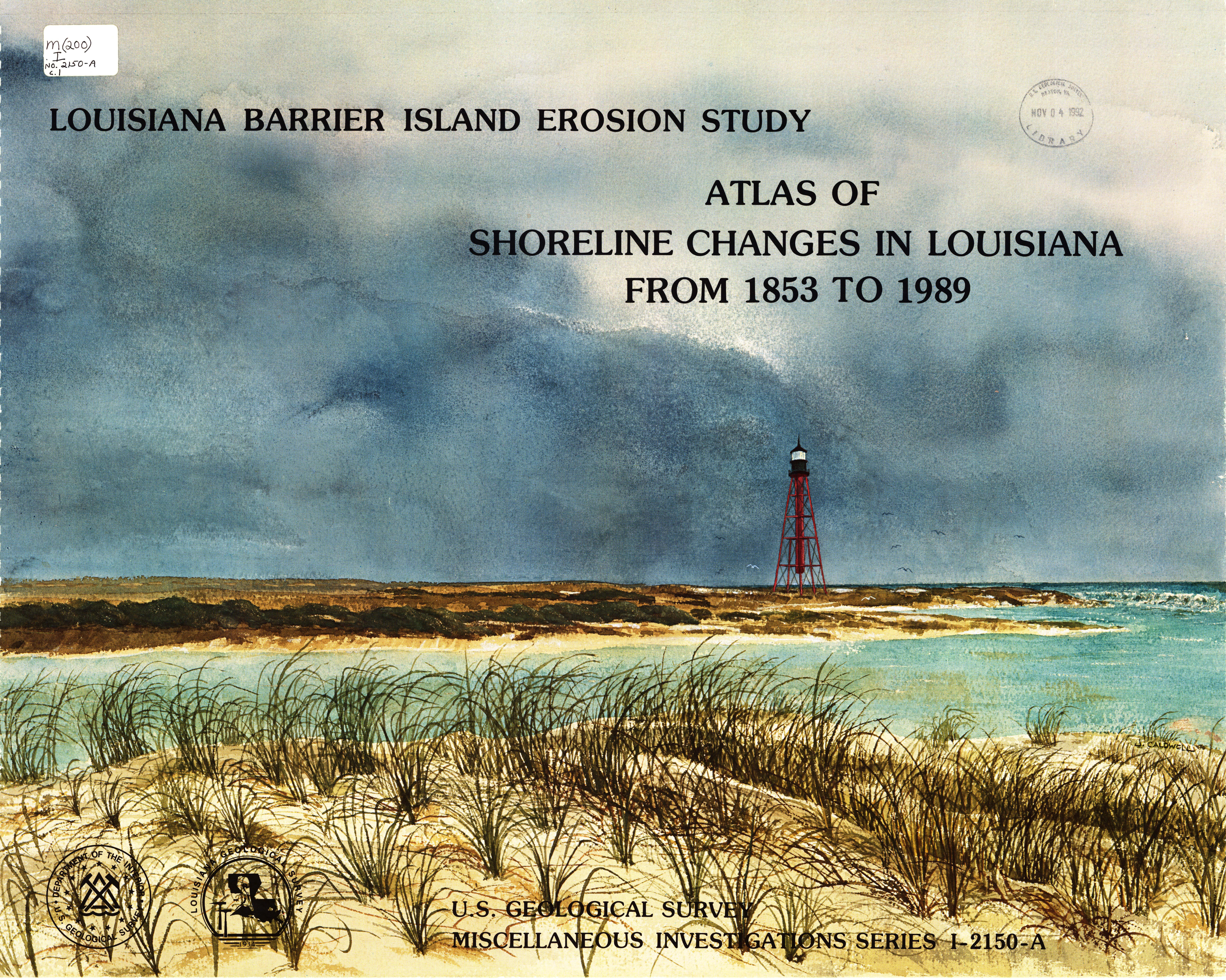
LOUISIANA BARRIER ISLAND EROSION STUDY

ATLAS OF SHORELINE CHANGES IN LOUISIANA FROM 1853 TO 1989



U.S. GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES I-2150-A

LOUISIANA BARRIER ISLAND EROSION STUDY

ATLAS OF SHORELINE CHANGES IN LOUISIANA FROM 1853 to 1989

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1992

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

Prepared in cooperation with the

LOUISIANA GEOLOGICAL SURVEY
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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.

