 1 1 21	Long. 93° 30'	"	"	"	"	2 1		
8 1 1 22	Long. 93° 29'	"	Cameron 15	"	"	3.9		
8 1 1 23	Long. 93° 28'	"	"	"	"	6.0		
8 1 1 24	Holly Beach Long. 93° 27'	"	"	"	"	3.9		
8 1 1 25	Holly Beach Long. 93° 26'	"	"	"	"	2.1		
8 1 1 26	Long. 93° 25'	"	"	"	"	2.1		
8 1 1 27	Long. 93° 24'	"	"	"	"	2.1		
8 1 1 28	Long. 93° 23'	"	"	"	"	3.9		
8 1 1 29	Long. 93° 22'	"	"	"	"	3.9		
8 1 1 30	Calcasieu Pass Long. 93° 21'	"	"	"	"	3.9		

Table 13 continued

Management Unit / Shoreline Type / Vegetation Type / Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr	or % Land Loss
8 1 1 31	Calcasieu Pass Long. 93° 20'	"	"	"	"	Adv.	
8 1 1 32	Long. 93° 19'	"	"	"	"	Adv.	
8 1 1 33	Long. 93° 18'	"	"	"	"	Adv.	
8 1 1 34	Long. 93° 17'	Cameron	Cameron 15	1954 air photos Jack Ammann Corp.	1969 USCE uncontrolled photomosaics	Adv.	
8 1 1 35	Long. 93° 16'	"	"	"	"	Adv.	
8 1 1 36	Long. 93° 15'	"	"	"	"	Adv.	
8 1 1 37	Long. 93° 14'	"	Sweet Lake 15	"	"	2.1	
8 1 1 38	Long. 93° 13'	"	"	"	"	2.1	
8 1 1 39	Long. 93° 12'	"	"	"	"	0	
8 1 1 40	Long. 93° 11'	"	"	"	"	0	
8 1 1 41	Long. 93° 10'	"	"	"	"	0	
8 1 1 42	Long. 93° 09'	"	"	"	"	Adv.	
8 1 1 43	Long. 93° 08'	"	"	"	"	Adv.	
8 1 1 44	Long. 93° 07'	"	"	"	"	2.1	
8 2 1 01	SE Sabine Lake	"	Port Arthur 15	USGS Quadrangle from 1956 photos	1972 NASA MX194	0.3	
8 2 1 02	S Calcasieu Lake	"	Cameron 15	1952 USN photos	1974 NASA MX293	0.3	
8 2 2 01	E Sabine Lake	"	Port Arthur 15	USGS Quadrangle from 1956 photos	1972 NASA MX194	0	
8 2 2 02	SW Mud Lake	"	Cameron 15	1952 USN photos	1974 NASA MX293	0	
8 2 2 03	NW Mud Lake	"	"	"	"	0.3	
8 2 2 04	N Mud Lake	"	"	"	"	0	
8 2 2 05	E Mud Lake	"	"	"	"	0.3	
8 2 2 06	Calcasieu Lake West Cove	"	"	"	"	0	
8 2 2 07	Calcasieu Lake East Cove	Cameron	Cameron & Sweet Lake 15	1952 USN Photos	1974 NASA MX293	1.1	
8 2 2 08	"	"	Sweet Lake 15	"	"	0.3	
8 2 2 09	"	"	Cameron 15	"	"	0	
8 2 2 10	NE Calcasieu Lake	Cameron & Calcasieu	Cameron & Sulphur 15	"	"	0.3	
8 2 2 11	Black Lake	Cameron	Sulphur 15	"	"	>10 ?	
8 2 6 01	Comissary Point Calcasieu Lake	"	Cameron 15	"	"	0.3	
8 2 6 02	Jubert Point Calcasieu Lake	"	"	"	"	0	
8 2 6 03	Black Lake	Cameron	Sulphur 15	"	"	0	
8 3 2 01	Lost Lake	Calcasieu	Orange, Texas 15	1952 USN photos	1972 NASA MX194		1.10
8 3 2 02	Phoenix Lake	"	"	"	"		0.85
8 3 2 03	True Ridge	Cameron	Johnson's Bayou & Port Arthur, TX 15	"	"		0.08

Table 13 continued

Management Unit	Shoreline Type	Vegetation Type	Site No.	Site Area	Parish	Quadrangle & Size(minutes)	Data Sources & Dates		Retreat Rate m/yr or	% Land Loss
8	3	2	04	Black Lake	"	Cameron & Sulphur 15	"	1974 NASA MX293		3.71
8	3	2	05	West Cove	"	Cameron 15	"	USGS orthophoto quads from 1974 photos		0.22
8	3	2	06	East Cove	"	Cameron & Sweet Lake 15	"	"		1.19
8	3	2	07	Alkali Ditch	"	Sulphur 15	"	1974 NASA MX293		0.44
8	3	3	01	Webb Gully	Calcasieu	Orange, Texas 15	1952 USN photos	1974 NASA MX293		0.62
8	3	3	02	Black Bayou Oil Field	Cameron & Calcasieu	Orange, Texas & Johnson's Bayou 15	"	"		1.41
8	3	3	03	Deer Island	Cameron	Orange, Texas 15	"	"		0.44
8	3	5	01	Turner Island	Calcasieu	"	USGS quadrangle from 1959 photos	1972 NASA MX194		0.05
8	3	5	02	Turner Island	"	"	"	"		0.18

