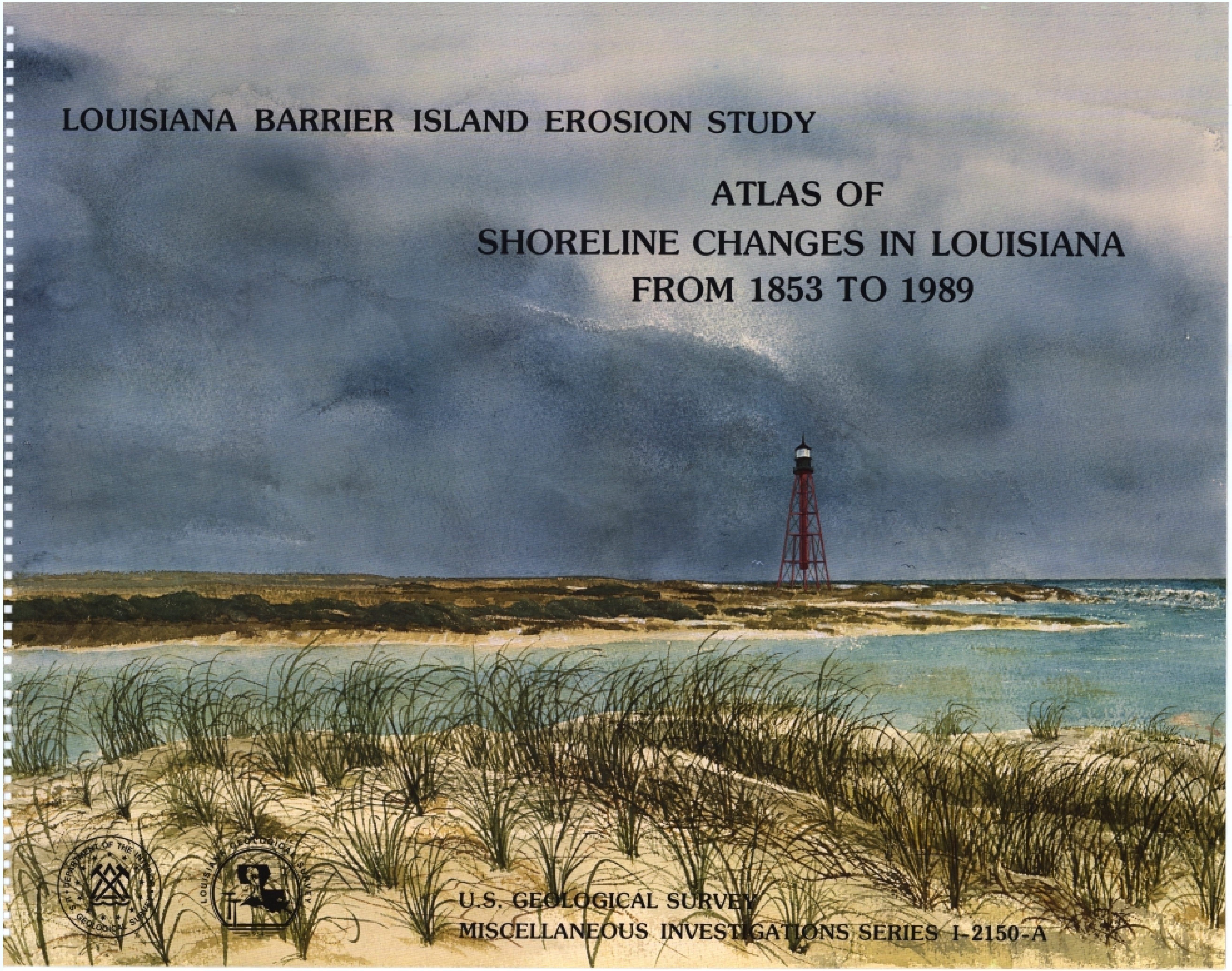
LOUISIANA BARRIER ISLAND EROSION STUDY

ATLAS OF
SHORELINE CHANGES IN LOUISIANA
FROM 1853 TO 1989



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LOUISIANA BARRIER ISLAND EROSION STUDY

ATLAS OF SHORELINE CHANGES IN LOUISIANA FROM 1853 to 1989

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C. G. Groat, Director & State Geologist

The Louisiana Barrier Island Erosion Study, a cooperative investigation between the U.S. Geological Survey (USGS) and the Louisiana Geological Survey (LGS), focused on the processes and geological conditions responsible for the widespread erosion of Louisiana's delta-plain ***coast.*** Many people within the two organizations participated in the preparation of this atlas, which is one of several products of the study.

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Foreword

It is with pleasure that we present this Atlas of Shoreline Changes. This atlas is one of many products of the Louisiana Barrier Island Erosion Study, conducted jointly by the U.S. Geological Survey and the Louisiana Geological Survey over the past five years. It demonstrates the positive results that are possible when Federal and State agencies work together to solve problems that concern many segments of the population.

The erosion of our Nation’s coasts and the degradation and loss of valuable wetlands affect all of us. Coastal businesses and homeowners endure the immediate consequences. But when one individual suffers, many suffer indirectly through higher prices, insurance premiums, and taxes. Diminished coasts and wetlands also affect those who value them as wildlife habitat, as abundant food resources, and as recreational areas.

Cooperative efforts, such as the Louisiana Barrier Island Erosion Study, allow the pooling of knowledge and resources. As a result, planners and decision makers, who must determine courses of remedial action, receive critical information expeditiously. This atlas is a small but important contribution to the information transfer process. We trust that it will provide not only evidence of the dramatic effects of coastal erosion and wetland loss in Louisiana but also understanding to those who must deal with mitigation approaches that will benefit society as a whole.

C. G. Groat
Director and State Geologist
Louisiana Geological Survey

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Director
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An Introduction to Coastal Erosion And Wetlands Loss Research

S. *Jeffress Williams* and *Asbury H.* Sallenger, **Jr.**

COASTAL EROSION AND WETLANDS LOSS

Louisiana leads the Nation in coastal erosion and wetlands loss. In places. erosion of the barrier islands, which lie offshore of the estuaries and wetlands and separate and protect them from the open marine environment, exceeds 20 m/yr (Penland and Boyd, 1981: McBride and others, 1989). Within the past 100 years. Louisiana's barrier islands have decreased on average in area by more than 40 percent, and some islands have lost 75 percent of their area (Penland and Boyd, 1981). A few of the islands are expected to disappear within the next three decades; their absence will contribute to further loss and deterioration of wetlands and back-barrier estuaries (McBride and others, 1989).

Louisiana contains 25 percent of the vegetated wetlands and 40 percent of the tidal wetlands in the 48 conterminous states. These coastal wetland environments, which include associated bays and estuaries, support a harvest of renewable natural resources with an estimated annual value of over $1 billion (Turner and Cahoon, 1987). Louisiana also has the highest rate of wetlands loss: 80 percent of the Nation's total loss of wetlands has occurred in this state. Several scientists have estimated the rate of wetlands loss in the Mississippi River delta plain to be more than 100 km^2/yr (Gagliano and others, 1981). Since 1956, over 2,500 km^2 of freshwater wetlands in Louisiana have been eroded or converted to other habitats. If these rates continue. an estimated 4,000 km^2 of wetlands will be lost in the next 50 years.

The physical processes that cause barrier island erosion and wetlands loss are complex, varied, and poorly understood. There is much debate in technical and academic communities about which of the many contributing processes, both natural and human-induced, are the most significant. There is further controversy over some of the proposed measures to alleviate coastal land loss. Much of the discussion focuses on the reliability of predicted results of a given management, restoration, or erosion mitigation technique. With a better understanding of the processes that cause barrier island erosion and wetland loss, such predictions will become more accurate. and a clearer consensus of how to reduce and mitigate land loss is likely to appear.

The U.S. Geological Survey (USGS) is undertaking two studies of coastal erosion and wetlands loss in Louisiana. The first, the Louisiana Barrier Island Erosion Study, is a cooperative effort with the Louisiana Geological Survey. Begun in fiscal year 1986, the study. as described in Sallenger and Williams (1989), will be completed in fiscal year 1990. During fiscal year 1988, Congress directed the USGS, jointly with the U.S. Fish and Wildlife Service, to develop a study plan extending the ongoing barrier island research to include coastal wetlands processes.

This plan resulted in the Louisiana Wetlands Loss Study, which was begun in the latter part of fiscal year 1988. The wetlands study is scheduled for completion in 1993. This introduction discusses the role of USGS research in understanding the processes of shoreline erosion and wetlands loss, followed by an overview of the study and an atlas summary

ROLE OF USGS RESEARCH IN COASTAL EROSION AND WETLANDS LOSS MITIGATION

The two current USGS Louisiana studies focus on developing a better understanding of the processes that cause coastal erosion and wetlands loss. particularly the rapid deterioration of Louisiana's barrier islands, estuaries, and associated wetlands environments. With a better understanding of these processes, the ability to predict erosion and wetlands loss should improve. More accurate predictions will, in turn, allow for proper management of coastal resources. such as setting new construction a safe distance from an eroding shoreline. Improved predictions will also allow for better assessments of the utility of different mitigation schemes. For instance, increased understanding of the processes that force sediment and freshwater dispersal over wetlands will make possible more accurate assessments of the practicality and usefulness of large-scale freshwater sediment diversions from the Mississippi River. Understanding the processes responsible for barrier island erosion will also aid in evaluating the relative merits of beach nourishment techniques and using hard coastal engineering structures.

While the USGS conducts relevant research on coastal erosion and land loss. other Federal and State agencies design and construct projects and otherwise implement measures for management of the coastal zone and for mitigation of coastal erosion or wetlands loss. The State of Louisiana, through Article 6 of the Second Extraordinary Session of the 1989 Louisiana Legislature, created the Wetlands Conservation and Restoration Authority within the Office of the Governor, the Office of Coastal Restoration and Management within the Department of Natural Resources, and the statutorily dedicated Wetlands Conservation and Restoration Fund. In March 1990, the Louisiana Wetlands Conservation and Restoration Authority submitted the Coastal Wetlands Conservation and Restoration Plan to the State House and Senate Natural Resource Committees for their approval. This plan proposed both short- and long-term projects to conserve. restore, enhance. and create vegetated wetlands. Also, the U.S. Army Corps of Engineers has completed the first phase of the Louisiana Coastal Comprehensive Wetlands Plan to mitigate land loss in Louisiana. In the second phase, the Corps of Engineers is working with appropriate Federal and State agencies, including the USGS, to assess the cost and utility of engineering projects to mitigate land loss.

Most scientists agree that some proposed projects and policies already are supported by an information base sufficient to justify their being undertaken now, without further research. However. for many potential projects, such as the use of hard engineering structures on beaches and large freshwater and sediment diversions, existing information is not sufficient, and decision making and planning will benefit from additional field investigations. Mitigation and control of coastal erosion and wetlands loss thus can be approached through a two-pronged effort. The appropriate Federal and State agencies could implement projects about which sufficient information already exists. At the same time. relevant research should continue on critical processes; this will allow incremental improvement in both erosion and land loss mitigation techniques and in evaluating the success of the implemented projects. The State of Louisiana, through the Wetlands Conservation and Restoration Authority, has provided its recommendations for both action and further research to the Louisiana Legislature in accord with this approach.

OVERVIEW OF THE STUDY

The Louisiana Barrier Island Erosion Study covers the barrier islands in the delta-plain region of coastal Louisiana. The study focuses on three overlapping elements: geologic framework and development of the barrier islands, processes of barrier island erosion, and transfer and application of results. The first step in identifying erosion processes was to establish the shallow geologic framework within which the barriers formed, eroded, and migrated landward. This analysis, which relies on both stratigraphy and geomorphology, is the basis for a regional model of erosion that incorporates many processes. The study focuses on the important processes that are not well understood but that are approachable experimentally: sea-level rise, storm overwash, onshore-offshore movement of sand, and longshore sediment transport. The methods include direct measurement of waves and currents during storms, computer modeling, and a compilation of historical patterns of erosion and accretion. The results of the study are directly applicable to various practical problems. For example, a better understanding of the rates at which sand is removed from beaches is crucial to determining how often an artificially nourished beach will need to be replenished. Investigations of the geologic framework within which the barriers formed lead to the identification and assessment of offshore sand resources that can be used for beach nourishment, as well as a greater capacity to accurately forecast future shoreline positions and coastal conditions.

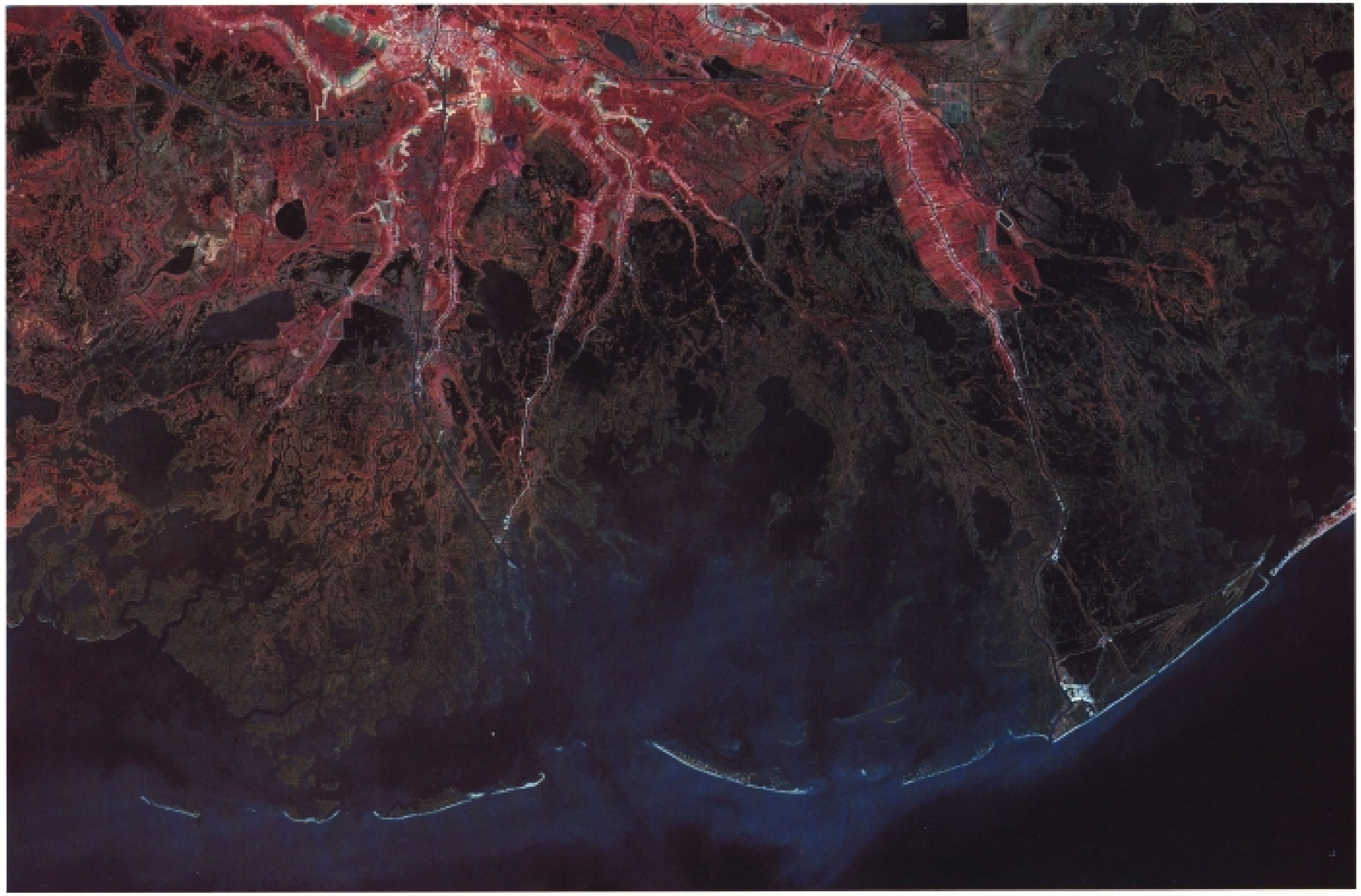
A particularly important finding is the role of barrier islands in protecting the wetlands, bays. and estuaries behind the islands. Barrier islands help reduce wave energy at the margin of wetlands and thus limit mechanical erosion. Barriers also limit storm surge heights and retard saltwater intrusion. The bays between Louisiana's barriers and wetlands are ecologically productive and would be significantly altered if the barriers erode away. Proposals have been made to restore and protect Louisiana's barrier islands in order to preserve estuaries and reduce wetlands loss, but until now there has not been enough information about the erosion processes to make a thorough assessment of their significance. For example, the Corps of Engineers, in a limited feasibility study. estimated that protecting the island of Grand Terre with engineering techniques would limit wetlands loss by 10 percent. This reconnaissance study, based on a modest computer modeling effort, was suitable for problem identification, but not for making the policy decision to proceed nor for developing details of engineering design. The results of the present USGS study will fill that gap by quantitatively assessing the importance of barriers protecting back-barrier wetland and estuary environments.