Library of Congress Cataloging-in-Publication Data

Louisiana Geological Survey.
Atlas of shoreline changes in Louisiana from 1853 to 1989: [Louisiana] / prepared by the U.S. Geological Survey in cooperation with the Louisiana Geological Survey; S. Jeffress Williams, Shea Penland, and Asbury H. Sallenger, editors; cartography by John I. Snead...[et al.].
p. cm. - - (Miscellaneous investigations; I–2150–A)
(Louisiana barrier island erosion study; I–2150–A)
Includes bibliographical references.
1. Coastal changes - - Louisiana - - Maps. 2. Shorelines - - Louisiana - - Maps. I. Geological Survey (U.S.) II. Title. III. Series. IV. Series: Miscellaneous investigations series (Geological Survey (U.S.)) ; I–2150–A.
G1362.C6C2L6 1992 <G&M>
551.4 ' 58 ' 09763022 - - dc20 92-4709
CIP
MAP

Manuscript approved for publication on July 22, 1991

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1992

For sale by U.S. Geological Survey, Map Distribution
Box 25286, Federal Center, Denver, CO 80225
and the Louisiana Geological Survey
Box G, University Station, Baton Rouge, LA 70893

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.

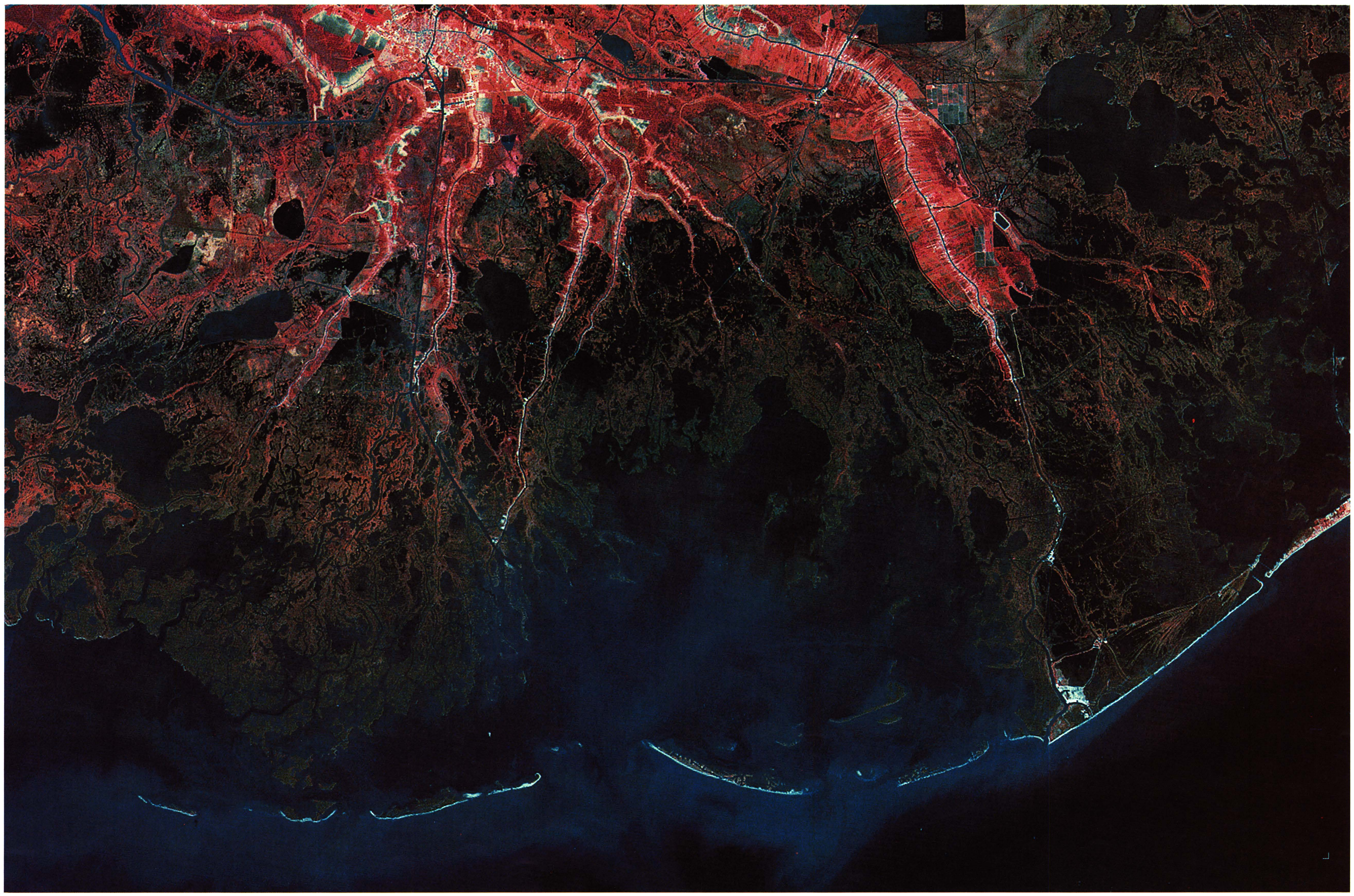
A particularly important finding is the role of barrier islands in protecting the wetlands, bays, and estuaries behind the islands. Barrier islands help reduce wave energy at the margin of wetlands and thus limit mechanical erosion. Barriers also limit storm surge heights and retard saltwater intrusion. 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