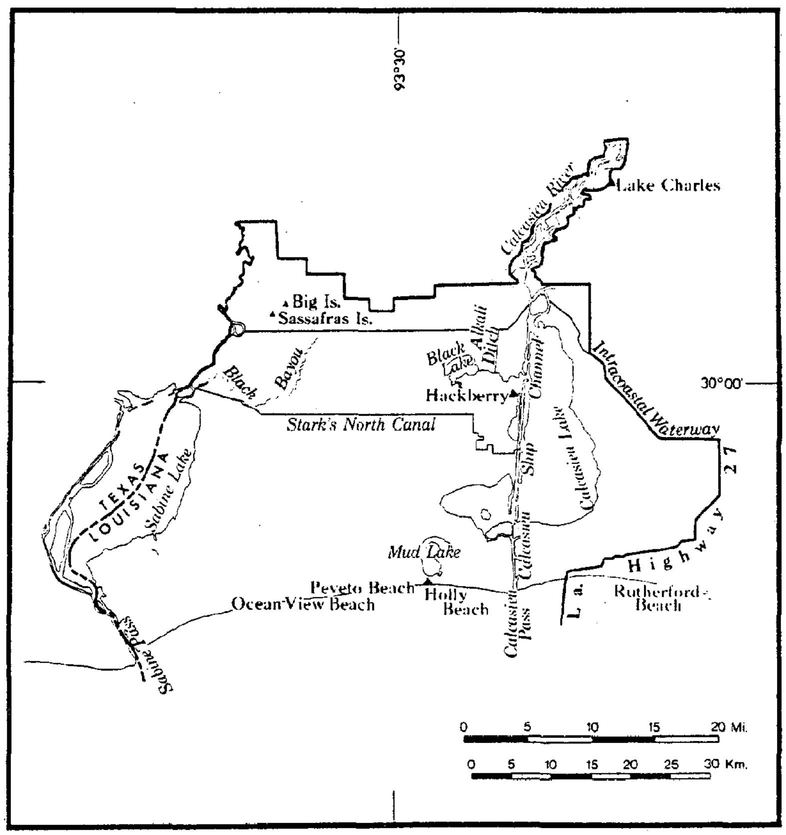


Figure 19. Place names in the Calcasieu-Sabine Management Unit.

Chapter 4

Current Erosion Mitigation Practices and Recommendations

Introduction

The preceding chapters have concentrated on where and why erosion is occurring in coastal Louisiana. The coastline is experiencing more erosion than accretion, and this trend should continue throughout much of the coastal area for some time. The question, therefore, is what can be done to mitigate erosion. This chapter addresses this question as it pertains to the Louisiana situation and includes:

1) A review of structural and non-structural measures currently in practice in Louisiana and elsewhere and their effectiveness;
2) A discussion of a rationale for designating areas for erosion control consideration and identification of such areas;
3) General recommentations for continuation of or change in management policies and techniques that may directly or indirectly affect the rate of erosion.

Engineering Structures and their Applicability in Louisiana

The principal forces causing shore erosion are the wind-induced energy of waves and currents resulting from storms. Beach material both above and below the still water level is loosened by the waves and moved away by the currents. A crude estimate of wave force is that for every one increment of wave height, storm forces have the potential to scour the beach two increments in depth. Under equilibrium conditions, the material transported away is replaced by material from updrift areas. Natural beaches exist in dynamic equilibrium--responding to external forces and gradually adjusting back to equilibrium. If, however, material is not available to replace what is transported away, the equilibrium is upset and erosion occurs.

A number of methods, from the dumping of automobiles and heavy trash objects along a bluff face to costly offshore breakwaters, have been devised to retard or stop erosion. Several of the more widely used structural solutions to erosion will be discussed in terms of their applicability along the Louisiana coast and lake shorelines.

Artificial Nourishment. Although it may be argued that artificial nourishment is not strictly a structural technique, it does involve heavy machinery in the form of trucks or dredges and can have immediate significant impact both onshore and offshore. Artificial nourishment has been used extensively where sand is available at a reasonable price. Erosion protection is provided by raising the beach level sufficiently to induce waves to break and thereby dissipate their energy before they reach the shore. This technique has the advantage of preserving the beach in a near-natural state, but nourishment is not always the best solution. Strong littoral currents can remove the sand fill so quickly as to make this technique uneconomical. Costs (1975) range from \$1.15 to \$1.50/m^3 of dredged material to \$3.80/m^3 if the material must be trucked in.

Artificial nourishment has been used in Louisiana, particularly at Grand Isle, where more than $1.53 \times 10^6 m^3$ of material have been placed since 1952. Much of this has been lost via littoral transport. Generally, coastal Louisiana is a sand-deficient environment. Consequently, costs of nourishment material are high. In the case of Grand Isle, nourishment could be economically justified; however, few, if any, other areas in the state could justify the cost.

Groins With or Without Nourishment. Groins are barriers built perpendicular to the shoreline, permeable or impermeable, normally at some regular spacing. They have the ability to trap sand on their updrift side if there is sufficient littoral drift, with a resultant erosion of material on the downdrift side. Artificial nourishment may be necessary in areas of insufficient littoral sediment supply and also to counteract the effect on the downdrift shoreline. Of the possible structural devices, groin systems cause the fewest problems for recreational use of the beach. However, without a comprehensive plan, single groins or groin systems may not only prove ineffective, but they could aggravate the erosion problem. Average costs of a groin field range from $330 to $1150 per meter of shore protected (1973 dollars) depending on the type of material used, spacing, and length of the groins.

Because of the finite amount of sediment being carried by littoral drift, groins become increasingly less effective as new ones are added. In the case of a natural section of shoreline that is owned by several individuals, the decision of one landowner to construct a groin would adversely affect the downdrift landowners and might or might not benefit the updrift landowner.

Groins constructed on Grand Isle have been of only limited value in stabilizing the beach and have required periodic nourishment. Moreover, Grand Isle is an area where there is not a deficiency of littoral material. In sand deficient areas, groins would not be effective. The Corps of Engineers (USCE) determined that a groin field 9.7 km long, spaced at 76m intervals, each extending 183 m gulfward, and costing $13 million would be required to provide adequate stability to the Grand Isle shoreline. This alternative was not cost effective.

Jetties. Jetties have essentially the same effect as groins in trapping sediments on the updrift side. They are usually considerably longer than groins and are often used to protect harbor or channel entrances. If sufficient material is trapped, the littoral drift can begin to move around the jetty and shoal areas develop. For navigational purposes, it may become necessary to dredge this material away.

The Louisiana coast has numerous jetties--all of which exhibit some accretion on the updrift side--that are used primarily to protect channel entrances. Grand Isle now has a jetty on each end that aids in stabilizing the island. A proposed extension of the east-end jetty was dismissed because it would not significantly reduce erosion of the central portion of the island; it could have severe, detrimental effects on Grand Terre, and it would only be effective at the east end where there is no appreciable problem.

The jetties at the mouth of the Calcasieu Ship Channel have effectively trapped sediment, and there is measurable accretion occurring for a distance of some twenty kilometers along the updrift coastline. West of the jetties on the downdrift side, however, erosion has been accelerating.