ATLAS SUMMARY AND RESEARCH STUDY RESULTS

This is the first in a series of three atlases and a set of scientific reports and publications that will present the results of the Louisiana Barrier Island Erosion Study. This atlas examines the magnitude and impact of historic shoreline change on the physical and cultural landscape of Louisiana's barrier islands. The ensuing chapters discuss coastal geomorphology and barrier island research in Louisiana over the past 40 years (Chapter 1) and cultural resources in Louisiana's coastal zone (Chapter 2). In Chapter 3, the Louisiana barrier shoreline is depicted in a vertical aerial photo mosaic. and Chapter 4 concludes with an extensive and quantitative compilation of shoreline changes from 1853 to 1989.

Two subsequent atlases will illustrate historical changes in offshore bathymetry (I-2150-B), and the shallow geologic framework (I-2150-C). Along with the series of atlases, which will present the data in maps and graphics with limited interpretation, several narrative reports, to be released as papers and maps, in the scientific literature, will summarize the study's scientific findings. Those reports will discuss the application of the study's results to the practical problems of erosion and land loss mitigation. This information will contribute to the basic data sets and technical knowledge needed by Federal. State, and local agencies to formulate realistic and cost-effective approaches to coastal restoration and erosion mitigation. In addition, the presentation of the research results in scientific forums and public programs increases the awareness of the public and scientific community that erosion in Louisiana is widespread and a serious problem.

Landsat-5 image of the South Central delta-plain coast of Louisiana by the U.S. Geological Survey as part of the New Orleans, Louisiana Satellite Image Map Folio no. LA1137, 1986 image.



Chapter 1 Barrier Island Erosion and Wetland Loss in Louisiana

by Shea Penland, S. Jeffress Williams, Donald W. Davis, Asbury H. Sallenger, *Jr.* and C. G. Groat

FIGURE 1.— Coastal erosion and accretion on the U.S. Gulf Coast (redrawn from U.S. Geological Survey, 1988).

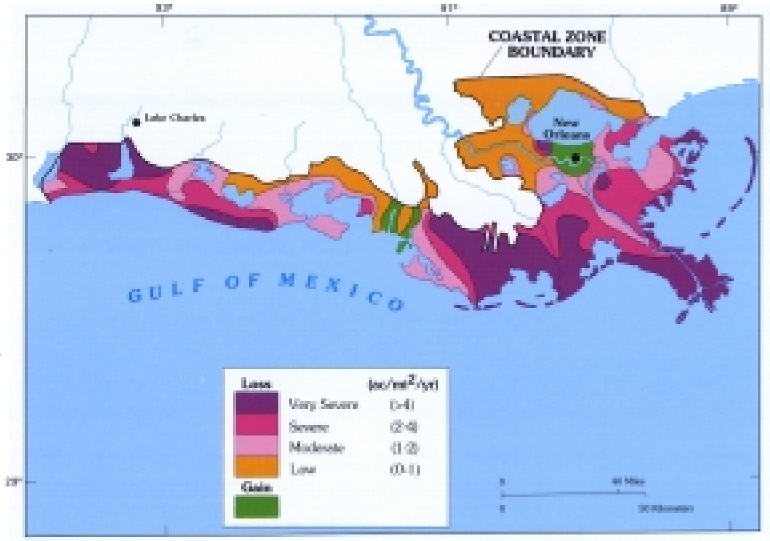


FIGURE 2.— Coastal land loss in Louisiana, 1955–1978 (redrawn and adapted from van Beek and Meyer-Arendt, 1982, p. 16).

TABLE 1. —Contributors to coastal land loss in Louisiana

Natural	Human-induced
Delta cycle process	Flood control
Subsidence	Canal dredging
Eustasy	Pipelines
Saltwater intrusion	Subsurface fluid withdrawal
Storm impact	Brine disposal
Water logging	Water pollution
Geosynclinal downwarping	Herbivory
Herbivory	

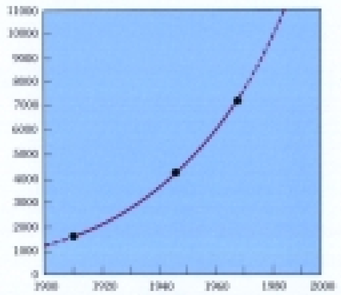


FIGURE 4.— Coastal land loss, in ha/yr, in Louisiana's Mississippi River delta plain, 1955–1978. (data from Gagliano and others, 1981, p. 298).

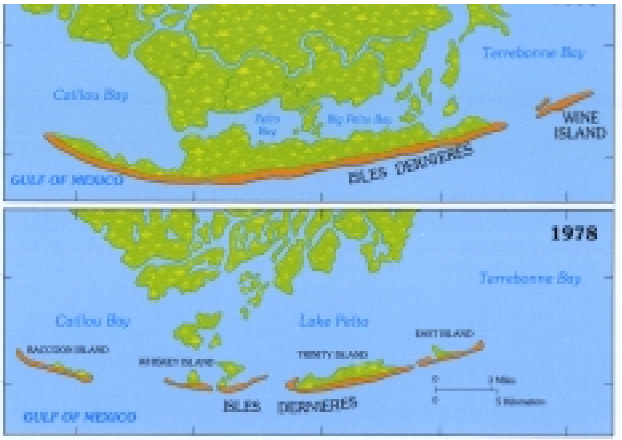


FIGURE 3.— Shoreline change in the Isles Dernieres, 1853–1978 (redrawn and adapted, by permission, from Penland and Boyd, 1981, p. 216; © 1981 by IEEE).

TABLE 2.—Solutions to Louisiana's coastal land loss problem

Tactics	Relative costs
Strategic management and retreat	$$$$
Sediment diversions	$$$
Marsh management	$$
Coastal erosion control	$
Research and development	¢

(Reprinted from Penland and others, 1990a, p. 686.)

INTRODUCTION

Coastal erosion and wetland loss are serious and widespread national problems with long-term economic and social consequences (fig. 1). The highest rates of erosion and wetland loss in the United States, and possibly the world, are found in coastal Louisiana (Morgan and Larimore, 1957; Gagliano and van Beek, 1970; Adams and others. 1978; Gosselink and others, 1979; Craig and others, 1980; Wicker. 1980: Sasser and others, 1986; Walker and others, 1987; Coleman and Roberts, 1989; Britsch and Kemp. 1990, Dunbar and others. 1990; Penland and others, 1990a; Williams and others, 1990). Louisiana's barrier systems protect an extensive estuarine system from offshore waves and saltwater intrusion from the Gulf of Mexico, but these islands are being rapidly eroded (Peyronnin, 1962; Penland and Boyd, 1981, 1982; Morgan and Morgan, 1983). The disappearance of Louisiana's barrier systems will result in the destruction of the large estuarine bay systems and the acceleration of wetland loss.

Coastal land loss severely impacts the fur. fish. and waterfowl industries. valued at an estimated $1 billion per year. as well as the environmental quality and public safety of south Louisiana's citizens (Gagliano and van Beek, 1970; Gosselink, 1984: Turner and Cahoon, 1987; Chabreck, 1988: Davis. 1990a; Davis, 1990b). In addition, the region's renewable resource base depends on the habitat provided by the fragile estuarine ecosystems. Understanding the geomorphological processes. both natural and human-induced (table 1). that control barrier island erosion, estuarine deterioration, and wetland loss in Louisiana is essential to evaluating the performance of the various restoration, protection, and management methods currently envisioned or employed (Penland and others, 1990a).

The challenge of coping with and combatting coastal erosion and wetland loss grows as the Gulf Coast population becomes more concentrated and dependent upon coastal areas. The Environmental Protection Agency (EPA) and National Research Council (NRC) have predicted that the rates of sea level rise will increase over the next century, which will result in dramatically accelerated coastal land loss (Barth and Titus, 1984; National Research Council, 1987). Because of its geologic setting, Louisiana provides a worst-case scenario for the future coastal conditions predicted by the EPA and NRC. More importantly. Louisiana's coastal problems illustrate the importance of understanding the processes driving coastal land loss. Many solutions to coastal land loss problems emphasize stopping the result of the geologic process and give inadequate consideration to the process itself. This approach results in engineering solutions that rely on expensive brute force rather than more sophisticated, less expensive approaches that operate in concert with natural processes revealed by scientific study (Penland and Suter, 1988a). This lack of understanding leads to oversimplified concepts and the false hope that easy solutions exist. A key objective of the U.S. Geological Survey (USGS) and Louisiana Geological Survey (LGS) cooperative coastal research program is to improve our knowledge and understanding of the processes and patterns of coastal land loss in order to help develop a strategy to conserve and restore coastal Louisiana.

COASTAL LAND LOSS

Behind Louisiana's protective barrier systems lie extensive estuaries that are rapidly disintegrating because of pond development. bay expansion, coastal erosion, and human impacts (Morgan, 1967). The chronic problem of wetland loss in Louisiana is well documented but poorly understood (Wicker 1980; Britsch and Kemp, 1990; Dunbar and others, 1990). Previous studies show that coastal land loss has persisted and accelerated since the 1900's. Much speculation and debate in the research, governmental, and environmental communities surrounds the issue of coastal land loss. the natural and human-induced processes that drive coastal change, and the strategy for coastal protection and restoration (table 2) (Penland and others, 1990a).

Coastal land loss is the result of a set of processes that convert land to water. Coastal ***change*** is a more complex concept. It describes the set of processes driving the conversion of one geomorphic habitat type into another. Coastal land loss and change typically involve first the conversion of vegetated wetlands to an estuarine water body, followed by barrier system destruction and the conversion of the estuarine water bodies to less productive open water. There are two major types of coastal land loss: coastal erosion and wetland loss. Coastal erosion is the retreat of the shoreline along the exposed coasts of large lakes, bays, and the Gulf of Mexico. In contrast. wetland loss is the development of ponds and lakes in the interior wetlands and the expansion of large coastal bays behind the barrier islands and mainland shoreline (Penland and others, 1990a).

COASTAL EROSION

Shoreline change in Louisiana averages -4.2 m/yr with a standard deviation of 3.3 and a range of +3.4 to -15.3 m/yr (U.S. Geological Survey, 1988) (table Bl in appendix B). This is the average of long-term (over 50-year) conditions per unit length of 600 km of shoreline. The average Gulf of Mexico shoreline change rate is -1.8 m/yr, the highest in the United States. By comparison, the Atlantic is being eroded at an average rate of 0.8 m/yr, while the Pacific coast is relatively stable with an average rate of change of 0.0 m/yr (U.S. Geological Survey, 1988). Most coastal erosion in Louisiana is concentrated on the barrier systems that front the Mississippi River delta plain (fig. 2).

Coastal erosion is not a steady process; bursts of erosion occur during and after the passage of major cold fronts, tropical storms, and hurricanes (Harper, 1977; Penland and Ritchie, 1979; Dingler and Reiss, 1988; Ritchie and Penland, 1988; Dingler and Reiss, 1990). Field measurements have documented 20-30 m of coastal erosion during a single 3- to 4-day storm. These major storms produce energetic overwash conditions that erode the beach and produce a lower-relief barrier landscape (Penland and others, 1989a; Penland and others, 1990a). This beach erosion has resulted in a significant (41 percent) decrease in the total area of Louisiana's barrier islands, from 98.6 km^2 in 1880 to 57.8 km^2 in 1980-a rate of 0.41 km^2/yr (Penland and Boyd, 1982).

The Isles Dernieres, in Terrebonne Parish, have the highest rate of coastal erosion of any Louisiana barrier system (fig. 3). From 1890 to 1988, the Isles Demieres shoreline was eroded 1,644 m at an average rate of 16.8 m/yr. The most erosion took place in the central barrier island arc at Whiskey Island, where the beach retreated a total of 2,573 m at an average rate of 26.3 m/yr. This erosion resulted in a 77 percent decrease in the total area of the Isles Demieres, from 3,360 ha in 1890 to 771 ha in 1988-an average rate of 26.4 ha/yr (Penland and Boyd, 1981; McBride and others, 1989a). Of immediate threat to Louisiana, and particularly to Terrebonne and Lafourche parishes, is the predicted loss of the Isles Dernieres by the early 21st century. Coastal erosion is expected to destroy East Island first, by 1998, and Trinity Island ultimately, by 2007. After the Isles Dernieres are destroyed, the stability and quality of the Terrebonne Bay barrier-built estuary and the associated coastal wetlands will be dramatically diminished (Penland and others, 1990a).

WETLAND LOSS

Louisiana contains at least 40 percent of the Nation's coastal wetlands. but is suffering 80 percent of its wetland loss. Most of the 4,697,100 ha of coastal wetlands found in the continental United States (except the Great Lakes area) lie along the Atlantic coast (52.7 percent) and the northern Gulf of Mexico (45.8 percent). Louisiana contains 55.5 percent of the northern Gulf of Mexico's coastal wetlands, or 1,193,900 ha (Alexander and others, 1986; Reyer and others. 1988) (table B2 in appendix B).

Within Louisiana. the Mississippi River delta plain comprises **995,694** ha of salt marsh, fresh marsh, and swamp, representing 74 percent of the State's coastal wetlands. The chenier plain accounts for the remaining 26 percent or 347,593 ha. Cameron Parish (on the chenier plain) has the largest expanses of salt and fresh marsh of a single parish, a total of 302,033 ha. Terrebonne Parish has the delta plain's largest expanse of coastal wetlands, with 233,711 ha. followed by Plaquemines Parish with 167,980 ha, Lafourche Parish with 118,224 ha, and St. Bernard Parish, with 104,906 ha (Alexander and others. 1986) (table B3 in appendix B). Louisiana's wetland parishes constitute the single largest concentration of coastal marshes in the contiguous United States.

The current rate of coastal land loss in south Louisiana is estimated to be over 12,000 ha/yr; 80 percent of the loss occurs in the delta plain (fig. 4) and 20 percent in the chenier plain (Gosselink and others, 1979: Gagliano and others, 1981). Previous studies indicate that the rate of coastal land loss has accelerated over the last 75 "years. Rates of loss within the delta plain alone have increased from 1,735 ha/yr in 1913, to 4,092 ha/yr in 1946, to 7,278 ha/yr in 1967, and finally to 10,205 ha/yr in 1980. In 1978, it was estimated that accelerating coastal land loss would destroy Lafourche Parish in 205 years, St. Bernard Parish in 152 years. Terrebonne Parish in 102 years. and Plaquemines Parish in **52 years** (Gagliano and others, 1981).