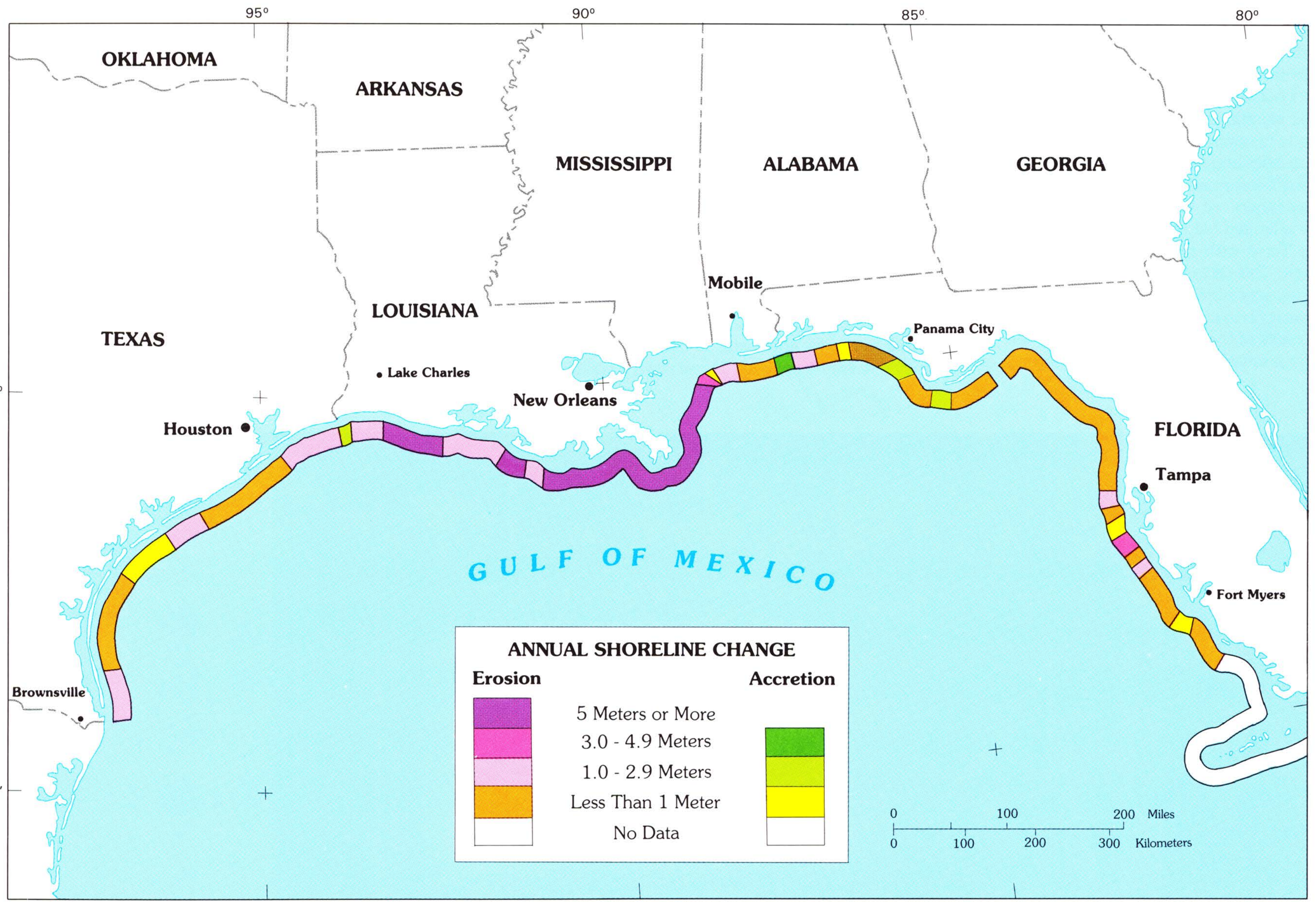


Figure 1.— Coastal erosion and accretion on the U.S. Gulf Coast (redrawn from U.S. Geological Survey, 1988).