Revetments. Revetments are protective coverings of a beach, bluff, or other feature that follow the natural (stable) slope of the feature and usually extend below the stillwater level. Various materials have been used, such as rubble, concrete, stone, asphalt, or sand bags. The prerequisite is that the material be strong enough to withstand the wave energy in the area it is used. The revetment must also be constructed high enough to prevent essentially all overtopping by waves, and the toe must be protected from undercutting. Erosion has been observed to increase at the toe during storms as a result of energy of the water as it runs up and down.

Much of the Louisiana coastline consists of flat expanses of marsh land where revetments would be ineffective. Revetments have been used successfully along Lake Pontchartrain, at Holly Beach, and in protecting the Coast Guard Station on Grand Isle, but their cost of $250 to $500/m reduces the corresponding cost effectiveness and restricts usage.

The revetment at Holly Beach is highly cost effective when one considers the alternative, which would be to require the relocation of the coastal highway that links Louisiana and Texas and provides an important hurricane evacuation route. Louisiana State Highway 82 is built on a narrow sand ridge that separates the Gulf of Mexico from extensive coastal marshes and the impounded marshes of the Sabine National Wildlife Refuge. The portion requiring protection is a 5 km stretch just west of Holly Beach. The revetment was built in 1970 and has survived several severe storms. It was constructed of cellular cobbletop concrete blocks over plastic filter cloth.

The highway was breached or seriously damaged in 1957, 1961, 1963, and 1969. Since the roadbed was only 15 meters from the gulf shoreline, even winter storms with waves of 1 meter overtop the road. This revetment was not designed to weather direct hurricane attack, but was intended to reduce continuous maintenance problems that result from normal winter storms. However, the revetment has weathered waves generated by Hurricanes Edith and Fern in 1971 and suffered only limited damage from Hurricane Delia in 1973.

Seawalls and Bulkheads. These are vertical structures paralleling the shoreline that extend from above the high water line to a depth below the scour line. A definite disadvantage is that waves striking these walls tend to scour the bottom at the toe of the wall. This deepening permits larger waves to enter, which increases the probability of overtopping and failure.

Some seawalls and bulkheads have been constructed in Louisiana, particularly along Lake Pontchartrain, but their high cost, $660/m and up, makes them only rarely cost-effective, such as in heavily industrialized areas.

Breakwaters. Both offshore and shore-connected breakwaters are used primarily in conjunction with harbors or marinas to provide a shelter from wave action. Offshore breakwaters are more commonly used and are placed far enough from shore so that littoral currents can move along the shore behind them. The sand carried between them and the shore tends to be deposited because of less turbulence in the protected area unless they are very far offshore or very short in length. Breakwaters are also the most expensive of structures.

A proposed breakwater offshore of Grand Isle was dismissed as not being economically justifiable. To be effective in preventing erosion or innundation of the island, the breakwater would have to be at least 4 meters above MSL. In addition, any breakwater would function as a complete littoral barrier (by interrupting littoral sediment transport) with potential adverse effects on the Grand Terre Islands.

Riprap. Although this term is often used interchangeably with "revetment," "riprap" implies that there is no order to the placement of the materials making up the structure. Riprap are composed of irregularly shaped stones or boulders and are usually the most economical of structures but their effectiveness is only short term and as a rule they are not aesthetically pleasing. They are commonly found in South Louisiana along the outside bend of river meanders and are used to protect campsites and other lightly developed shorelines.

Levees. Artificial levees are sometimes used as protection against erosion where the segment of shoreline to be protected is of considerable length. Their effectiveness is variable, and subsequent unintentional impacts such as the deterioration of marshes behind the levees are sometimes far worse than the erosion itself. In most instances, levees are practical only where Recent sediments are relatively shallow (e.g., Southwest Louisiana). Except where the impounding of marshes is desired, gates or culverts or similar structures should be constructed where natural drainage intersects the levee to allow for water exchange and nursery access.

Assessment of the Louisiana Coastline: Where is Protection Justified?

The term "critical erosion" is commonly used to indicate an area that warrants immediate consideration for erosion mitigation procedures. It is a qualitative term that indicates that significant erosion is occurring along sections of the coast where the present land use is desirable but cannot be maintained with the present rate of erosion. The USCE in its regional Shoreline Inventory of Louisiana (1971) uses "critical erosion" as a synonymous term with one of the directives of section 106(a) of Public Law 90-483 approved 13 August 1968, which is as follows:

> ...(2),identifying those areas where erosion presents a serious problem because the rate of erosion, considered in conjunction with economic, industrial, recreational, agricultural, navigational, demographic, ecological, and other relevant factors, indicates that action to halt such erosion may be justified....

The USCE's analysis of Louisiana shorelines (1971) resulted in the identification of two general areas of critical erosion: (1) Grand Isle and the western end of Grand Terre and (2) portions of Lake Pontchartrain, mostly along the southern shore where structures were not already present. Benefit-cost analyses were made for other areas but the resulting low ratios led to the recommendation that federal projects should not be adopted for these other areas.

The USCE's 1971 assessment of Louisiana shorelines is used here as a guideline, with the recognition that Louisiana's interests do not necessarily always coincide with the USCE's recommendations. The state may ultimately decide that additional (or fewer) areas warrant protection, but any additional areas might have to be protected at the state's cost.

For the purpose of this report, a reevaluation of the USCE's (1971) assessment is now necessary because:

1) Additional eroding shorelines have been included in this study that were not analyzed by the USCE;
2) Several years have elapsed since the USCE assessment during which time further economic development of shorelines has occurred and rates of erosion have changed.

The determination of areas to be considered for erosion mitigation procedures for this study was largely based on the types of land uses affected. Areas studied include: those where there has been significant loss or destruction of public lands, including recreational areas, historic sites, conservation areas, and areas where there has been significant economic loss to private landowners. This method of determination of areas to be considered is generally consistent with the various methods developed by other coastal states that have been accepted by or proposed to the federal government. A review of several such plans for other states is included in the Appendix. In order to classify an area as having "critical" erosion, the key is to define what constitutes the term "significant." A detailed benefit-cost analysis must be performed. If the ratio of benefits to cost is greater than one, then erosion is critical, and erosion protection measures can be justified. Usually several analyses need to be performed for each area because an analysis is necessary for each proposed alternative procedure.

Detailed benefit-cost analyses are not within the scope of this effort. However, based on the results of the benefit-cost analyses already performed by the USCE, we can suggest other areas that warrant analysis. This study, therefore, does not define areas of critical erosion; rather, it suggests areas that may qualify as critical and consequently justify a benefit-cost analysis.