New research indicates that coastal land loss is proceeding more slowly now than it did in the 1970's; further, today's loss rate is lower than it was expected to be. Britsch and Kemp's (1990) mapping study of coastal land loss used 50 15-minute USGS quadrangle maps of the Mississippi River delta plain and 1932-1933 U.S. Coast and Geodetic Survey Air Photo Compilation sheets (1:20,000 original scale) for interpretation for 1956-1958, 1974, and 1983. Coastal land loss rate curves were generated for each quadrangle and the entire delta plain. This study showed that rates increased after the 1930's from 3,339 ha/yr during the 1956-1958 period to 7,257 ha/yr in 1974 (Britsch and Kemp,1990). After 1974, the land loss rate decreased to 5,949 ha/yr in 1983 (fig. 5). This rate corresponds closely to those measured by Gagliano and others (1981) through 1967; however, the maximum land loss rate for 1978 exceeded the maximum land loss rate from Britsch and Kemp (1990) for **1974.**

Dunbar and others (1990) mapped a land loss rate trend for the chenier plain similar to that found in the delta plain. The land loss rates in the chenier plain accelerated after the 1930's from 582 ha/yr to a maximum of 3,589 ha/yr in 1974 (fig. 6). Since 1974, the land loss rates have decreased to 2,004 ha/yr in 1983. Dunbar and others (1990) combined the results from the chenier plain study and the results of the Britsch and Kemp (1990) delta plain study to develop a comprehensive and accurate perspective on Louisiana's total coastal land loss problem. The most surprising aspect of these two studies is that they document that land loss rates for the entire coastal zone have decreased despite the fact that they were expected to accelerate for the foreseeable future. Consistent with the land loss rate curves for the individual delta and chenier plains. the composite land loss rate curve for the entire coastal zone depicts an acceleration in land loss from 3,921 ha/yr in 1932 to 10,846 ha/yr in 1974 (fig. 7); by 1983 the rate had decreased to 7,953 ha/yr. Land loss rates had been expected to exceed 13,000 ha/yr by that date.

As the composite land loss time series show, the general trend across Louisiana's coastal zone is primarily toward decreasing or constant rates with isolated quadrangles of increasing rates. The areas of decreasing or constant land loss in the delta plain include the interior wetlands, Pontchartrain basin. Atchafalaya basin, and the Mississippi River mouth (table 3). Areas of increasing land loss in the delta plain include Lake Maurepas, Thibodaux, Chandeleur Sound marshes, lower Barataria basin, and lower Terrebonne basin. On the chenier plain the regional trend is toward decreasing or constant land loss rates, by quadrangle, except in the Grand Lake area, where the rates are increasing (table 4). The Britsch and Kemp (1990) and Dunbar and others (1990) studies document that, although the rates are not as high now as they once were, Louisiana still faces a catastrophic coastal land loss problem.

TABLE 3.—*Land loss rates on the Mississippi River delta plain*

Quadrangle Name	Time Period 1	Average Loss (m²/yr)	Time Period 2	Average Loss (m²/yr)	Time Period 3	Average Loss (m²/yr)
Barataria	1939–1956	1.09	1956–1974	1.20	1974–1980	0.70
Bay Dogris	1953–1958	0.42	1958–1973	1.44	1974–1983	1.26
Bayou Du Large	1953–1956	0.18	1956–1974	1.01	1974–1980	0.55
Bayou Sale	1957–1958	0.31	1958–1973	0.38	1974–1983	0.19
Belle Isle	1940–1956	0.28	1956–1974	0.32	1974–1980	0.11
Black Bay	1953–1958	0.21	1958–1973	0.27	1974–1983	0.22
Bonnet Carre	1936–1956	0.10	1956–1974	0.44	1974–1980	0.19
Breton Island	1953–1958	0.26	1958–1973	0.18	1974–1983	0.11
Caillou Bay	1953–1956	0.22	1956–1974	0.40	1974–1980	0.43
Cat Island	1953–1958	0.3	1958–1973	0.28	1974–1983	0.11
Chef Menteur	1953–1956	0.49	1956–1974	0.41	1974–1980	0.25
Covington	1953–1958	0.02	1958–1973	0.18	1974–1983	0.02
Cut Off	1939–1956	0.22	1956–1974	0.50	1974–1980	0.50
Dernieres	1953–1956	0.24	1958–1973	0.22	1974–1983	0.24
Dulac	1953–1956	0.37	1956–1974	0.96	1974–1980	1.06
East Delta	1953–1958	1.17	1958–1973	1.80	1974–1983	0.27
Empire	1953–1956	0.26	1956–1974	1.12	1974–1980	2.56
Fort Livingston	1953–1958	0.34	1958–1973	0.83	1974–1983	0.89
Gibson	1939–1956	0.11	1956–1974	1.50	1974–1980	0.45
Hahnville	1939–1956	0.11	1958–1973	0.07	1974–1983	0.43
Houma	1939–1956	0.13	1956–1974	0.24	1974–1980	0.17
Jeanerette	1957–1958	0.06	1958–1973	0.28	1974–1983	0.06
Lac des Allemands	1940–1956	0.13	1956–1974	0.11	1974–1980	0.56
Lake Decade	1951–1956	0.25	1958–1973	1.22	1974–1983	0.28
Lake Felicity	1953–1956	0.29	1956–1974	1.32	1974–1980	1.54
Leeville	1953–1958	0.29	1958–1973	0.40	1974–1983	0.90
Marsh Island	1953–1956	0.23	1956–1974	0.36	1974–1980	0.24
Mitchell Key	1953–1958	0.05	1958–1973	0.35	1974–1983	0.27
Morgan City	1951–1956	0.29	1956–1974	1.37	1974–1980	0.36
Morgan Harbor	1953–1958	0.19	1958–1973	0.32	1974–1983	0.28
Mound Key	1939–1956	0.05	1956–1974	0.36	1974–1980	0.36
New Orleans	1939–1958	0.17	1958–1973	0.26	1974–1983	0.14
Oyster Bayou	1951–1956	0.07	1956–1974	0.15	1974–1980	0.15
Point Chicot	1953–1958	0.08	1958–1973	0.28	1974–1983	0.27
Point au Fer	1951–1956	0.11	1956–1974	0.15	1974–1980	0.17
Pointe a la Hache	1953–1958	0.29	1958–1973	0.75	1974–1983	0.77
Pontchatoula	1939–1956	0.07	1956–1974	0.06	1974–1980	0.06
Rigolets	1953–1958	0.11	1958–1973	0.24	1974–1983	0.26
Slidell	1939–1956	0.06	1956–1974	0.15	1974–1980	0.05
Southwest Pass	1953–1958	0.19	1958–1973	0.17	1974–1983	0.02
Spanish Fort	1939–1956	0.03	1956–1974	0.01	1974–1980	0.005
Springfield	1939–1958	0.01	1958–1973	0.01	1974–1983	0.05
St. Bernard	1953–1956	0.29	1956–1974	1.23	1974–1980	0.73
Terrebonne Bay	1953–1958	0.18	1958–1973	0.29	1974–1983	0.49
Thibodaux	1949–1956	0.002	1956–1974	0.02	1974–1980	0.07
Three Mile Bay	1953–1958	0.09	1958–1973	0.11	1974–1983	0.13
Timbalier Bay	1939–1956	0.21	1956–1974	0.22	1974–1980	0.41
Venice	1953–1958	0.61	1958–1973	1.50	1974–1983	0.44
West Delta	1953–1956	1.41	1956–1974	2.0	1974–1980	1.34
Yscloskey	1953–1958	0.12	1958–1973	0.60	1974–1983	0.53

(Data from Britsch and Kemp, 1990, p. 15–18.)

TABLE 4.—*Coastal land loss rates on the Louisiana chenier plain*

Quadrangle¹ Name	Time Period 1	Average Loss (m²/yr)	Time Period 2	Average Loss (m²/yr)	Time Period 3	Average Loss (m²/yr)
Abbeville	1934–1954	0.070	1954–1974	0.245	1978–1983	0.258
Cameron	1933–1955	0.071	1955–1974	2.468	1974–1983	0.586
Chenier Au Tigre	1935–1951	0.035	1951–1974	0.268	1978–1983	0.127
Constance Bayou	1933–1955	0.041	1955–1974	0.802	1974–1983	0.495
Forked Island	1935–1955	0.019	1955–1974	0.162	1978–1983	0.165
Grand Lake East	1933–1955	0.224	1955–1974	0.438	1974–1983	1.643
Grand Lake West	1933–1955	0.048	1955–1974	1.116	1978–1983	1.302
Hog Bayou	1933–1955	0.027	1955–1974	0.723	1974–1983	0.151
Johnsons Bayou	1933–1955	0.068	1955–1974	3.119	1978–1983	1.022
Pecan Island	1933–1955	0.063	1951–1974	0.792	1974–1983	0.752
Sulphur	1933–1955	0.047	1955–1974	1.833	1978–1983	0.285
Sweet Lake	1933–1955	0.129	1955–1974	1.796	1974–1983	0.939

¹Approximate area of a 15-minute quadrangle is 300 m².
(Data from Dunbar and others, 1990, p. 13.)

TABLE 5.—*Barrier systems of Louisiana*

System	Headland	Islands	Tidal Inlets	Back-barrier Water Bodies
Bayou Lafourche	Caminada-Moreau	Timbalier Island E. Timbalier Island Grand Isle Caillou Island	Cat Island Pass Little Pass Timbalier Raccoon Pass Belle Pass Caminada Pass Barataria Pass	Timbalier Bay Caminada Bay Barataria Bay
Plaquemines	Bayou Robinson Grand Bayou Dry Cypress Bayou	Cheniere Ronquille Grand Terre Islands Shell Island Sandy Point	Barataria Pass Pass Abel Quatre Bayoux Pass Pass Ronquille Pass La Mer Chaland Pass Grand Bayoux Pass Shell Island Coupe Fontanelle Pass Scofield Pass Bay Coquette Pass	Barataria Bay Bay Ronquille Bay La Mer Bay Joe Wise Bastian Bay Bay Coquette
Isles Dernieres	Bayou Petit Caillou	Raccoon Island Whiskey Island Trinity Island East Island Wine Island Shoal	Boca Caillou Coupe Colin Whiskey Pass Coupe Carmen Coupe Juan Wine Island Pass Cat Island Pass	Caillou Bay Lake Pelto Terrebonne Bay
Chandeleur	St. Bernard	Chandeleur Island Curlew Island Grand Gosier Island Breton Island	Pass Curlew Grand Gosier Pass Breton Island Pass	Chandeleur Sound Breton Sound

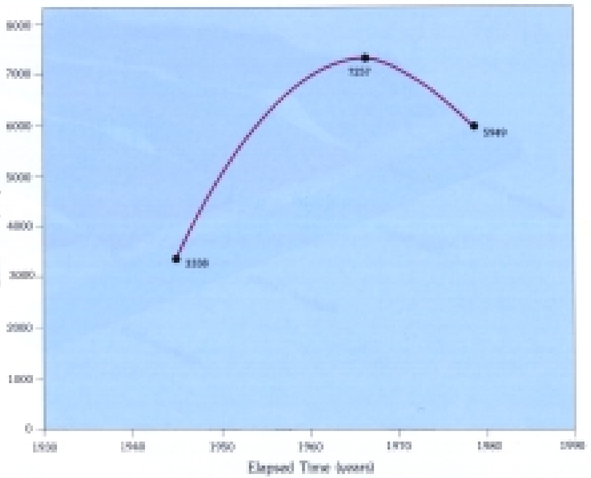


FIGURE 5.— Coastal land loss rate curve for the Mississippi River delta plain (data from Britsch and Kemp, 1990, p. 22).

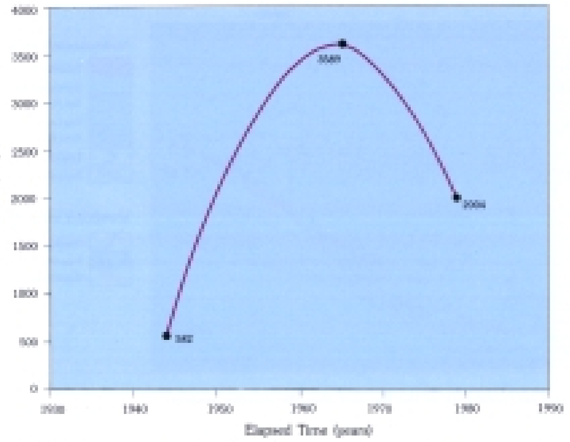


FIGURE 6.— Coastal land loss rate curve for the Mississippi River chenier plain (data from Dunbar and others, 1990, p. 12).

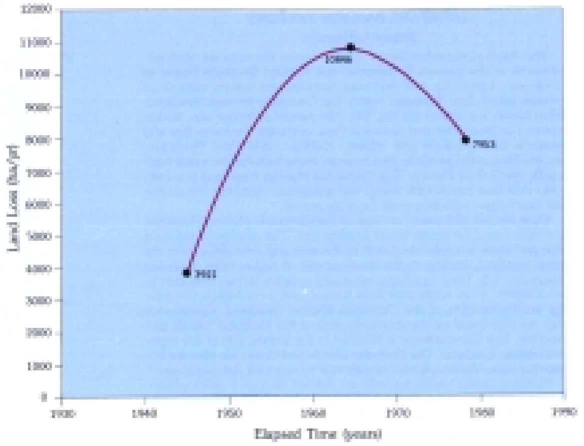


FIGURE 7.— Composite coastal land loss rate curve for the Mississippi River delta and chenier plains in Louisiana (data from Dunbar and others, 1990, p. 14).

BARRIER ISLAND LANDSCAPE

REGIONAL GEOLOGY

The geology of Louisiana's coastal zone is intimately tied to the history of the Mississippi River during the Holocene Epoch. The Mississippi River has built a delta plain consisting of seven delta complexes, ranging in age from about 7,000 years old to the contemporary Balize and Atchafalaya complexes (Fisk. 1944; Kolb and Van Lopik, 1958; Frazier; 1967: Coleman, 1988). The main distributary of the Mississippi River shifts to a more hydraulically efficient course about every 1,000 years, resulting in the complex geomorphology of Louisiana's coastal zone (fig. 8). When avulsion occurs, a new delta complex begins prograding in a different area. Deprived of its former sediment supply, the abandoned delta complex experiences transgression due to relative sea level rise. which in turn is driven by compactional subsidence of the deltaic sediments. The delta-switching process builds new deltas and establishes the framework necessary for barrier island development (Coleman and Gagliano, 1964; Kwon, 1969; Penland and others, 1981).

During transgression, the deltaic landscape is dominated and reworked by marine processes. In what can be visualized as a three-stage process, coastal erosion transforms the once-active delta into a succession of transgressive depositional environments (fig. 9) (Penland and others, 1988a). The first stage is an erosional headland with flanking barrier islands. Long-term relative sea level rise and erosional shoreface retreat lead to stage 2, the detachment of the barrier system from the mainland and the formation of a barrier island arc (Boyd and Penland, 1988). The final stage occurs when relative sea level rise and repeated storm impacts overcome the ability of the barrier island arc to maintain its subaerial integrity. The arc becomes submerged, forming an inner-shelf shoal (Penland and others, 1986a). Shoreface retreat processes then continue to drive the inner-shelf shoal landward across the subsiding continental shelf and smooth the mainland shoreline.