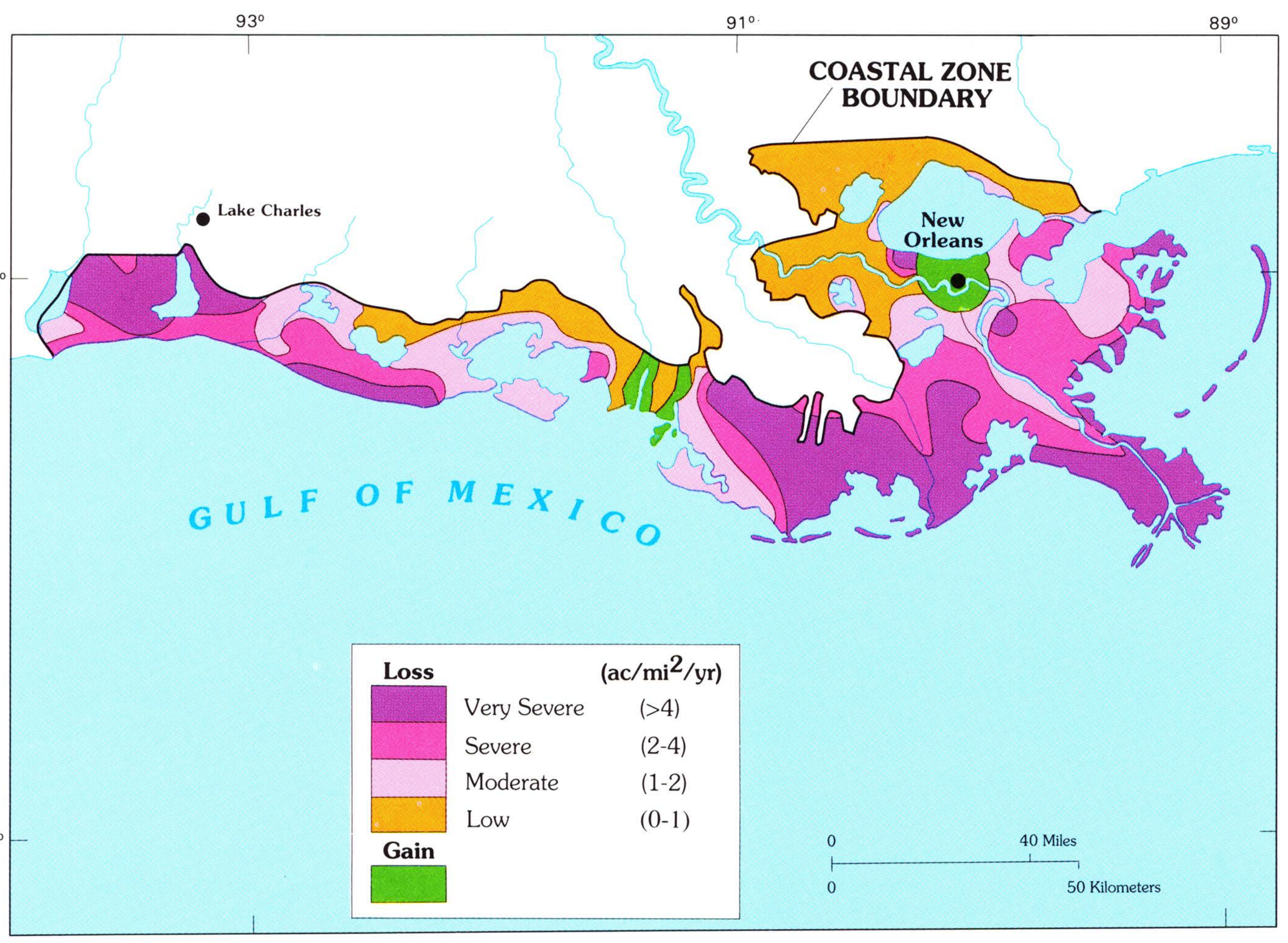


Figure 2.— Coastal land loss in Louisiana, 1955–1978 (redrawn and adapted from van Beek and Meyer-Arendt, 1982, p. 16).

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	

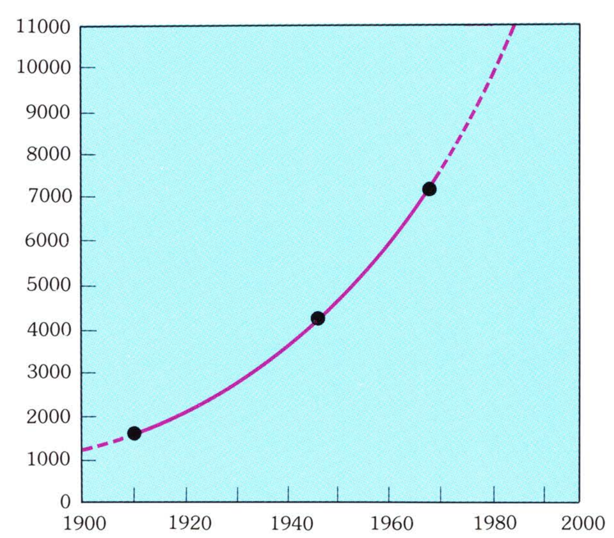


Figure 4.— Coastal land loss, in ha/yr, in Louisiana's Mississippi River delta plain, 1955–1978. (data from Gagliano and others, 1981, p. 298).