In additon to identifying possible areas of critical erosion, the following geographical review includes suggested procedures for managing erosion where appropriate. Because the USCE (1971) is a primary reference for portions of the ensuing discussion, the geographic sequence of discussion presented by the USCE (1971) has been followed to facilitate comparison of information and viewpoints.

The first area, defined by the USCE (1971) as Zone I, extends from the Sabine River to the Southwest Pass of Vermilion Bay and includes the Calcasieu-Sabine, Mermentau, and part of the Vermilion Management Units.

Forty-eight kilometers of the gulf shoreline are developed into summer homes, commercial establishments for the tourist trade, and public accessible beaches. An additonal 72 km of undeveloped shoreline are included in two wildlife management areas. The coastline fronting

Rockefeller Wildlife Refuge is undergoing extensive erosion. The lack of natural coarse-grain sediment renders large-scale structural solutions ineffective. Although mitigation is desirable, there is no apparent cost effective solution.

The largest concentration of recreational development is at Holly Beach, with 398 camps or summer homes (Gary and Davis, unpublished ms.). The other established tourists beaches at Ocean View, Constance, and Peveto are much less developed structurally. East of the Mermentau River, the shoreline is completely undeveloped and for the most part has not been utilized for recreational purposes.

Erosion and accretion patterns are mixed over this area. From Sabine Pass to Calcasieu Pass the shoreline is retreating at a relatively slow rate. This retreat is in sharp contrast with the USCE (1971) findings that reported this area as accreting. From Calcasieu Pass to the natural mouth of the Mermentau River, accretion is occurring, but no development exists except for a handful of camps at Rutherford Beach. There is a high rate of erosion from the Mermentau River to Chenier Au Tigre. Along some sections, over 150 m of erosion has occurred between 1954 and 1969. A longer time-span analysis indicates that in some places along this sector, over 1200 m of erosion has occurred in the last 150 years (USCE 1971). This sector of coastline is undeveloped but a large portion of it is in public ownership.

Erosion is occurring along the Southwest Louisiana coast because of a sediment deficiency. The jetties at Calcasieu Pass have been effective in trapping sediment. The source of this sediment is thought to be largely the reworking of eroded sediments to the east. The construction of additional jetties and/or groins is not recommended because they would only compete for the small amount of sediment available.

The small, largely recreational communities primarily located west of Calcasieu Pass favor structural measures. Holly Beach is the largest of these settlements; therefore, if structures are justified at any of the areas, it would be there.

Holly Beach lost its two most gulfward streets paralleling the beach, and 30 houses were in the foreshore zone by the early 1970s. In 1971, the USCE conducted a study of the feasibility of possible measures to protect the remaining shoreline. Based on the design criteria of a 1.5 m high stone covered dune and a 4.2 km long revetment to protect the main highway, respective benefit-cost ratios of 0.3 and 0.5 were calculated, and the projects were not undertaken. However, because of its proximity to larger cities and the desire for recreation on the part of the people who live in these cities, the Holly Beach area has a history of being rebuilt after catastrophes such as hurricanes. Because there is insufficient littoral material (estimated at 45,800 to 76,400 m^3/yr in 1971) to maintain a stable beach in this area, the most sound management approach would consist of setback laws to protect new development and provisions to prohibit the repair of severely damaged existing structures on the beach. As an interim partial solution, we recommend an examination of the feasibility of placing spoil (resulting from maintenance dredging of the mouth of the Calcasieu Ship Channel) into the nearshore gulf on the west side of the jetties.

We further recommend that the revetment west of Holly Beach along highway 82 be maintained because it is an important hurricane evacuation route, the revetment has been moderately successful, and alternative routes for highway 82 would result in higher construction costs because of the more unstable nature of sediments located inland of the highway's present position.

The future for the gulf coastline of Southwest Louisiana may be better than the present and recent past. The continued development of the Atchafalaya Delta may ultimately result in increasing the sediment supply to southwest Louisiana.

The effects of the continued input of Atchafalaya River sediments should first be noticed along the eastern sections of coastal Southwest Louisiana. A periodic monitoring scheme should be developed to note any significant input of sediments along this section of coast.

The inland lakes and bays of Zone 1 (USCE 1971) are eroding at variable rates. Calcasieu and Sabine Lakes, because of their low erosion rates and lack of development, do not appear justified for erosion control. Residents of small settlements on the northeast side of Calcasieu Lake have taken it upon themselves to place riprap along the shoreline. This appears to be a viable solution in this area of relatively stable sediments.

Lake Charles, situated on the Calcasieu River floodplain and bordered by the city that bears its name, has been the focus of a diversified approach towards erosion mitigation. Beach nourishment along the north shore has resulted in the formation of a new public beach. Filling and placement of revetments along the east shore has resulted in additional public access to the lakeshore. In addition to greater public access, the area has increased its aesthetic appeal and has done so without the closing off of any additional nursery areas. Although erosion is not currently a problem, continued maintenance of the lakeshore in the form of periodic beach nourishment and revetment repair will probably be required.

The marshes east and south of Calcasieu Lake are eroding at a rather high rate. Much of this area is in public ownership as part of the Sabine National Wildlife Refuge. The proposal to construct a levee along the shoreline cannot be recommended at this point for the following reasons:

1) The area is an important shrimp nursery and the levees, if continuous, would prevent access to larval and juvenile shrimp.

2) The presence of deep relict Pleistocene channels indicates a larger subsidence potential that may increase levee maintenance costs.

3) At this point it is only speculation that levees would halt the erosion of these marshes. The exact cause of the erosion have never been accurately determined.

If the erosion of marshes is determined to be related to salt-water intrusion, we recommend that alternative structures (e.g., weirs and gates) be examined. If the levee were to function also as a hurricane evacuation route and present roads are insufficient, we recommend the examination of the feasibility of enlarging the present highway system (La. 82 and 27) and/or the construction of a causeway.

Grand and White Lakes are eroding rather rapidly. Despite the somewhat alarming rate of erosion, it is not critical because the shorelines are essentially undeveloped. Erosion may be reduced by keeping the flood gates of the control structures open from the fall through winter seasons, thereby causing water levels to drop. This may be in conflict with water requirement needs of the area, and the year-to-year fluctuations in climate would necessitate a flexible schedule of the opening and closing of the structures.