The modern Mississippi River delta plain is North America's largest deltaic estuary (fig. 10). Two distinct types of estuaries occur here: barrier-built and delta-front (Schubel, 1982). Barrier-built estuaries develop as a result of delta abandonment; barrier islands form. lakes develop into larger bays, and salt marshes encroach upon the surrounding freshwater marshes and swamps under the effects of submergence (Scruton, 1960; Penland and others, 1988a). In contrast. the delta-front estuaries are associated with active delta building and the development of freshwater swamps and marshes (van Heerden and Roberts. 1988; Tye and Coleman, 1989).

The coastline of the Modern delta plain stretches 350 km from Point au Fer east to Hewes Point in the northern Chandeleur Islands. It is surrounded by 17 barrier islands attached to several major deltaic headlands (table 5). These islands and headlands can be organized into four distinct barrier systems, each tied to an abandoned delta complex: from west to east they are the Isles Dernieres, Bayou Lafourche, Plaquemines, and Chandeleur barrier systems. The back-barrier lagoons are connected to the Gulf of Mexico by 25 tidal inlets, which allow the exchange of a diurnal tidal regime. Within the official Louisiana coastal zone boundary of the delta plain, alluvium, fresh marsh, salt marsh, bay, and barrier island environments occur (Snead and McCulloh, 1984). The Bayou Lafourche, Plaquemines, Isles Dernieres, and Chandeleur barrier-built estuarine systems make up 62 percent of the Mississippi River delta plain, whereas the delta-front estuaries account for 18 percent, and the remaining area is mapped as alluvium. Barrier-built estuaries are the most productive component of the delta cycle (Gagliano and van Beek, 1970).

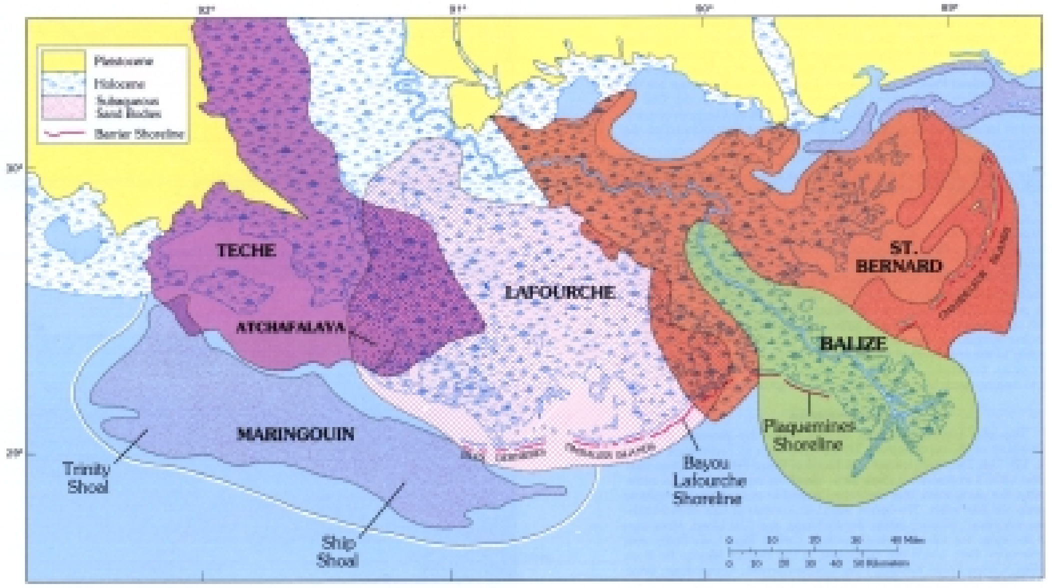


FIGURE 8.— The Mississippi River delta complex, with barrier islands indicated (redrawn and adapted, by permission, from Frazier, 1967, p. 289; © 1967 by the Gulf Coast Association of Geological Societies).

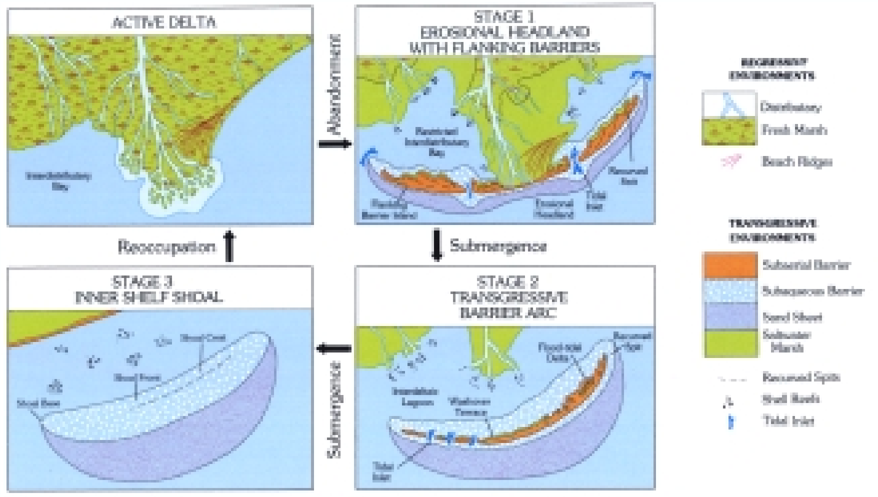


FIGURE 9.— A model of barrier island development (redrawn and adapted, by permission, from Penland and Boyd, 1981, p. 211; © 1981 by IEEE).

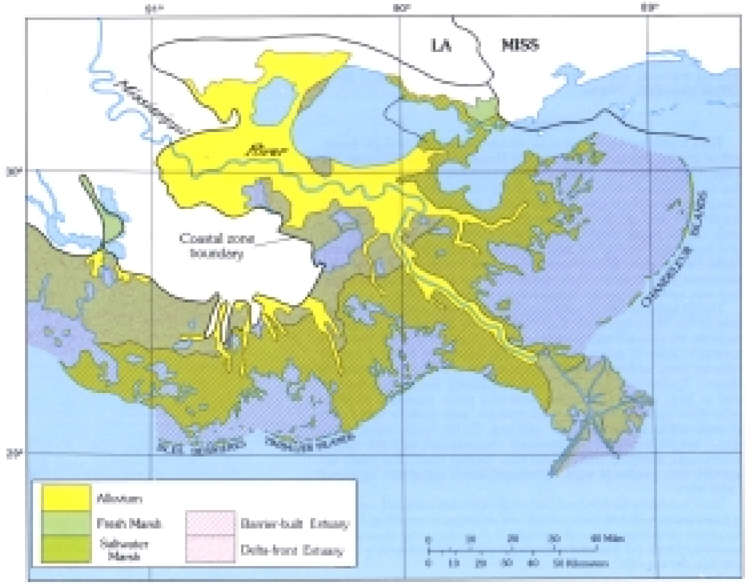


FIGURE 10.— Distribution of barrier-built and delta-front estuaries in the Mississippi River delta plain.

LOUISIANA BARRIER SYSTEMS

Bayou Lafourche

The Bayou Lafourche barrier system forms the seaward geologic framework of the eastern Terrebonne and western Barataria basins in Terrebonne, Lafourche, and Jefferson parishes; the system consists of Timbalier Island, East Timbalier Island. the Caminada-Moreau Headland, Caillou Island. and Grand Isle (fig. 11). The system stretches over 60 km between Cat Island Pass and Barataria Pass, enclosing Timbalier Bay and Caminada Bay (Penland and others, 1986b). Little Pass Timbalier, Raccoon Pass, and Caminada Pass connect these back-barrier water bodies with the Gulf of Mexico. The Caminada-Moreau Headland is a low-profile mainland beach with marsh and mangrove cropping out on the lower beach face, reflecting rapid shoreline retreat.

Over the last 300 years. erosion of the Caminada-Moreau Headland has supplied sand for barrier island development. The amount of sediment in the surf zone increases downdrift to the east and west away from the central headland, leading to the development of higher-relief washover terraces (fig. 12). These landforms eventually coalesce farther downdrift to form a higher, more continuous dune terrace. and a continuous foredune ridge on the margins of the Caminada-Moreau Headland. Continuous dunes are also found on the downdrift ends of the Timbalier Islands and Grand Isle. The Caminada spit is attached to the eastern side of this abandoned deltaic headland. The Timbalier Islands and Grand Isle also are laterally-migrating, flanking barrier islands built by recurved spit processes.

Flanking barrier islands typically are formed through a series of processes that includes recurved spit building, longshore spit extension, subsequent hurricane impact and breaching, and island formation, The morphology of Timbalier Island and Grand Isle reflects the geomorphic imprint of the recurved spit process. The recent (1887-1978) history of the Bayou Lafourche barrier system illustrates erosion of the central headland with concurrent development and lateral migration of the flanking barrier islands (fig. 13).

Plaquemines

The Plaquemines barrier system, which derives its name from the abandoned Plaquemines distributary network of the Modern delta complex, forms the seaward geologic framework of the eastern Barataria basin in Jefferson and Plaquemines parishes (fig. 14). The system is 40-50 km long and consists of the Grand Terre Islands attached to the Robinson Bayou and Grand Bayou headlands and Shell Island attached to the Dry Cypress Bayou headland. It encloses Barataria Bay, Bay Ronquille, Bay La Mer, Bastian Bay. and many other smaller water bodies. Barataria Pass, Pass Abel, Quatre Bayou Pass, Pass Ronquille, Pass La Mer, Chaland Pass, Grand Bayoux Pass, and Schofield Pass are the major tidal inlets that connect the back-barrier areas with the Gulf of Mexico. The morphology varies from washover flats and terraces concentrated in headland areas to dunes and dune terraces concentrated on the flanking barrier islands (Ritchie and others, 1990).

Grand Terre is the largest flanking barrier island of the Plaquemines barrier system. Erosion of the Bayou Robinson and Grand Bayou headlands over the last 400 years has supplied sand for the northwest extension of Grand Terre across the southern entrance to the Barataria basin. Repeated hurricanes and barrier island breaching, combined with an increasing tidal prism in Barataria Bay, has led to the development of Pass Abel and Quatre Bayoux Pass over the last 100 years, dividing Grand Terre (fig. 15).

Shell Island is the second-largest flanking barrier island in the Plaquemines system. Enclosing Bastian Bay. Shell Island at one time protected this prolific oyster ground from the direct influence of the Gulf of Mexico. With construction of the Empire jetties and placement of a shore-parallel pipeline system, the natural pattern of sediment transport was disrupted, leading to the breaching of Shell Island by Hurricane Bob in 1979. In recent years, this breach has been dramatically enlarged, allowing open water to destroy much of the Bastian Bay oyster grounds (fig. 16).

Isles Dernieres

The Isles Dernieres barrier system forms the seaward geologic framework of the southwestern Terrebonne basin in Terrebonne Parish (fig. 17). "Isle Derniere" means Last Island in Cajun French and was used in the 1800's to describe a single large island not separated by tidal inlets. Today, the plural form, Isles Dernieres. is used to account for the multiple islands and tidal inlets. The barrier island arc consists of four main islands: Raccoon Island, Whiskey Island, Trinity Island, and East Island. More than 30 km long, the Isles Dernieres enclose Caillou Bay, Lake Pelto; and Terrebonne Bay. which are connected to the Gulf of Mexico by Boca Caillou, Coupe Colin, Whiskey Pass. Coupe Carmen, Coupe Juan. Wine Island Pass, and Cat Island Pass. Whiskey Island and Trinity Island are dominated by washover flats and terraces (Ritchie and others, 1989). Raccoon Island is dominated by washover and dune terraces and East Island by dune terraces and continuous dunes.

The Isles Dernieres barrier system originated from the erosion of the Bayou Petit Caillou headland distributaries and beach ridges over the last 600-800 years (Penland and others, 1985: Penland and others. 1987a). Coastal changes in the Caillou headland observed between 1853 and 1978 illustrate the transition from an erosional headland into a barrier island arc (see fig. 9). In 1853, Pelto and Big Pelto bays separated the Caillou headland and the flanking barriers from the mainland by a narrow tidal channel less than 500 m wide. By 1978, the size of these bays had increased three-fold and they had coalesced to form Lake Pelto. During this period, the Gulf shoreline of the Caillou headland eroded landward over 1 km. The Isles Dernieres now lie several kilometers seaward of the retreating mainland, and at current rates, they will be destroyed by 2007 (McBride and others. 1989a).

Chandeleur

The Chandeleur barrier island arc forms the seaward geologic framework of the St. Bernard delta complex (Treadwell, 1955; Penland and others. 1985; Suter and others, 1988). It encloses the Mississippi River delta plain's largest barrier-built estuary (fig. 18). Over 75 km long, the Chandeleur Islands enclose Breton Sound and Chandeleur Sound in Plaquemines and St. Bernard parishes, and incorporate Chandeleur Island. Curlew Island, Grand Gosier Island (north and south) and Breton Island (north and south). The tidal inlets separating the southern islands include Pass Curlew. Grand Gosier Pass, and Breton Island Pass. The Chandeleur Islands derive their name from the Catholic candle mass, which was performed on the islands several hundred years ago.

The Chandeleur Islands are the oldest transgressive barrier island arc found on the Mississippi River delta plain and are the product of the erosion of the St. Bernard delta complex over the last 1,500 years. The arc's asymmetric shape is the result of its oblique orientation to the dominant southeast wave approach, which leads to the northward transport of sediment. Toward the north, the Chandeleur Islands' morphology is dominated by large washover fans and flood-tidal deltas separated by hummocky dune fields. The islands' wide beaches, with multiple bars in the surf zone, reflect an abundance of sediment. To the south, island widths narrow, heights decrease, and washover channels and fans give way to discontinuous washover terraces and flats. Farther south. the island arc fragments into a series of small, ephemeral islands and shoals separated by tidal inlets.

The Chandeleur Islands have historically retreated landward, undergoing fragmentation by hurricane impact and subsequent rebuilding (fig.19). Chandeleur and Breton sounds average 3-5 m deep and separate the Chandeleur Island arc from the retreating mainland shoreline by a lagoon more than 20 km wide.

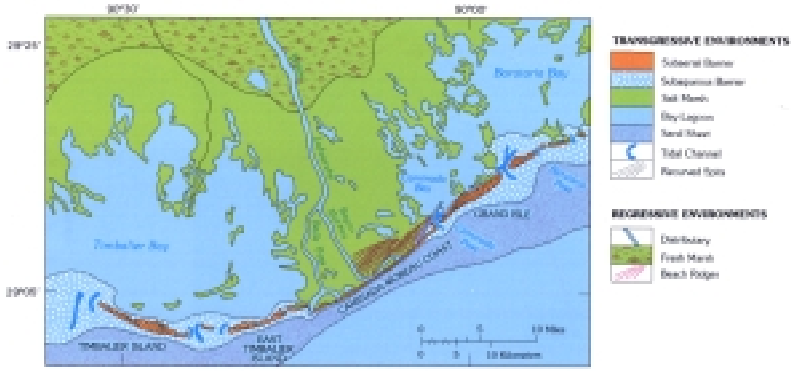


FIGURE 11.— Coastal environments of the Bayou Lafourche barrier system (redrawn from Penland and others, 1988b, p. 19).