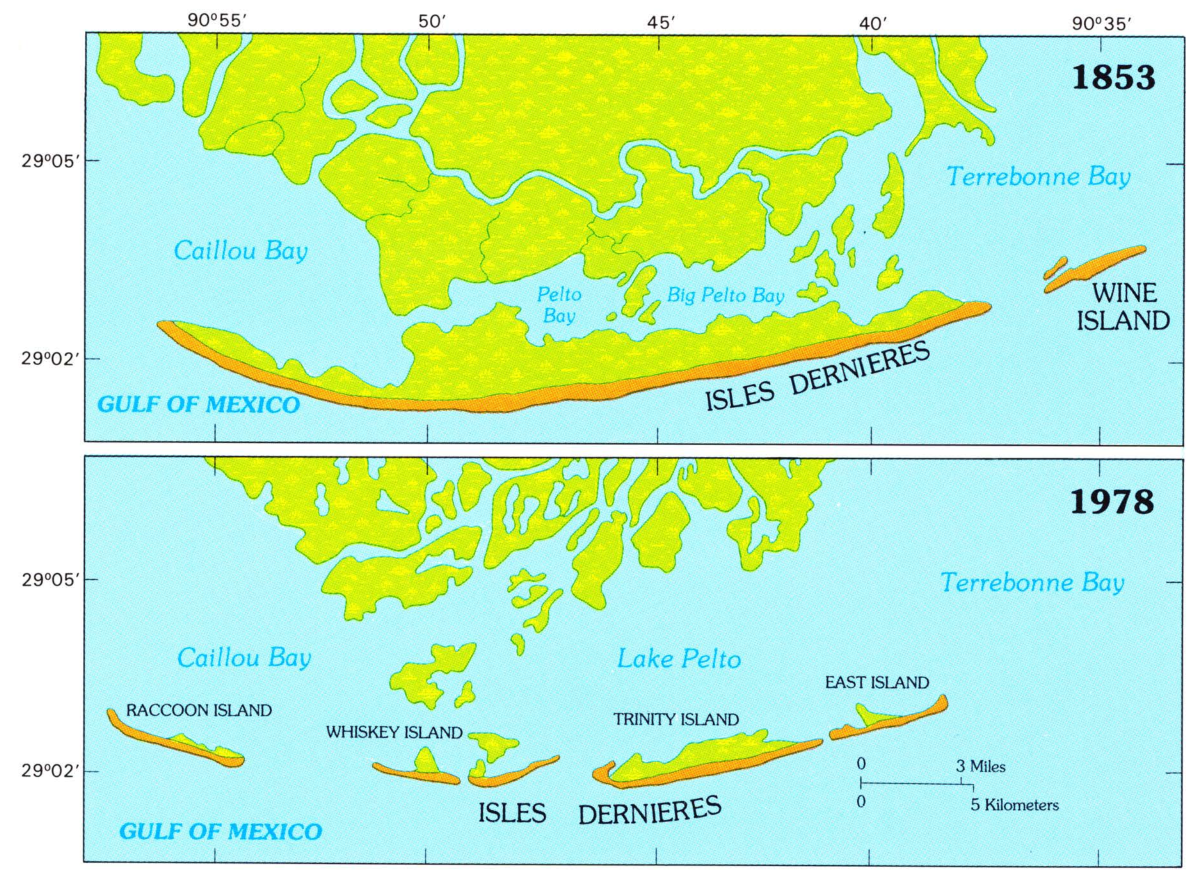


Figure 3.— Shoreline change in the Isles Dernieres, 1853–1978 (redrawn and adapted, by permission, from Penland and Boyd, 1981, p. 216; © 1981 by IEEE).