Zone II extends from Southwest Pass at Marsh Island to Point au Fer and includes the Vermilion and Atchafalaya Managment Units. Of the 386 km of combined gulf and bay shorelines, only 3 km are developed--1 km of public beach (Cypremort Beach) and 2 km of summer and weekend camps. Wildlife management areas account for approximately 35.4 km of the undeveloped land, not including the newly designated Atchafalaya Delta Wildlife Management Area.

Erosion rates for the Vermilion area appear to be decreasing when results of this study are compared with those reported by the USCE (1971). This undoubtedly is the result of sediments from the Atchafalaya River.

Because of the extremely limited development in the area, the natural protection afforded by Marsh Island, the extensive shell reefs, and the relatively large sediment input from the Atchafalaya River and consequent formation of a new delta, it is recommended that land use management be the primary technique employed in the mitigation of shoreline erosion.

Zone III (USCE 1971) is a small segment that essentially is comprised of Point au Fer Island. Although erosion is occurring along Four League Bay, the gulf shoreline of Point au Fer Island, and in the inner marsh areas, the land is privately owned and is undeveloped. No procedures are recommended for this area.

Zone IV (USCE 1971) extends from Racoon Point on Isles Dernieres to Sandy Point along the present Mississippi River Delta. It includes most of the Terrebonne and all of the Barataria Management Units.

One of the characteristic features along much of the coastline in Zone IV is the presence of barrier islands. These features provide natural protection from erosion for landward areas. These features are ephemeral and are associated with the decay and reworking of deltaic sediments. Their continued existence is dependent upon sediment supply. The barrier islands of coastal Louisiana have a natural tendency to erode and to be displaced landward, particularly after major storms. Because of the dynamic and fragile nature of barrier islands and the natural protection they provide, development should not occur on them, and practices to enhance their maintenance should be encouraged, e.g., limited nourishment. These inlands should be left to migrate according to the wave and current regimes and all structural measures should be prohibited. Fortunately much of the land encompassing barrier islands is in public ownership. Thus, the dynamic behavior of these islands does not adversely affect any present development with the exception of one major area: Grand Isle and vicinity.

The USCE (1971) labeled Grand Isle and the western part of Grand Terre Island proper (Fort Livingston) as areas of critical erosion. The history of use of structures and beach nourishment, the long-standing use of Grand Isle as a recreational community, and the intensive development of this area provide an excellent case study of man's attempt to maintain stability against a dynamic natural environment.

With 1353 camps, 308 hotel rooms, 5 marinas, and 7 charter boat services, Grand Isle represents Louisiana's major seaside recreational area (Gary and Davis, unpublished ms). An estimated 450,000 visitations per year are made to the state park and the private beach, with two-thirds of these visitations taking place between June and September. The beach on Grand Isle varies from 7.6 to 122 m in width, is approximately 12.2 km long, and has a maximum elevation of 1.8 m. Almost 8.7 km of the beach is private with public access, and the remainder is located within a state park. There are 6.6 km of development associated with the oil and fishing industries.

In addition to the extensive development, there are three major potential changes that would affect Grand Isle within the next ten years. Construction of the Louisiana Superport would undoubtedly benefit the town in terms of new jobs and revenue generated from the predicted $169 million annual income of the port. A long-delayed expansion of the two-lane highway from Lafitte to Larose would shorten the driving time between New Orleans and Grand Isle from 2.75 to 1.75 hours, thereby making visits and short vacations to Grand Isle more attractive. The third change, which is actually a result of the growth and potential of Grand Isle, is a combination hurricane protection and beach erosion project designed by the USCE and authorized by Congress in 1976. This project consists of a 792 m long jetty at the western end of the island (that was constructed by Louisiana in 1972) and a 54.9 m wide vegetated dune with a crown elevation of 3.5 m above mean sea level. The selected design criteria was a 50-year storm, and the project has a benefit to cost ratio of 1.7. First costs will be $10.6 million, with a federal share of $6.4 million. However, the money has not yet been appropriated. The project also calls for periodic maintenance to be undertaken by Louisiana.

Clearly, Grand Isle appears to have a favorable future for the coming decades. The recreation-oriented economic activities are anticipated to grow rapidly with no significant physical expansion of petroleum-related facilities. It has been estimated that the permanent population of the town will increase from 2236 in 1970 to 3900 in 1980, and 6100 by 1990, and the summer visitor days will increase to over 11 million in 1985 (Gary and Davis, unpublished ms.). Because of present development and the commitment to possible future development of the area and that Grand Isle represents the only major access to the Gulf shore in southeast Louisiana, it appears desirable to continue measures to stabilize Grand Isle.

The real question is not one of desirability but of practicality. The island has experienced severe damage to structures and loss of land because of hurricane surges and shore erosion, which have threatened its existence as a major recreational area. Table 14 lists past efforts to stabilize the island and evaluates their effectiveness.

Table 14

Case History of Shoreline Erosion and Mitigation Efforts on Grand Isle

Year	Problem and Mitigation Effort	Cost	Effectiveness
1853-1935	Western end receded 457 meters; accretion at east end.	-	-
1935-1955	1829 m of west end advanced 305 m gulfward; center of island receded 30 to 90 m; eastern end retreated 152 m. No major action by any group other than individual property owners prior to 1951. Vertical bulkheads.	-	Ineffective; isolated structures accelerated erosion directly gulfward and were undermined.
1951-1952	La. Hwy 1 threatened; Dept. of Hwys constructed 4 to 152 m timber groins in one location and 10 to 76 m timber groins in another.	$480,000	Ineffective; constructed based on east-to-west littoral transport when actually the reverse is the predominant case; no maintenance since initial construction.
1954-1955	State Dept. of Public Works placed 8.8 x $10^5 m^3$ of sand as artificial nourishment to groin systems.	188,000	3.06 x 10^5 m^3 of sand were lost from system in less than 1 year; beach east of each groin system gained width and volume and stabilized.
1956	Timber groin constructed 152 m gulfward by Humble Oil Co. and artificially nourished with dredge material from offshore.		More effective than Dept. of Hwys groins; trapped material on both sides benefitting shorelines; no maintenance; effectiveness destroyed by construction of east-end jetty.
1957	Hurricane Flossy in 1956 resulted in severe erosion and scour; much of nourishment carried away; Dept. of Public works placed 1.07 x 10^5 m^3 sand along 7.2 km of beach.	76,000	Satisfactory; initially 2.68 x 10^5 m^3 of sand were estimated as necessary but natural swell action aided in rebuilding the beach.
1958-1959	Dept. of Public Works built a 285 m jetty 305 m west of eastern end to stabilize island.	150,000	Within 4 years after construction, 7.65 x $10^5 m^3$ of sediment trapped west of jetty; 1.21 x $10^5 m^2$ of island lost east of jetty.