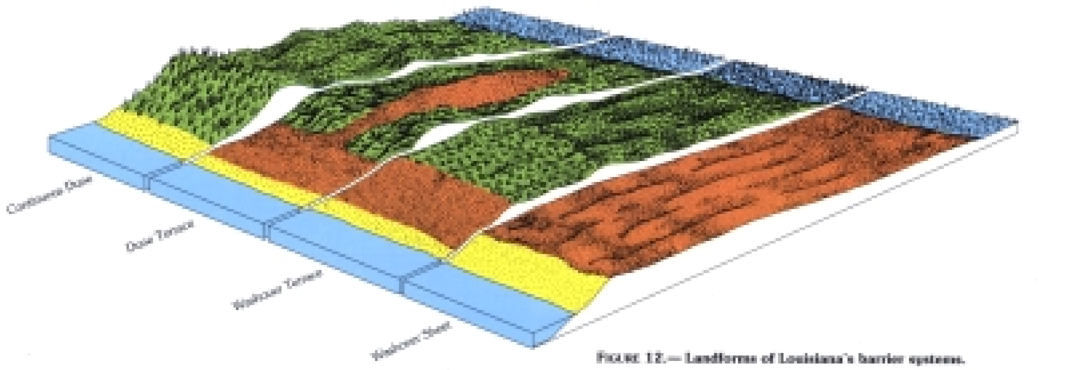


FIGURE 12.— Landforms of Louisiana's barrier systems.

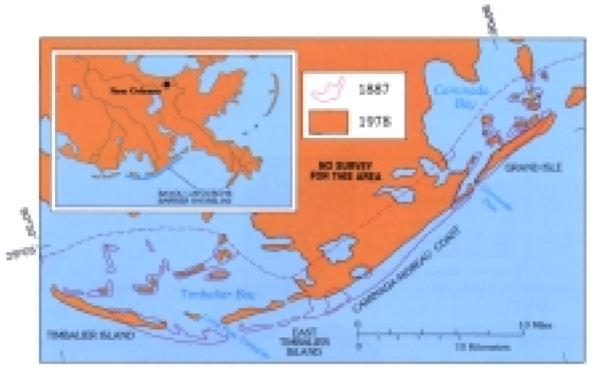


FIGURE 13.— Shoreline change along the Bayou Lafourche barrier system, 1887–1978 (redrawn from Penland and Boyd, 1985, p. 86).

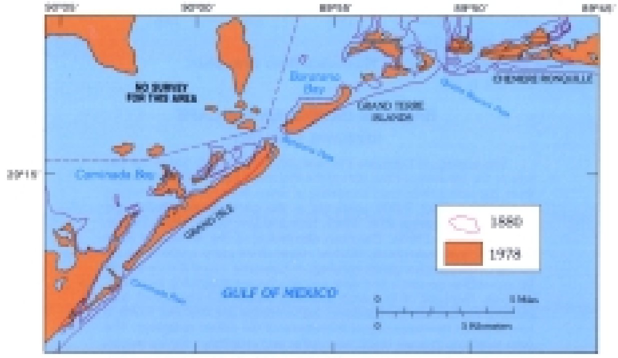


FIGURE 15.— Shoreline change at Grand Terre, 1880–1978 (redrawn, by permission, from Penland and Suter, 1988a, p. 335; © 1988 by the Gulf Coast Association of Geological Societies).

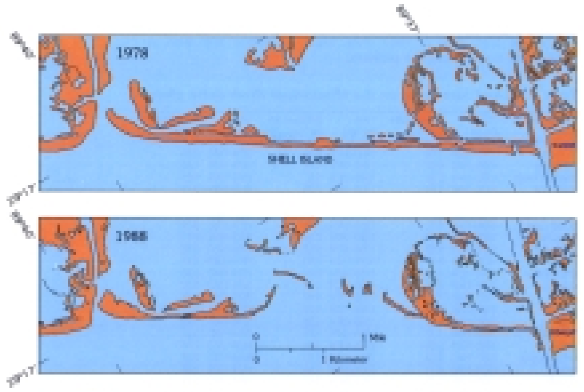


FIGURE 16.— Shoreline change at Shell Island, 1978–1988 (redrawn, by permission, from Penland and Suter, 1988a, p. 337; © 1988 by the Gulf Coast Association of Geological Societies).

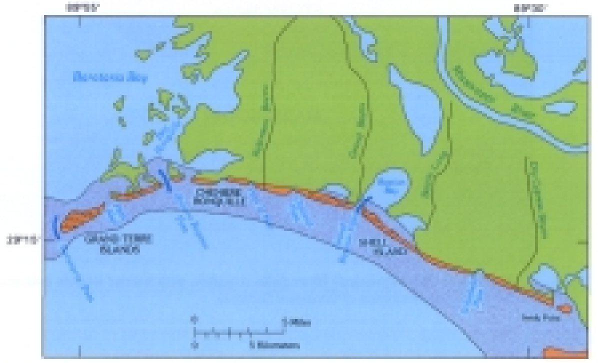


FIGURE 14.— Coastal environments of the Plaquemines barrier system (redrawn, by permission, from Boyd and Penland, 1988, p. 449; © 1988 by the Gulf Coast Association of Geological Societies).

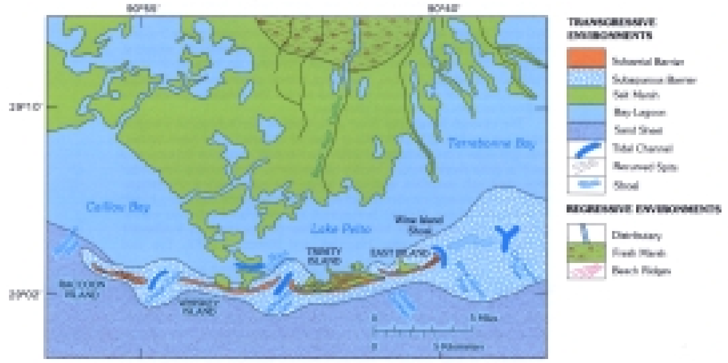


FIGURE 17.— Coastal environments of the Isles Dernieres barrier system (redrawn and adapted, by permission, from Penland and Suter, 1988, p. 370; © 1988 by the Gulf Coast Association of Geological Societies).

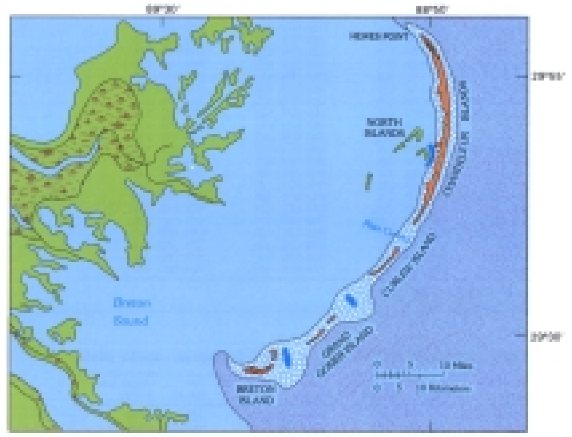


FIGURE 18.— Coastal environments of the Chandeleur barrier system (redrawn, by permission, from Penland and others, 1988a, p. 939; © 1988 by the Society of Economic Paleontologists and Mineralogists).

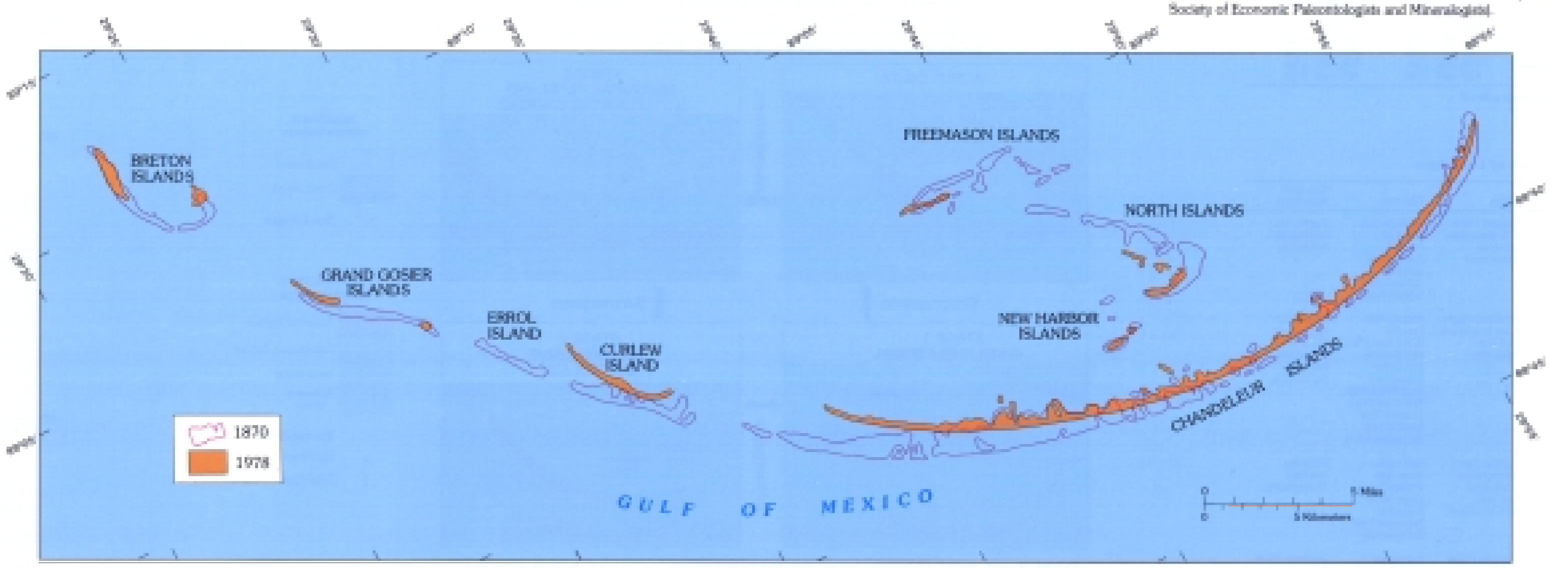


FIGURE 19.— Shoreline change on the Chandeleur Islands, 1870–1978 (redrawn, by permission, from Penland and others, 1985, p. 220; © 1985 by Elsevier Science Publishers).

BARRIER ISLAND EROSION RESEARCH

PREVIOUS RESEARCH

U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers has conducted several regional planning studies since the 1930's to facilitate the design of beach erosion projects. The Corps of Engineers' first detailed barrier island erosion study was conducted for Grand Isle in 1936; subsequent coastal erosion reports were issued for Grand Isle in 1955, 1962, 1972, and 1980 (U.S. Army Corps of Engineers. 1936, 1978, 1980). All of these investigations analyzed the erosion conditions along the coast, reviewed the causative processes, and proposed and analyzed several designs for beach protection.

The most comprehensive study of Grand Isle was the 1980 Corps of Engineers report, which contains extensive information on coastal erosion, coastal processes, sand resources, and designs for the Corps of Engineers‘ beach erosion and hurricane protection project, which was built in 1984. Combe and Soileau (1987) reported on the successful performance of this project at Grand Isle during and after Hurricanes Danny Elena. and Juan in 1985.

Another series of studies concentrated on coastal geomorphology, shallow subsurface geology, coastal processes. and coastal erosion in the area between Raccoon Point and Belle Pass, which includes the Isles Dernieres and the Timbalier Islands (Peyronnin, 1962). It was reported that at Belle Pass the coast had been eroded 2,027 m between 1890 and 1960 (fig. 20). The Timbalier Islands were reported to be undergoing erosion at the rate of 10-30 m/yr, and the Isles Dernieres at a rate of 8-10 m/yr. Peyronnin (1962) estimated that the total material lost from these islands between 1890 and 1934 was 84,100,000 m^3-a rate of net loss of 1,911,500 m^3/yr. Peyronnin (1962) concluded that the barrier islands between Raccoon Point and Belle Pass are important defenses against sea attack on the mainland, and recommended beach nourishment as the most viable remedial action.

The Corps of Engineers updated the 1962 Raccoon Point-to-Belle Pass report in 1975 (U.S. Army Corps of Engineers, 1975a). The shoreline change history was updated from 1959 to 1969; beach erosion had accelerated and the land loss rates were placed at 60 ha/yr. This report also evaluated a variety of erosion control scenarios, including no action. beach nourishment. barrier restoration, and building rock seawalls. The recommended plan was the construction of earthen dikes designed to close existing breaches in the barrier islands, and a maintenance procedure to close future breaches. The Corps of Engineers (1975a) estimated that this project would preserve more than 1,950 ha of marshlands over the next 10 years. Another Corps of Engineers (1975b) report indicated that, if the barrier islands were left unprotected, the Isles Dernieres and Timbalier Islands would continue to deteriorate and wetland loss could approach 16,500 ha of marshland over the next 50 years.

The Corps of Engineers' first comprehensive inventory of the coastal erosion problem in Louisiana was part of a national shoreline study of the extent and nature of shoreline erosion, which culminated in the publication of an atlas (U.S. Army Corps of Engineers. 1971). The atlas identified the physical characteristics of the Louisiana shoreline. historical changes, and the ownership and use of the coastal areas.

Louisiana Attorney General

The first comprehensive study of coastal erosion in Louisiana was conducted by Morgan and Larimore (1957) for the Office of the Attorney General of the State of Louisiana (Morgan, 1955). At the time, Louisiana was engaged in a dispute with the Federal government about the ownership of offshore oil and gas rights. The study aimed to document the historical trends in coastal change in order to establish the position of the State's 1812 shoreline, which was critical in determining Louisiana's three-mile limit.

The study used historical cartographic data dating back to, 1838 from the U.S. Coast and Geodetic Survey (formerly the U.S. Coastal Survey and currently the National Oceanic and Atmospheric Administration [NOAA]), the USGS, the Corps of Engineers. and the State of Louisiana. Aerial photographs from 1932 and 1954 were analyzed to update the historical maps. Measurements of shoreline change were made at intervals of one minute of longitude from the Texas border to the Mississippi border. For continuity, all maps were enlarged or reduced to a common scale of 1:20,000.

The erosion rates around the Mississippi River delta plain ranged from 2.8 to 18.9 m/yr (Morgan and Larimore, 1957). Only the mouth of the Mississippi River was mapped as accretional. The most severe erosion was taking place on the Timbalier Islands and the Caminada-Moreau Headland. Morgan and Larimore (1957) interpreted the regional variation in shoreline change as a function of geologic control due to natural subsidence. Because young deltas subside faster than older ones. the higher rates of coastal erosion were found on recently abandoned delta complexes.

Using newer aerial photography and the same method of analysis, Morgan and Morgan (1983) updated that study to 1969 (figs. 21 and 22). Measurements were again made every minute of longitude and and supplemented with measurements of changes in land area. The average shoreline erosion rate in Louisiana between 1932 and 1954 was measured at 2.0 m/yr (Morgan and Larimore, 1957); it increased to 5.2 m/yr between 1954 and 1969 (Morgan and Morgan, 1983). The loss of land area followed a similar pattern. Morgan and Morgan (1983) calculated a loss rate of 144.4 ha/yr due to shoreline erosion between 1932 and 1954 and an increase in the rate to 171.4 ha/yr for the 1954-1969 period. This increase represents a change from 0.5 ha/yr per mile of coast (1932-1954) to 0.6 ha/yr per mile of coast (1954-1969). The erosion rates on the barrier islands from the Isles Dernieres and the Timbalier Islands as far east as the Caminada-Moreau Headland slowed from 11.2 to 7.0 m/yr and from 18.9 to 11.3 m/yr, respectively. In contrast, the erosion rates in the Barataria Bight and Chandeleur Islands increased from 4.9 to 5.2 m/yr and from 4.2 to 5.5 m/yr, respectively. Morgan and Morgan (1983) suggested that the increasing rates of erosion were associated with areas of more extensive human impacts.

Louisiana Department of Transportation and Development

Using the same methods, Adams and others (1978) updated the Morgan and Larimore (1957) study from 1954 to 1974, to make the third statewide assessment of shoreline change. The State was subdivided into eight management units to assess the patterns of erosion and accretion along lake shores. tidal inlets, and interior marshes. The Terrebonne and Barataria basin shorelines were found to be subject to the most erosion in the State; they retreated 207 m between 1954 and 1969 at a rate of 13.8 m/yr. Erosion on the Chandeleur Islands was found to be proceeding at a slower rate, 5.4 m/yr.