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 B1 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 Dernieres 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 Dernieres, 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 (mi^2/yr)	Time Period 2	Average Loss (mi^2/yr)	Time Period 3	Average Loss (mi^2/yr)
Barataria	1939–1956	1.08	1956–1974	1.20	1974–1983	0.70
Bay Dogris	1932–1958	0.42	1958–1974	1.44	1974–1983	1.26
Bayou Du Large	1932–1958	0.18	1958–1974	1.61	1974–1983	0.65
Bayou Sale	1937–1956	0.31	1956–1974	0.36	1974–1983	0.19
Belle Isle	1940–1956	0.38	1956–1974	0.32	1974–1983	0.15
Black Bay	1932–1958	0.21	1958–1974	0.37	1974–1983	0.52
Bonnet Carre	1936–1958	0.10	1958–1974	0.44	1974–1983	0.19
Breton Island	1932–1958	0.26	1958–1974	0.18	1974–1983	0.11
Caillou Bay	1932–1958	0.22	1958–1974	0.40	1974–1983	0.43
Cat Island	1932–1958	0.0	1958–1974	0.09	1974–1983	0.11
Chef Menteur	1932–1958	0.49	1958–1974	0.41	1974–1983	0.28
Covington	1932–1958	0.02	1958–1974	0.18	1974–1983	0.02
Cut Off	1939–1958	0.22	1958–1974	0.53	1974–1983	0.39
Derouen	1932–1956	0.24	1956–1974	0.22	1974–1983	0.24
Dulac	1932–1958	0.37	1958–1974	0.98	1974–1983	1.99
East Delta	1932–1958	1.17	1958–1974	1.90	1974–1983	0.27
Empire	1932–1958	0.35	1958–1974	1.12	1974–1983	2.66
Fort Livingston	1932–1958	0.34	1958–1974	0.53	1974–1983	0.89
Gibson	1939–1958	0.11	1958–1974	1.50	1974–1983	0.45
Hahnville	1935–1958	0.11	1958–1974	0.57	1974–1983	0.43
Houma	1939–1958	0.13	1958–1974	0.24	1974–1983	0.17
Jeanerette	1937–1956	0.08	1956–1974	0.08	1974–1983	0.06
Lac des Allemands	1945–1958	0.13	1958–1974	0.11	1974–1983	0.66
Lake Decade	1931–1956	0.25	1956–1974	1.31	1974–1983	0.38
Lake Felicity	1932–1958	0.29	1958–1974	1.32	1974–1983	1.61
Leeville	1932–1958	0.28	1958–1974	0.40	1974–1983	0.90
Marsh Island	1932–1956	0.23	1956–1974	0.39	1974–1983	0.24
Mitchell Key	1932–1956	0.05	1958–1974	0.03	1974–1983	0.07
Morgan City	1931–1956	0.20	1956–1974	1.37	1974–1983	0.93
Morgan Harbor	1932–1958	0.19	1958–1974	0.32	1974–1983	0.38
Mount Airy	1939–1958	0.05	1958–1974	0.08	1974–1983	0.08