Table 14 continued

Year	Problem and Mitigation Effort	Cost	Effectiveness
1961-1962	Damage from Hurricane Carla in 1961 and previous storms; Dept. of Public Works placed 2.68 x $10^5 m^3$ of sand within 10 groins near center of island; westward groin field experienced loss while adjacent shore on both sides was stable.	$115,000	Satisfactory: Westward groin system unaffected.
1964	To increase beach area and reduce shoaling east of east-end jetty, Dept. of Public Works extended this jetty by 427 m.	200,000	Accretion due to the jetty extended 2743 m westward totalling 9.56 x 10^5 m^3. Within 1 year, sufficient amount of sand trapped by jetty that littoral drift began flanking jetty again.
1965-1966	Extensive damage to dune line and jetty from Hurricane Betsy; large shoal east of jetty scoured inland; DPW, under Corps of Engineers specifications, borrowed 4.21 x $10^5 m^3$ of sand from accretion west of jetty to rebuild natural dunes.	447,000	Reconstructed dune remained relatively stable except near west end where 1829 m of island receded up to 137 m from 1969-1971. Vegetation established along remainder of dune aiding in stabilization.
1966	Repair of jetty after Hurricane Betsy; determined that jetty would not function properly unless tied into shore and repaired where failure occurred.	25,000 83,500	Satisfactory.
1967	Erosion of shoal east of jetty led to rapid erosion east and north of landward end of jetty; threatened Coast Guard Loran Station; constructed 305 m long revetment of nylon material and concrete.	27,000	By end of 1968, 274 m had failed as a result of overtopping, uplift pressure, and leaching of the foundation.
1970	Continued erosion near Coast Guard Station; 30,760 m^2 land lost since 1965; Corps of Engineers designed rubble mound revetment, tying into east-end jetty 467 m along pre-erosion shoreline.	176,000	Satisfactory; designed for 1.5 m waves accompanying 10 year storm; no maintenance required.
1972	Rapid erosion of west end -- loss of 60,000 m^2 in 4 months of 1970; DPW, under Corps of Engineers specs, constructed 792.5 m jetty at west end to divert tidal currents away from shoreline east of Caminada Pass and trap littoral material moving east to west during periods of wave approach from the east-southeast. Also placed fill between jetty and west end of island.	1,065,000	Satisfactory; jetty does not interrupt west-to-east littoral drift.
1975-1976	Hurricane Carmen (September, 1974) Completely destroyed existing low level dune along the entire shoreline; emergency sand dune and beach replenishment project (9 km of shoreline) for Federal Disaster Administration in conjunction with U.S. Army Corps of Engineers.		Satisfactory.

In spite of the various efforts to halt erosion of the gulf shore on Grand Isle, a general recession of the beach continues along the central and western portions of the island. The west end of the island was finally stabilized in 1972 with the construction of a jetty. Grand Isle is a very attractive recreation area, and much development ($42 million in 1970) already exists. Consequently, a plan was needed to mitigate the effects of shoreline erosion. Several alternative plans were designed by the USCE. The plan that was most favored (or rather, least objectionable to all parties concerned) and eventually authorized by Congress in 1976 will be discussed below.

The recommended improvements were designed to provide protection from beach erosion and the hurricane-driven waves that occur once every fifty years; this design hurricane is associated with 160 km/h winds. Included in the plan are a stone jetty at the western end of the island, a sandfill dune, and gulfside berm improvement. The dune, which would extend along 12.1 km of shoreline, would have a 3.05 m wide crown, an elevation of 3.5 m mean sea level, and would be protected from wind erosion by vegetation. The beach would be widened to at least 55 m, and slope from the toe of the dune at 2.6 m to 0.9 m mean sea level (MSL), where it would assume its natural slope to the bottom. The jetty has already been constructed using emergency state appropriations. Sandfill for the construction of the recommended dune and berm, estimated at 1.91 x $10^6 m^3$, would be dredged from borrow pits 610 m offshore of each end of the island.

The first costs associated with this project are $10.6 million, of which $6.4 million is the federal share. In addition, periodic nourishment of the dune and berm at five-year intervals will be necessary and that responsibility will be borne primarily by Louisiana. Although the $88,000 cost may appear high, since 1952, expenditures by local interests to preserve the island have approximated two-thirds of the estimated annual maintenance costs. Additional annual benefits include: prevention of erosion damage to existing and future development over the life of the project, estimated at $289,000; prevention of hurricane wave damages to existing and future development, estimated at $378,000; $317,000 in recreational development as a result of improvements; and $198,000 worth of intensified land use (increased property value). The benefit to cost ratio is 1.7.

The funds for this improvement plan have yet to be appropriated, but this plan does appear to be cost effective, and implentation should begin as soon as possible.

Erosion occurring along the inner lakes and bays in the Terrebonne and Barataria Managmenet Units is occurring at rather high rates. There is little man can do to halt these processes other than increasing the supply of sediment over these marshes. Most of the shorelines are privately owned and undeveloped. No specific recommendations can be made other than general land use management guidelines, which are included later in this chapter.

Zone V (USCE 1971) is synonymous with the Mississippi Delta Management Unit. The gulf shoreline exhibits essentially no development activity. Oil and shipping industries account for 2.4 km of development along the bay shoreline in South and Southwest Passes. South Pass is also the site of 0.3 km of public docking facilities. Wildlife management areas comprise much of the eastern, undeveloped delta. Because of the complex changes associated with this highly dynamic area, land use management should be the only technique employed in erosion mitigation.

Zones VI and VII (USCE 1971) is presented in this report as the Pontchartrain-Breton Sound Management Unit. The coastline consists of low relief, discontinous barrier islands. This entire coastline is undeveloped and is part of the Breton Island National Wildlife Refuge. The barrier islands have been designated as wilderness area, thereby insuring no development. The area is inaccessible to most of the public.