Louisiana Department of Natural Resources

The first comprehensive study focusing on Louisiana's barrier islands was conducted by the Laboratory for Wetland Soils and Sediments at Louisiana State University between 1978 and 1983 under the sponsorship of NOAA's Office of Coastal Zone Management (Mendelssohn and others, 1986). The analysis of shoreline change was based on two independent sets of data. Changes in Gulf shoreline positions were derived by applying the Orthogonal Grid Mapping System technique to a series of historical aerial photographs and National Ocean Survey T-charts; this produced a high-water line location for every 100 m of shoreline (Shabica and others, 1984). The data base for the Chandeleur Islands included eight sets of imagery for the 1922-1978 period: the rest of Louisiana's barrier islands were covered by 12 sets of imagery from 1934 to 1978. The second data set was obtained by digitizing the surface area of each barrier island on the Louisiana coast. This method analyzed U.S. Coast and Geodetic Survey maps for 1869-1956 together with a series of land cover maps (scale 1:10,000) based on 1979 aerial photography. The results were presented as a time series of variation in island area (Penland and Boyd, 1981, 1982).

The most serious shoreline erosion problems identified were along the Caminada-Moreau Headland, where erosion rates ranged from 10 to 20 m/yr (fig. 23). The highest rate of shoreline retreat measured for the 44-year period was 22.3 m/yr in the vicinity of Bays Marchand and Champagne. Erosion rates decreased eastward to 9.6 m/yr at Bayou Moreau. Field measurements made along the Caminada-Moreau Headland in 1979 showed that tropical cyclones eroded the shoreline more than 40 m-over 70 percent of the total erosion for that year (Penland and Boyd, 1982).

Erosion rates in the Belle Pass area were found to have averaged 18.6 m/yr before 1954: after that, shoreline erosion slowed. and switched to accretion after 1969. In 1934, jetties 150 m long and 60 m wide were built at Belle Pass to improve the navigation channel at Bayou Lafourche. The jetty system had little effect on the local sediment dispersal pattern; the shoreline continued to be eroded at rates averaging 18 m/yr, with no significant updrift sand accumulation. In fact, the system had to be extended landward several times to keep pace with the retreating shoreline. In 1968, however. the jetties were expanded to 220 m long and 140 m wide and the channel was dredged to a depth of 6 m, expanded to a width of 90 m, and extended 2 km offshore. After that. sedimentation began taking place along the eastern side of Belle Pass. Since 1969, accretion rates there have averaged 5.5 m/yr; the area is a sink for material that would otherwise be transported farther west to the Timbalier Islands (Dantin and others. 1978).

Timbalier Island and East Timbalier Island are the western-flanking barriers of the Caminada-Moreau Headland. East Timbalier Island. a marginal recurved spit, is being eroded at a rate of over 15 m/yr. Updrift erosion and downdrift accretion cause the rapid lateral migration of these islands. Timbalier Island, for example. has been eroded on its updrift end at an average rate of 18.6 m/yr. Downdrift. erosion decreases and witches to accretion at the western end. averaging 17.4 m/yr.

Between 1935 and 1956, the combined area of the Timbalier Islands increased, reflecting the low frequency of tropical storms during that period. After 1956, the area of both islands began decreasing rapidly. These reductions were determined to be a result of the extension of the jetties at Belle Pass and the seawall along East Timbalier Island. The structures interrupted the transport of sediment from its source within the Caminada-Moreau Headland (Penland and Boyd, 1982).

East of the Caminada-Moreau Headland, the rates of shoreline change were found to vary from 5 m/yr of erosion on the west where the Caminada spit is attached to the erosional headland, to near stability adjacent to Caminada Pass. This pattern of shoreline change reflects the increasing sediment abundance in the nearshore zone. downdrift toward Grand Isle. The Caminada spit was breached several times in this century by hurricane landfall: the major breaches were caused by Hurricane Flossy in 1956 and Hurricane Betsy in 1965 (fig. 24). These breaches were unstable and filled rapidly because of the ready supply of sediment from the Caminada-Moreau Headland (Penland and Boyd, 1982).

Before 1972, the western end of Grand Isle adjacent to Caminada Pass had been eroded, while accretion had occurred on its downdrift, eastern end at Barataria Pass. With construction of the jetty system on the western shore of Caminada Pass in 1973, the west-end erosion temporarily stopped. Before jetty construction at Barataria Pass in 1958, the eastern end of Grand Isle had accreted 3-6 m/yr; after that it increased to over 10 m/yr. The land area of Grand Isle increased from 7.8 km^2 in 1956 to 8.8 km^2 in 1978. This increase has been attributed to repeated beach nourishment projects and to the construction of the Barataria Pass and Caminada Pass jetties (Penland and Boyd, 1982).

The highest erosion rates found within the Isles Dernieres (over 15 m/yr) were along the central portion of the island arc (fig, 25). Downdrift, erosion rates decreased to approximately 5 m/yr. Because no coastal structures have been built in the Isles Dernieres, the sediment dispersal system is undisturbed. The island area has decreased steadily from 34.8 km^2 in 1887 to 10.2 km^2 in 1979 (Penland and Boyd, 1982).

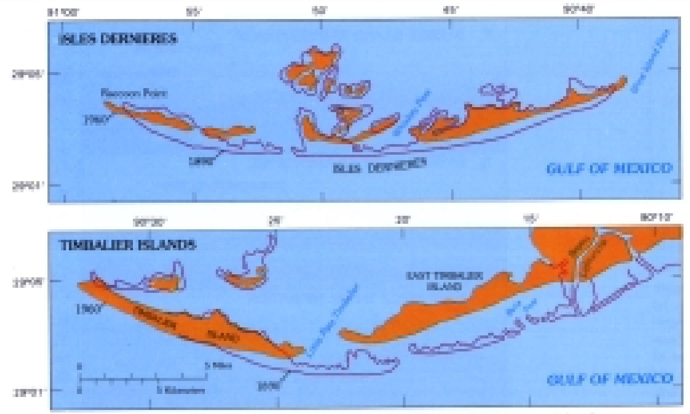


FIGURE 20.— Shoreline change on the Isles Dernieres and Timbalier Islands between 1890 and 1960 (redrawn, by permission, from Peyronnin, 1962; © 1962 by the American Society of Civil Engineers).

FIGURE 21.— Rate of shoreline change in eastern Louisiana, 1812–1954 and 1954–1969 (redrawn from Morgan and Morgan, 1983, p. 11).

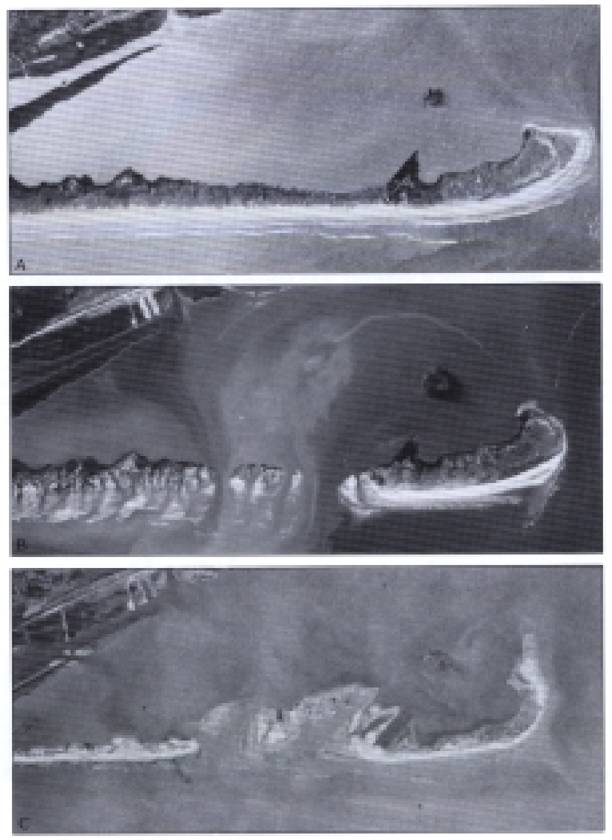


FIGURE 24.— Historical breaching at the Caminada spit. (A) Pre-breach conditions in 1950. (B) After Hurricane Flossy in 1956; note the pattern of seaward-oriented overwash features. (C) After Hurricane Betsy in 1965; note the pattern of landward-oriented overwash features. (Photos from U.S. Army Corps of Engineers, New Orleans District.)

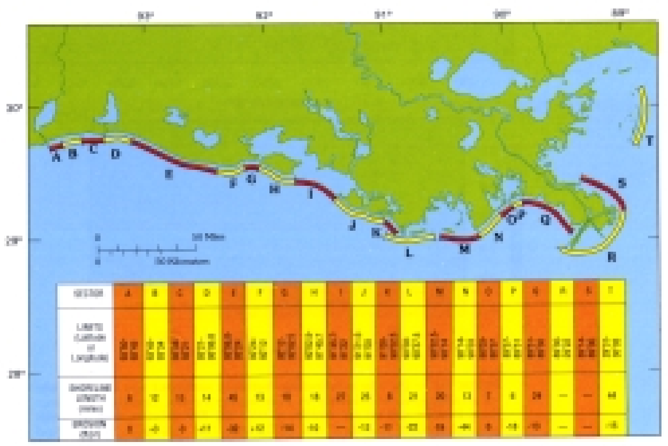


FIGURE 22.— Natural sectors used to evaluate shoreline and areal change on Louisiana's coast (redrawn from Morgan and Morgan, 1983, p. 14).

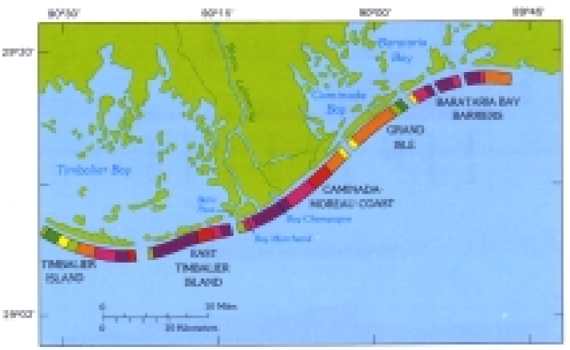


FIGURE 23.— Distribution and rate of shoreline change on the Bayou Lafourche barrier system (redrawn from Penland and Boyd, 1982, p. 25).

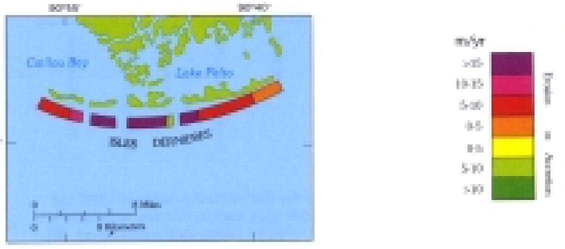


FIGURE 25.— Distribution and rate of shoreline change for the Isles Dernieres barrier system (redrawn from Penland and Boyd, 1982, p. 32).

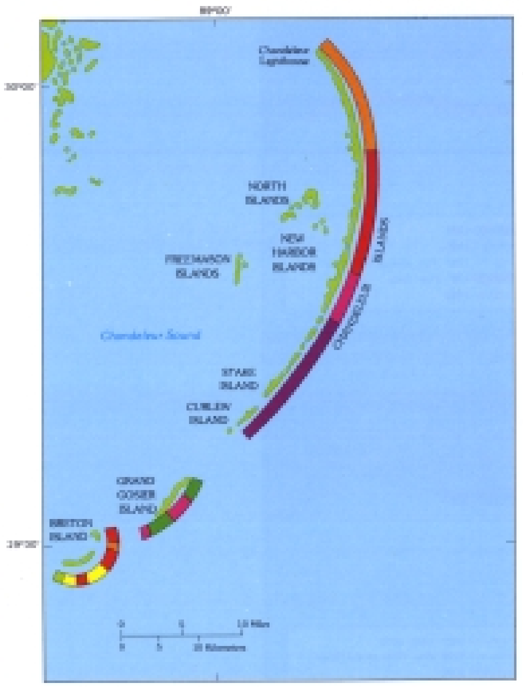


FIGURE 26.— Distribution and rate of shoreline change for the Chandeleur barrier system (redrawn from Penland and Boyd, 1982, p. 34).

The pattern of shoreline change in the Chandeleur Islands is the result of their oblique orientation to the dominant wave approach. Erosion rates exceed 15 m/yr on the southern end of the islands. Northward, beach erosion rates decrease to about 5 m/yr at the Chandeleur lighthouse (Penland and Boyd, 1982) (fig. 26).

Periodically, hurricanes destroy the southernmost areas of the Chandeleur Islands, and are followed by the partial reemergence and rebuilding of the islands. Between 1869 and 1924, nine tropical cyclones made landfall, but only two were above force 2 in strength. These hurricanes resulted in a slight decrease in island area. Between 1925 and 1950, five tropical cyclones made landfall, but only one was of hurricane force. During this period. the island area increased slightly. Between 1950 and 1969, a rapid decrease in island area (from 29.7 to 21 km²) was observed-the result of the landfall of five major hurricanes, one of which was Camille, a force 5 storm. Between 1969 and 1979, when few hurricanes occurred, the island area increased again (Penland and Boyd, 1982).

A report to the Louisiana Department of Natural Resources (van Beek and Meyer-Arendt, 1982) analyzed the processes of coastal land loss, Louisiana's coastal geomorphology, erosion and accretion patterns, and potential remedial measures. Maps were constructed to depict the variability in annual shoreline change from 1955 to 1978, structural modifications, physical characteristics. shorefront use, hydrologic units, and place names. The barrier islands were described as "hot spots" of coastal erosion in Louisiana. The average rates of shoreline change calculated for Louisiana's barrier systems were: Isles Dernieres, -11.8 m/yr; Timbalier Islands, -12.1 m/yr; the Caminada-Moreau Headland. -12.7 m/yr; Grand Isle +1.8 m/yr; the Plaquemines barrier system, -8.0 m/yr; and the Chandeleur Islands, -10 m/yr. The report concluded that Louisiana's barrier systems provide important protection for human life and property, and for the renewable resources of the remaining estuarine wetlands. Beach nourishment. barrier restoration using fill, the creation of back-barrier marshes, and revegetation projects were recommended as the most cost-effective remedial actions (van Beek and Meyer-Arendt, 1982).

CURRENT USGS-LGS RESEARCH IN LOUISIANA

In 1982, in response to the seriousness of the State's coastal land loss problems, the LGS began a program of basic and applied coastal geomorphological and geologic research. This included the inventory of coastal resources; provision of technical assistance to local, State, and Federal agencies; sharing geoscience information about coastal land loss in Louisiana and the Gulf of Mexico; and assessing various coastal protection and restoration practices. It was realized from the start that the formulation and implementation of effective policies and practices to create, restore, and protect Louisiana's coastal zone would be hindered until a sufficient understanding of the causes and processes of coastal land loss in Louisiana was acquired.

Since 1982, the LGS has been working cooperatively with the USGS to conduct geologic framework studies to assess the hard mineral resources available for projects to control coastal erosion. In 1986, the USGS entered into a cooperative research effort on barrier erosion with the LGS and the Coastal Studies Institute at Louisiana State University (Sallenger and others, 1987, 1989). In 1988 the USGS expanded its effort in Louisiana by directing new research aimed at the critical processes of wetland loss, as well as establishing the Louisiana Coastal Geographic Information System Network (Sallenger and Williams, 1989; Williams and Sallenger, 1990). The current program focuses not only on research on coastal geomorphology, geology, and land loss but also on the transfer of the research results through scientific journals, conference proceedings, in-house publications, geographic information system (GIS) networks. field trips, and organized symposia.