New Orleans	1935–1958	0.17	1958–1974	0.26	1974–1983	0.14
Oyster Bayou	1931–1956	0.07	1956–1974	0.18	1974–1983	0.15
Point Chicot	1932–1958	0.08	1958–1974	0.08	1974–1983	0.07
Point au Fer	1931–1956	0.11	1956–1974	0.16	1974–1983	0.17
Pointe a la Hache	1932–1958	0.28	1958–1974	0.75	1974–1983	0.71
Pontchatoula	1939–1958	0.07	1958–1974	0.09	1974–1983	0.08
Rigolets	1932–1958	0.11	1958–1974	0.24	1974–1983	0.26
Slidell	1939–1958	0.06	1958–1974	0.15	1974–1983	0.05
Southwest Pass	1932–1958	0.10	1958–1974	0.12	1974–1983	0.02
Spanish Fort	1936–1958	0.03	1958–1974	0.01	1974–1983	0.003
Springfield	1939–1958	0.01	1958–1974	0.01	1974–1983	0.03
St. Bernard	1932–1958	0.29	1958–1974	1.23	1974–1983	0.70
Terrebonne Bay	1932–1958	0.18	1958–1974	0.29	1974–1983	0.49
Thibodaux	1949–1958	0.003	1958–1974	0.02	1974–1983	0.07
Three Mile Bay	1932–1958	0.08	1958–1974	0.11	1974–1983	0.10
Timbalier Bay	1934–1958	0.21	1958–1974	0.22	1974–1983	0.41
Venice	1932–1958	0.61	1958–1974	1.50	1974–1983	0.54
West Delta	1932–1958	1.41	1958–1974	2.0	1974–1983	1.04
Yscloskey	1932–1958	0.12	1958–1974	0.60	1974–1983	0.53

(Data from Britsch and Kemp, 1990, p. 15–16.)

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

Quadrangle[1] Name	Time Period 1	Average Loss (mi^2/yr)	Time Period 2	Average Loss (mi^2/yr)	Time Period 3	Average Loss (mi^2/yr)
Abbeville	1934–1954	0.075	1954–1974	0.245	1974–1983	0.255
Cameron	1933–1955	0.077	1955–1974	2.468	1974–1983	0.596
Cheniere Au Tigre	1935–1951	0.076	1951–1974	0.358	1974–1983	0.127
Constance Bayou	1932–1955	0.641	1955–1974	0.822	1974–1983	0.495
Forked Island	1935–1955	0.019	1955–1974	0.152	1974–1983	0.145
Grand Lake East	1932–1955	0.324	1955–1974	0.438	1974–1983	1.643
Grand Lake West	1933–1955	0.048	1955–1974	1.116	1974–1983	1.302
Hog Bayou	1932–1955	0.537	1955–1974	0.723	1974–1983	0.151
Johnsons Bayou	1933–1955	0.088	1955–1974	3.119	1974–1983	1.022
Pecan Island	1935–1955	0.063	1951–1974	0.792	1974–1983	0.752
Sulphur	1933–1955	0.047	1955–1974	1.823	1974–1983	0.395
Sweet Lake	1933–1955	0.129	1955–1974	1.796	1974–1983	0.839