In addition to the landward movement of these islands, their overall area has been reduced by 259 km^2 from 1812 to 1954 (USCE 1971). Although these islands are a valuable resource both as a biological habitat and as a storm buffer against wave energy, their highly dynamic nature precludes any economical cost-effective stabilization plan; thus, the area should be left to natural processes.

Although Lake Borgne is presently eroding and the rate of erosion appears to be accelerating, the shoreline is privately owned and undeveloped. Therefore, no action is recommended.

Approximately forty percent of the Lake Pontchartrain shoreline is presently developed. Erosion rates are variable, but there is an apparent increasing trend. The present intensive development and the likelihood of future development necessitates a more detailed examination than is presented here.

The USCE (1971) has designated several areas of Lake Pontchartrain as areas of critical erosion. These are: Illinois Central Railroad traversing the St. John the Baptist Parish shoreline, St. Charles Parish levee, Orleans Parish levee, Fort Pike, Fountainbleau State Park beach, and Mandeville. Recommended methods for mitigating effects of erosion for these areas are structural with the exception at Fountainbleau State Park where beach nourishment was proposed.

The trend along Lake Pontchartrain is evident. Since nearly all of the lake is eroding, the only item needed in order to warrant protection measures under the formula for defining critical erosion is development. Recent developments such as the north shore area south of Slidell included the construction of a spoil levee, although this levee protects only the newer devlopment and has left the previously built campsites unprotected. Generally the type of structures used are levees or seawalls. These have the effect of cutting off any inner marsh areas as nursery grounds and interrupting the natural water exchange.

Further development of New Orleans East will require shoreline protection along the lake shoreline as far east as South Point. Future development should be encouraged only north of Lake Pontchartrain on nearby Pleistocene sediments. Stricter zoning and development policies should be developed to insure that the state will not have to pay for future protection against erosion of areas presently undeveloped. A regional plan for the entire lake should be developed that precludes using public funds for subsidizing private development in wetland areas.

General Management Concepts and Guidelines. Shoreline erosion along Louisiana's coast and estuaries is a complex process that has pervaded for at least several thousand years. However, within the past century or so, erosion has dominated over land building processes.

The problem of erosion in Louisiana is by no means unique. Erosion is occurring along sections of virtually every coastal state. However, Louisiana is in a better position than most states to do something about it. First, much of coastal Louisiana is rural. Settlements requiring coastal access have largely developed on more stable Pleistocene sediments or along natural levees. Most of these preferred areas are being utilized. Therefore continued growth of South Louisiana will place increasing pressure to develop more hazard-prone areas. Secondly, the processes that have extended Louisiana's coastline seaward for thousands of years are still active.

To take advantage of these processes, a regional approach to mitigating erosion is necessary. The deposition of Mississippi River sediment into deep offshore waters can be diverted to more inland areas, thus helping to curb erosion. Such a plan has been proposed by

Gagliano and van Beek (1970). Although the legal entanglements of such a plan are numerous, the technology of implementing such a plan is available. To the west, the formation and growth of the Atchafalaya Delta has reversed the trend from erosion to accretion in Atchafalaya Bay and vicinity. The continued seaward and latitudinal growth of the delta may solve the problem of coastline erosion of Southwest Louisiana. A plan to provide for proper spoil placement needs to be adopted that would insure maximum growth. Channelization for navigation is necessary; however, a monitoring scheme needs to be developed to insure that sediments will be carried to Southwest Louisiana via littoral transport rather than being discharged through man-made channels into deep offshore waters. It is impossible to predict when Southwest Louisiana will be the recipient of sufficient amounts of sediment to retard erosion. In the interim, developments such as Holly Beach will continue to be plagued by erosion. Setback regulations and other building codes need to be developed for that section of coast.

Other than Mississippi and Atchafalaya River sediments, there is no material available for extensive marsh and beach nourishment. Therefore, most erosion control measures will be limited to small holding actions where erosion is extreme and where economic or social values make these measures cost effective.

The following general recommendations can help to lessen the potential for escalation of erosion:

1) Prohibit dredging immediately landward of barrier islands. The removal of shell or creation of channels creates a depression in which low lying barrier island sands can become buried.

2) Avoid structural methods that would deprive downdrift shorelines of laterally moving sediment except in the case of Grand Isle and historic sites.

3) No large expenditures of public funds are recommended along the Chenier Plain coastline because these projects will be left stranded inland as the result of extensive mudflat deposits that are anticipated concurrent with Atchafalaya River development.

4) Structural controls along lakeshores in the Chenier Plain are effective where subsidence potential is minimal. However, the design of such structures should not lead to impoundment of adjacent marsh areas or interruption of natural drainage patterns. Erosion along shorelines with high subsidence potential (e.g., Deltaic Plain) can be mitigated only by means of limiting development.

5) Inner marsh erosion can be mitigated by limiting dredging practices that lead to extensive canal networks that disrupt normal drainage patterns, increase saltwater intrusion, and increase freshwater runoff. Placement of continuous dredge spoil across the marsh surface interrupts sheet flow and sediment dispersal.

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Appendix

Shoreline Erosion/Mitigation Planning
Synopses of State Coastal Zone Management Programs

The requirements regarding state shoreline erosion/mitigation planning, article 923.26 of interim-final 305/306 regulations subsection 305(b)(9), March 1, 1978, are as follows.

> In order to meet the requirements of subsection 305(b)(9) of the Act and to coordinate these requirements with those of subsections 305(b)(3) and 306(c)(9), States must include a planning process that can assess the effects of shoreline erosion. Evaluation must include assessment of ways to mitigate, control or restore areas adversely affected by erosion. This process must include:
>
> (1) A method for assessing the effects of shoreline erosion;
> (2) Procedures for managing erosion effects, including non-structural procedures;
> (3) Articulation of State policies pertaining to erosion, including policies regarding preferences for non-structural, structural and/or no controls;
> (4) A method for designating areas for erosion control, mitigation and/or restoration as areas of particular concern or areas for preservation and restoration, if appropriate;
> (5) A mechanism for continuing refinement and implementation of necessary management policies and techniques, if appropriate; and
> (6) An identification of funding programs and other techniques that can be used to meet management needs.

These requirements insure that the impacts of erosion will be considered in the overall management plan of the state. The purpose of assessing the causes and effects of shoreline erosion is to explicitly determine state policy for handling erosion control, mitigation, and/or restoration be it structural, non-structural, or non-control. All state plans submitted after 1 October 1978 or plans approved after that date must include provisions for fulfilling the above regulations. Several of the state plans that have already received approval as well as several other submitted plans will be reviewed in the following section with respect to article 923.26--Shoreline Erosion/Mitigation Planning.