The framework studies have focused on the evolution of coastal Louisiana during the Quaternary (figs. 27 and 28). The history of sea level fluctuations was delineated and correlated with the development of Wisconsina" and Holocene shelf-phase and shelf-margin deltas for the Mississippi River by means of high-resolution seismic surveys combined with vibracores and deep borings (Boyd and Penland, 1984; Suter and Berryhill, 1985; Suter and others, 1985; Suter, 1986a, b; Tye, 1986: Tye and Kosters, 1986; Penland and others, 1987a; Suter and others, 1987; Suter, 1987; Berryhill and Suter, 1987; Boyd and Penland, 1988; Penland and Suter, 1989; Kindinger, 1989; Kindinger and others, 1989; Boyd and others, 1989a; Boyd and others, 1989b; Penland and others, 1989b; Penland, 1990; McBride and others, 1990).

Within the Mississippi River delta plain, emphasis has been placed on understanding the transgressive phase of the delta-cycle process and in particular the formation and evolution of barrier systems (Penland and others, 1985; Suter and Penland, 1987a; Penland and others, 1988a; Suter and others, 1988; Dingler and Reiss, 1989). A thorough stratigraphic analysis of Louisiana's barrier systems led to the development of new depositional models explaining the sedimentary sequences, facies structure. and patterns of coastal evolution found in the transgressive depositional systems of the Mississippi River delta plain (figs. 9 and 29). Of particular interest have been the sedimentary and botanical factors that affect the formation of coastal marshes as well as the contribution of organic and inorganic sediment in maintaining the surface elevation of marshes against the effects of subsidence and eustasy (Kosters and Bailey, 1983; Kosters and others, 1987; Kosters, 1987; Penland and others. 1988b; Kosters, 1989). Kosters (1989) developed a model describing the dynamics of vertical marsh accretion as it relates to the formation of wetland peats in the Barataria basin (fig. 30).

The LGS houses a" extensive collection of high-resolution seismic and vibracore data from coastal Louisiana to the seaward margin of the continental shelf. The collection contains more than 15,000 km of Geopulse, Uniboom, and 3.5-kHz subbottom seismic profiles, and over 500 vibracores from the delta and chenier plains and the inner continental shelf of Louisiana.

The accurate mapping of coastal changes is fundamental to any coastal research program. Using zoom transfer photogrammetry combined with computer mapping and GIS technology, LGS has developed a precise system for accurately documenting coastal erosion and wetland loss in Louisiana and the Gulf of Mexico (McBride, 1989a, b; McBride and others, 1989a). To complement the coastal mapping system, LGS uses airborne videotape surveys to map high-resolution geomorphic changes, storm impacts, and oil spills. Since 1984, LGS has conducted a" aerial videotape survey of coastal Louisiana each summer and of Louisiana, Mississippi, Alabama, and Florida after the impact of hurricanes Danny, Elena, Juan, Florence, and Gilbert (fig. 31) (Penland and others, 1986c; Penland and others, 1987b, c, d, e; Penland and others. 1988c; McBride and others, 1989b; Penland and others. 1989c, d). These surveys are the baseline for monitoring both natural and human-caused geomorphic changes along the coast. Aerial videotapes have also been made of the Mississippi River delta and chenier plains from the interior wetlands to the Gulf of Mexico. The videotape surveys are housed in a" archive at the LGS and facilities are available for public viewing.

The rates of subsidence and relative sea level rise, the primary causes of coastal land loss in Louisiana, have bee" determined using tide gages, geodetic leveling lines, and radiocarbon data (Ramsey and Moslow, 1987; Penland and others, 1988b; Penland and others, 1989e; Ramsey and Penland, 1989; Nakashima and Louden, 1989; Penland and Ramsey, 1990). The rates of relative sea level rise range from 0.9-1.3 cm/yr on the delta plain to 0.4-0.6 cm/yr on the chenier plain (fig. 32). The thickness of the Holocene sequence and the relative age of the sediment appear to be the regional controls of subsidence (fig. 33).

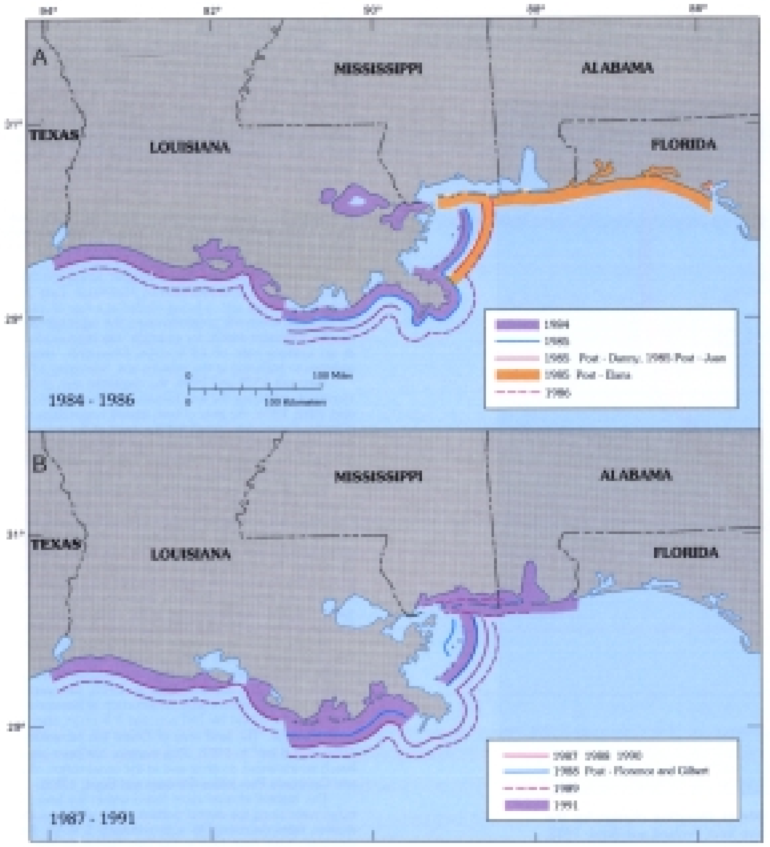


FIGURE 31.- Location of Louisiana Geological Survey aerial videotape surveys in Louisiana and the northern Gulf of Mexico, (A) 1984-1986; (B) 1987-1991.

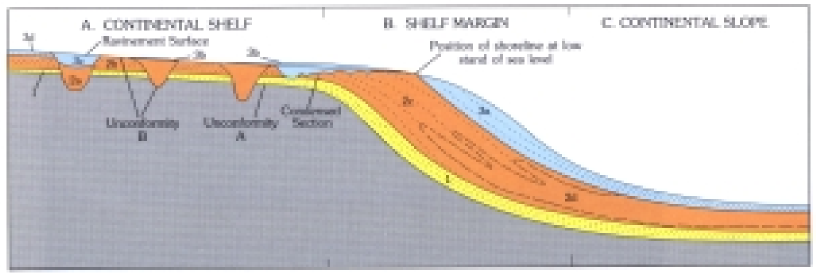


FIGURE 27.- Idealized model of Quaternary facies deposition on the Louisiana continental shelf. (1) Transgressive and aggradational deposits from previous sea-level rise. (2) Sediments associated with regressive phase of cycle: (a) fluvial and distributary channel fill; (b) shelf-phase deltaic deposits; (c) shelf-margin deltaic deposits: (d) mass transport deposits resulting from instabilities in shelf-margin deltas. (3) Sediments primarily associated with rising sea level: (a) fine-grained sediments relating to deltaic deposition during initial sea level rise and (or) abandonment of delta; (b) transgressive sands reworked from coarse-grained deltaic and alluvial deposits; (c) transgressive fluvial and estuarine sediments within fluvial channels; (d) aggradational deposits, thin on outer shelf, thickening landward. Application of the concepts of Vail and others (1977) produces a depositional sequence consisting of 1, 2b, 2c, 2d, and 3d; an overlying sequence incorporates 2a, 3a, 3b, and 3c. Unconformities A and B represent lowstand surfaces modified by shoreface erosion during transgression (redraw", by permission, from Suter and others, 1987, p. 203; © 1987 by the Society of Economic Paleontologists and Mineralogists)

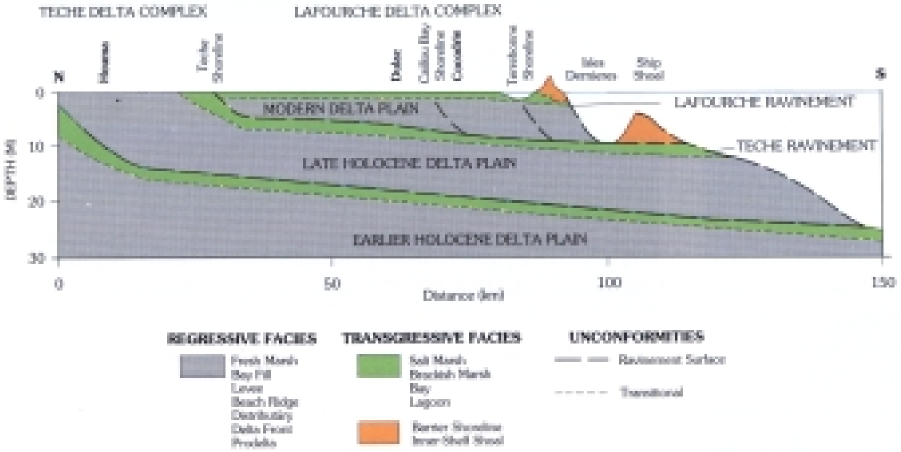


FIGURE 28.- Idealized model of the development of shelf-phase delta plains of the Mississippi River during the Holocene transgression (reprinted, by permission, from Penland and others, 1987a, p. 1696; © 1987 by the American Society of Civil Engineers)

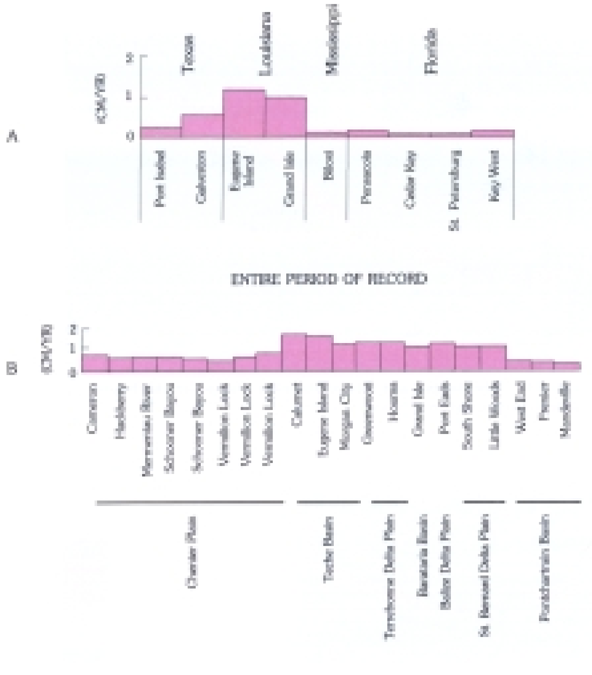


FIGURE 32.- (A) Relative sea level rise in the Gulf of Mexico between 1908 and 1983, based on National Ocean Survey tide gage stations (redrawn, by permission, from Penland and others, 1989e, p. 50; © 1989 by the Louisiana Geological Survey). **(B) Relative sea level rise in Louisiana between 1931 and 1983, based on Corps of Engineers tide gage stations** (redrawn, by permission, from Penland and others, 1989e, p. 51; © 1989 by the Louisiana Geological Survey).

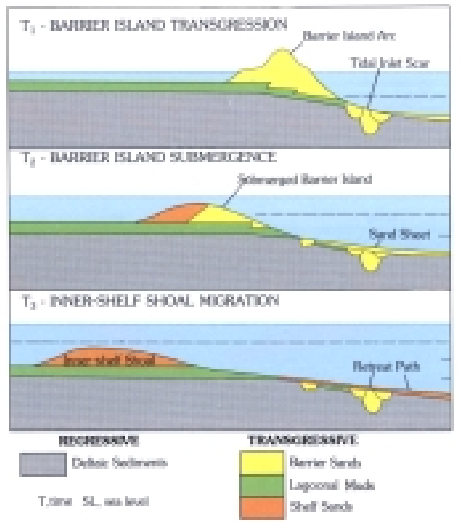


FIGURE 29.-A model of transgressive submergence; the process of shoreline and shelf sand generation on the Mississippi River delta plain. Transgression occurs when the shoreline migrates landward in response to delta abandonment, leading to erosion and reworking during shoreline and shoreface retreat. Submergence occurs when the depth of water increases as a result of eustatic, isostatic, or tectonic processes (redraw", by permission, from Penland and others, 1988a, p. 947; © 1988 by the Society of Sedimentary Geology).

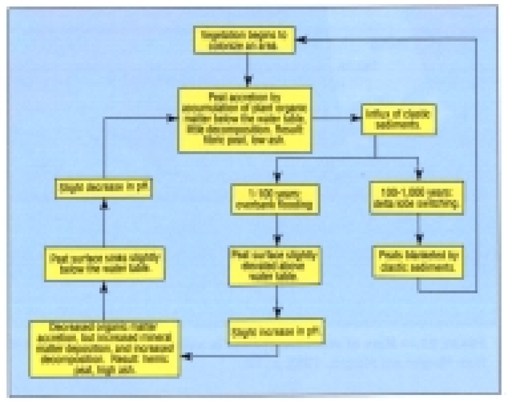


FIGURE 30.- Model of marsh accretion in the Barataria basin (redrawn. by permission, from Kosters, 1989, p. 110; © 1989 by the Society of Sedimentary Geology).

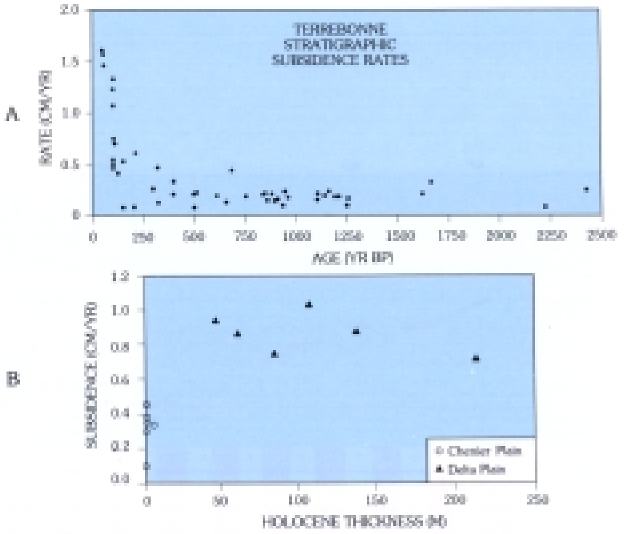


FIGURE 33.- (A) The relationship between sediment age and the rate of stratigraphic subsidence in Terrebonne Parish, Louisiana (redrawn from Penland and others, 1988b, p. **95). (B) The relationship between rate of relative sea level rise (RSL) based on tide gage records and the thickness of the Holocene sediments at the referenced station location. Note that the highest rates correlate to the thickest Holocene areas in the Mississippi River delta plain** (redrawn, by permission, from Penland and Ramsey, 1990, p. 340; © 1990 by the Coastal Education and Research Foundation).