The Massachusetts Coastal Zone Management Plan is by far the most comprehensive shoreline erosion/mitigation planning to date. This plan emphasizes non-structural solutions to erosion problems, citing both long-term effectiveness and federal program emphasis (e.g., National Flood Insurance Program) as determining factors. The report points out that non-structural solutions more closely simulate natural processes, are aesthetically more compatible with natural landforms, and are less likely to cause adverse effects on adjacent areas. They are also considerably less expensive. Structural measures are to be reviewed on a case-by-case basis and only selectively permitted, such as in areas where natural buffers have been irrevocably lost, if adjacent or downdrift effects are minimized.

The method employed by Massachusetts in assessing the effects of shoreline erosion consisted of classifying these effects as "critical" or "moderate," based on how the land was used. The areas chosen for classification consisted of: recreational beach, other public lands or facilities, private property, and conservation lands. Based on the above criteria, affected coastal areas were then classified as areas of particular concern or areas for preservation and restoration.

Non-structural protective and restorative measures such as beach nourishment, dune stabilization, zoning, and acquisition of hazard-prone areas by state or local government are to be given preference over structural solutions. However, regardless of the type of solution used, the plan explicitly defines the conditions under which federal and/or state monies may be used to finance the solution measures. The conditions include: a greater than local significance and substantial public benefit from the area in question; adequate regulations to prevent the deterioration of the area once stabilized or restored; established design criteria for the solution to be employed; and identification and acceptance of the responsibilities associated with future maintenance. Structural measures should be restricted to cases where, in addition to the above criteria, non-structural solutions have been evaluated as ineffective, too costly, or otherwise infeasible and where the implementation of said structural measure will not seriously impair natural processes or adversely affect adjacent or down coast areas. A number of state, local, and federal departments have been assigned to regulate, permit, and carry out the reviewed solution measures.

The California management plan tends toward the opposite approach of that taken by Massachusetts in that structural solutions are not viewed with such disdain. Its major policy is that structural (e.g., breakwaters, groins, revetments) solutions that alter natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger of erosion and when designed to eliminate or mitigate adverse impacts on local sand supply. In addition, stability and structural integrity must be assured from any activity in the coastal zone, and these activities are not to create or to contribute significantly to the erosion or destruction of the site or surrounding area or in any way require the construction of protective structures that would adversely affect natural landforms.

The state's basic approach to shoreline erosion/mitigation planning is to prevent development in areas prone to erosion rather than to construct protective works. However, where protective structures are permitted, based on the above policies, their Department of Navigation and Ocean Development is authorized to plan, design, and administer funds for the construction of the projects. This department, along with several federal agencies, is responsible for the assessment, based primarily on aerial photography and subsequent beach profiles, of eroding and erosion-prone areas along the California coast.

The Wisconsin plan only briefly discusses the problem of shore erosion because at the time of its preparation, article 923.26 was not mandatory. Wisconsin's general policy is to regulate, via the appropriate state agencies, any development in the coastal zone so that the rate of bluff recession and other types of eroding shorelines would not be accelerated. A setback of 23 meters (75 feet) from the high water mark is required in unincorporated areas unless an existing development pattern exists. Structural protection from erosion is permitted so long as it does not interfere with navigation or damage fish and game habitat. The plan is mandated to support local and state efforts in identifying and designating hazard areas as areas of special management concern and to assist in the development of specific management policies as well as to provide financial and technical support to implement these policies. Information regarding recession rates, littoral drift, slope failure, and alternate erosion control measures is presently lacking, and the plan hopes to remedy this deficiency by supporting research and public education on these problems.

The Rhode Island shore erosion mitigation plan is to be completed during the first year of program implementation. The plan recognizes the natural protection offered by barrier beaches and dunes and assigns a high priority to the preservation and protection of the "shoreline system" (e.g., beaches, cliffs and bluffs, wetlands, dunes). Permits are required for any activity on the shoreline system. The use of non-structural methods to solve erosion problems is encouraged, particularly in areas of non-critical erosion. Areas of critical erosion (as defined by the Corps of Engineers) may justify the use of structural measures. The plan requires that all permit applications for erosion control projects demonstrate that non-structural methods have been fully evaluated as possible solutions to the problem. Where non-structural methods are deemed unsuitable, it must be demonstrated that the proposed structural solution will have a reasonable probability of controlling erosion at the site and will not cause adverse impacts in or around adjacent areas.

The North Carolina program has not yet established a firm policy on shoreline erosion mitigation planning. It is state policy to control the location and design of structure and to prevent damage to natural protective features such as beaches, dunes, and inlet lands. The need for an inventory and analysis of erosion-prone areas as well as for an analysis of current shore erosion management practices is recognized and is assigned a high priority in the state's policy development process. The policies so developed will also recommend a state participation formula that considers social, physical, and economic thresholds that could give priority to requested erosion control projects.

The State of Oregon prefers land-use management practices and non-structural solutions for erosion mitigation. However, where shown to be necessary, structures are to be designed so as to minimize adverse impacts on currents, erosion, and accretion patterns. Regarding the land-use management program, permitted uses are to be based on the capabilities and limitations of, for example, beach and dune areas to sustain different levels of use or development. Additional considerations include the need to protect areas of critical enviromental concern, scenic, scientific, or biological importance, and significant wildlife habitat. Oregon requires: (1) a site investigation report financed by the developer (2) the posting of performance bonds to assure adverse effects can be corrected and (3) reestablishing vegetation within a specific time. In addition, if littoral drift is interrupted, methods of sand bypass are to be investigated and provided where possible. Protective structures are permitted when: (1) visual impacts are minimized (2) necessary beach access is maintained (3) negative impacts on adjacent property are minimized and (4) long-term costs (e.g., maintenance) to the public are avoided.

In Hawaii, land-use management is used extensively to preclude development in erosion-prone areas. Where this is not appropriate, non-structural techniques rather than structural techniques are used whenever possible to mitigate shoreline erosion. Non-structural techniques, such as the replenishment of beaches, have been used successfully. Structural techniques are most often employed where development of the shoreline has occurred or where valuable public beaches are threatened by erosion.