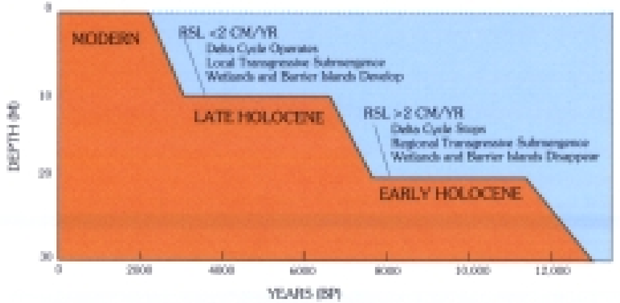


FIGURE 34.— The relationship between changes in relative sea level (RSL) and coastal stability in the Mississippi River delta plain during the last stages of the Holocene transgression.

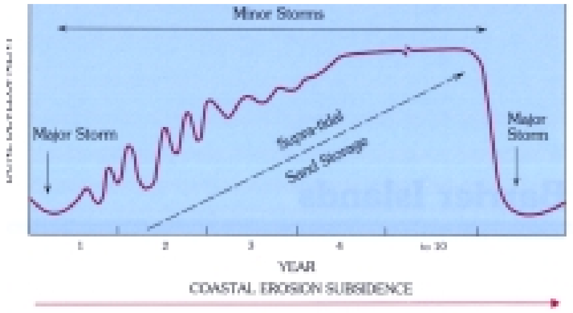


FIGURE 35.— Model of sand dune development in Louisiana as a function of storms and the return period of hurricane impact. Increasing volume of supratidal sand storage leads to dune development and revegetation, increasing the stability of the barrier shoreline. Major storms are hurricanes; minor storms are cold fronts (redrawn, by permission, from Ritchie and Penland, 1988, p. 121; © 1988 by Elsevier Science Publishers).

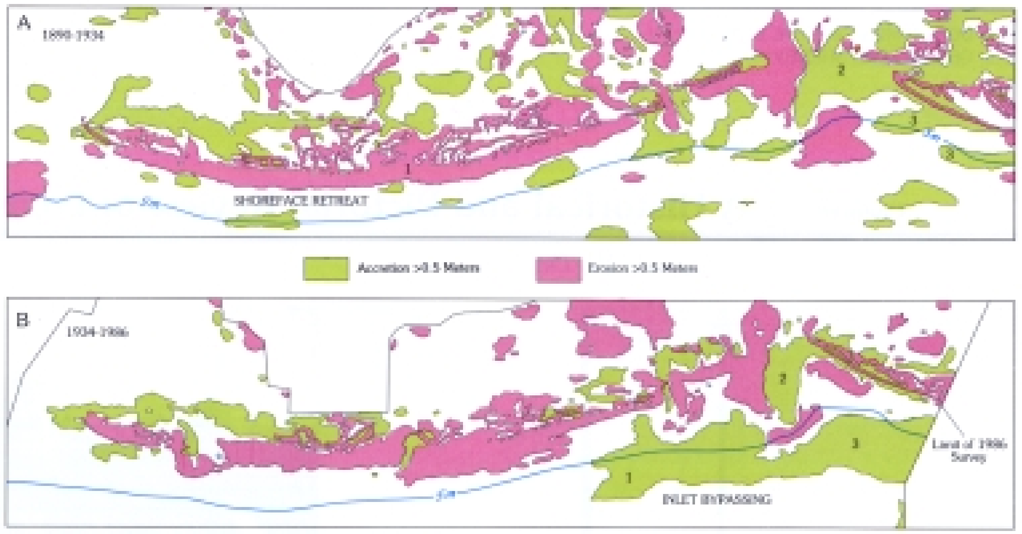


FIGURE 36.— Seafloor and island changes along the Isles Dernieres barrier system (a)1890 -1934; (b)1934 - 1986. (1) Shoreface erosion; (2) sediment deposited from longshore transport in shallow water close to Timbalier Island; (3) sediment deposited from longshore transport offshore of Timbalier Island. The 5-m depth contour is from 1986 (redrawn, by permission, from Jaffe and others, 1989, p. 407; © 1989 by the Gulf Coast Association of Geological Societies).

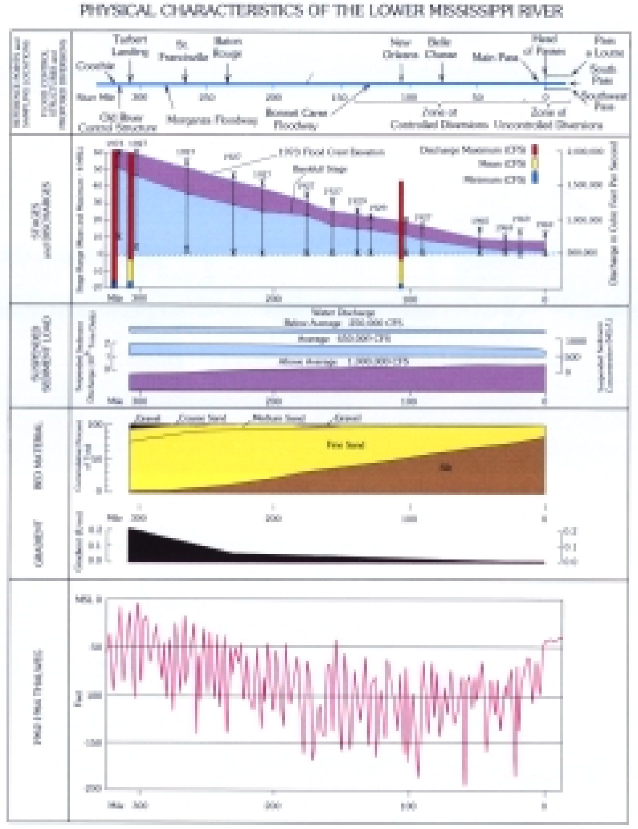


FIGURE 37.— Physical characteristics of the lower Mississippi River alluvial valley and delta plain (redrawn, by permission, from Mossa, 1988, p. 305; © 1988 by the Gulf Coast Association of Geological Societies).

The geologic studies of the barrier systems and continental shelf revealed the occurrence of several stillstands in sea level during the last stages of the Holocene transgression. Three major delta plains have been identified to date, each separated by a maximum flooding or ravinement surface that was the product of a significant rise in sea level. It appears that whenever relative sea level rises rapidly (over 2 cm/yr) for centuries. the delta cycle process of the Mississippi River Stops, and the wetlands, estuarine bays. and barrier islands gradually disappear. In contrast. it appears that whenever relative sea level rise rates drop below 2 cm/yr, the delta cycle process creates new wetlands. estuarine bays. and barrier islands (fig. 34). The implication of this pattern. in light of the EPA and NRC scenarios for future sea level rise, is that the delta and chenier plains of the Mississippi River already are in a cycle of coastal land loss; if the rate of sea level rise approaches 3 cm/yr over the next century as predicted, drastic changes in the coastal area can be expected.

Overwash processes associated with cold fronts, tropical storms, and hurricanes are important contributors to beach erosion. high rates of sediment transport, and dramatic landscape changes (Ritchie and Penland, 1988; Dingler and Reiss, 1988; Penland and others, 1989a; Ritchie and Penland, 1989; Dingler and Reiss, 1990; Ritchie and Penland, 1990a). Because sand dunes provide protection from storm surge and high-energy wave impacts, understanding their formative processes and vegetation dynamics is critical to the development of effective sediment management practices (Ritchie and others, 1989; Ritchie and Penland, 1990b; Ritchie and others, 1990). Extensive field work over the last decade has documented a predictable pattern of storm impact, beach erosion, overwash, and sand dune development controlled by frequent minor cold fronts, infrequent major hurricanes, and sand supply (fig. 35).

A sediment budget analysis of barrier island erosion and deposition between Raccoon Point and Sandy Point is in progress to determine the volume of sediment transported and the regional trends of dispersal (Jaffe and others, 1988; Jaffe and others, 1989; Williams and others, 1989a). The sediment budget analysis compares historical bathymetric surveys with new ones conducted by the USGS to determine the volumetric trends in erosion or deposition on the seafloor and shoreline changes (fig. 36). The results will aid in the development of effective sediment management practices for the barrier systems.

In order to better understand the availability of water and sediment, Mossa (1988, 1989) has investigated the discharge-and-sediment dynamics of the lower Mississippi River system. The study shows that optimum conditions for diverting surplus fresh water and sediment from the Mississippi River occur in winter and spring (Mossa and Roberts, 1990). The use of diversions will require different management strategies during high and low flow years due to the physical characteristics of the Mississippi River (fig. 37). During years with high discharges, the sediment concentration and load maxima typically precede discharge maxima by several months. By the time the maxima discharge peaks, the sediment load is greatly reduced. In low-discharge years, the highest suspended sediment concentrations and loads closely coincide with the discharge maxima.

The performance and impact of coastal structures have been investigated to determine the best approach to coastal erosion control The results indicate that projects using sediment and vegetation in beach nourishment and shoreline restoration projects are the most cost-effective (Mossa and others, 1985: Penland and others, 1986d; Nakashima and others, 1987: Nakashima, 1988, 1989; Penland and Suter, 1988a; Mossa and Nakashima, 1989).

For controlling coastal erosion, the location, quality, and quantity of sediment resources must be known. High resolution seismic surveys, using vibracores to ground truth the interpretations, were used to define the availability of sediment resources for barrier island erosion control. To support the subsurface sand resource mapping, extensive surficial sediment surveys were conducted between Raccoon Point, Sandy Point, and offshore to Ship Shoal in order to map the surface texture distribution (Circe' and Holland, 1987, 1988; Circe and others, 1988, 1989; Williams and others, 1989b). Seven major surficial sediment facies were identified and mapped by collecting sediment samples from selected sites throughout the region (fig. 38).

New research results must be made available in forms that decision-makers can understand and use. One of the goals of the cooperative LGS and USGS coastal research program is to make information available in the form of atlases, journal papers, and conference proceedings. This atlas of Louisiana shoreline change between 1853 and 1989 builds on previous work by Morgan and Larimore (1957). Morgan and Morgan (1983). Adams and others (1978), Penland and Boyd (1981, 1982), van Beek and Meyer-Arendt (1982), McBride and others (1989a), and the U.S. Army Corps of Engineers (1975, 1978, 1980). The information and new research results presented are the most accurate analysis to date of barrier island changes surrounding the Mississippi River delta plain in Louisiana. The chapters in this atlas are intended to provide the reader with insight to the geomorphology, geology, and resources of Louisiana's barrier systerns as well as the status of previous research and current USGSLGS research on the coastal land loss problem.

Sediment can be used in three ways: beach nourishment. shoreline restoration, and back-barrier marsh building (fig. 39). Beach nourishment projects are intended for developed shorelines, such as Grand Isle. which have an existing infrastructure that must be protected from beach erosion and storm impacts. Shoreline restoration and back-barrier marsh building are for uninhabited barrier islands; they aim to restore habitat integrity in order to preserve the estuary protected by a barrier system. The sediment resource inventory documented that there is enough material available for the foreseeable future to protect and restore Louisiana‘s barrier systems (Suter and Penland, 1987b; Penland and Suter, 1988b; Penland and others, 1988d; Williams and Penland, 1988; Suter and others, 1989; Penland and others, 1990b, c).

COASTAL RESEARCH SUMMARY

Louisiana‘s coastal land loss crisis cannot be managed effectively until the patterns of coastal change and the factors that influence them are understood. The search for this knowledge has been the theme of coastal research in Louisiana over the last half century, and is the continuing objective of the LGS and USGS coastal research programs today. The studies have concentrated on identifying the land loss problem; analyzing the geologic framework and accompanying coastal processes, including the dynamics of vegetation and sediment loss; and assessing the feasibility of erosion control projects. All of this work aims to develop new geoscience information useful for developing management policies and strategies.

Louisiana's coastal land loss problem is becoming more severe because of global climate changes that are causing the rate. of worldwide sea level rise to accelerate. At the same time, both the population and industrial development are moving onto the fragile barrier-built estuaries and low-lying deltaic wetlands, which are at the highest risk. The management of Louisiana's coastal zone over the next century will require a compromise between these socioeconomic demands and the protection and restoration of sensitive coastal environmental resources.

Continued ignorance of or disregard for the geologic processes that continually reshape Louisiana's coastal zone will result in the failure of any comprehensive coastal protection or restoration plan. Predicting the performance of projects to control coastal land loss and assessing likely future coastal conditions requires an understanding of how a particular coastal environment has formed and what natural changes have taken place in recent geologic history. To make wise decisions, coastal planners, engineers, and managers as well as political decisionmakers and the public must be made aware of the new results of scientific investigations so that they can understand the range of management approaches and the associated social, financial, and environmental costs as well as the risks associ ated with each approach. Cooperation is necessary among federal, state. and local agencies to ensure that scientific information and expertise is applied to site-specific projects.

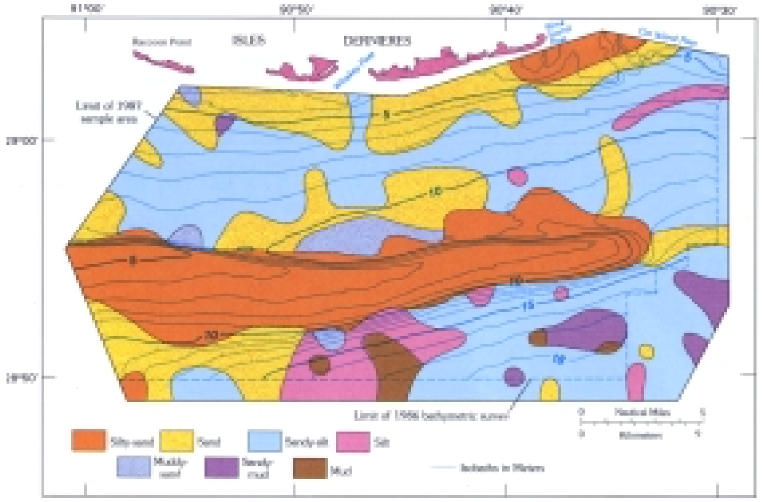


FIGURE 38.— Seven major sediment facies of the inner shelf off south-central Louisiana (redrawn, by permission, from Williams and others, 1989a, p. 573; © 1989 by the Gulf Coast Association of Geological Societies).

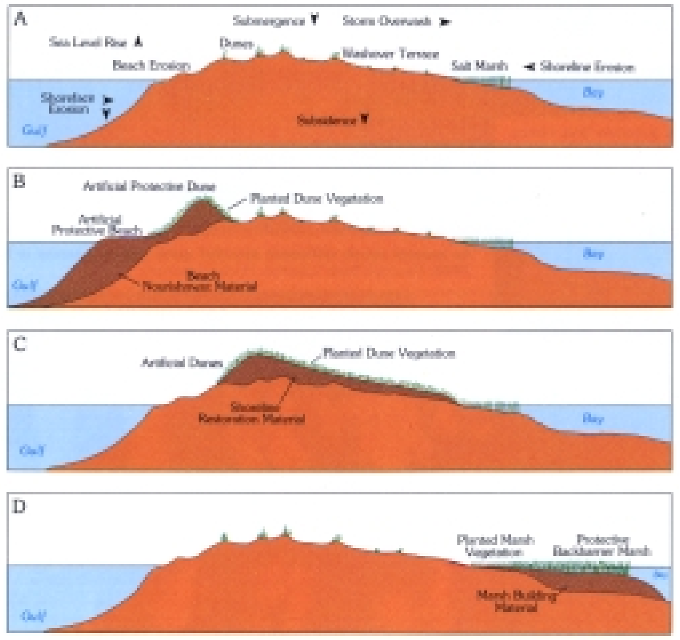


FIGURE 39.— Three designs for using sediment and vegetation to preserve and protect Louisiana's barrier systems. (A) Barrier island erosion problems. (B) Beach nourishment. (C) Barrier island restoration. (D) Back-barrier marsh building.

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