[1]Approximate area of a 15–minute quadrangle is 300 mi^2.
(Data from Dunbar and others, 1990, p. 10.)

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 Schofield Pass Bay Couquette Pass	Barataria Bay Bay Ronquille Bay La Mer Bay Joe Wise Bastian Bay Bay Couquette
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

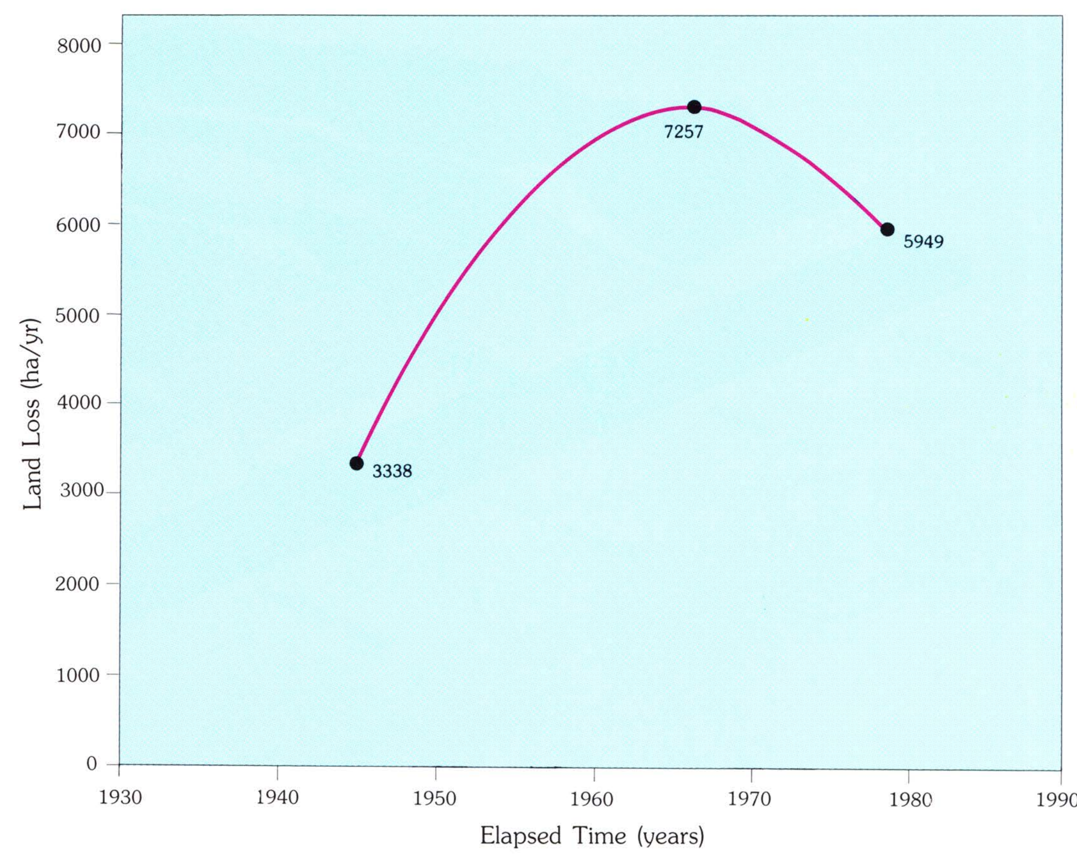


FIGURE 5.— Coastal land loss rate curve for the Mississippi River delta plain (data from Britsch and Kemp, 1990, p. 22).

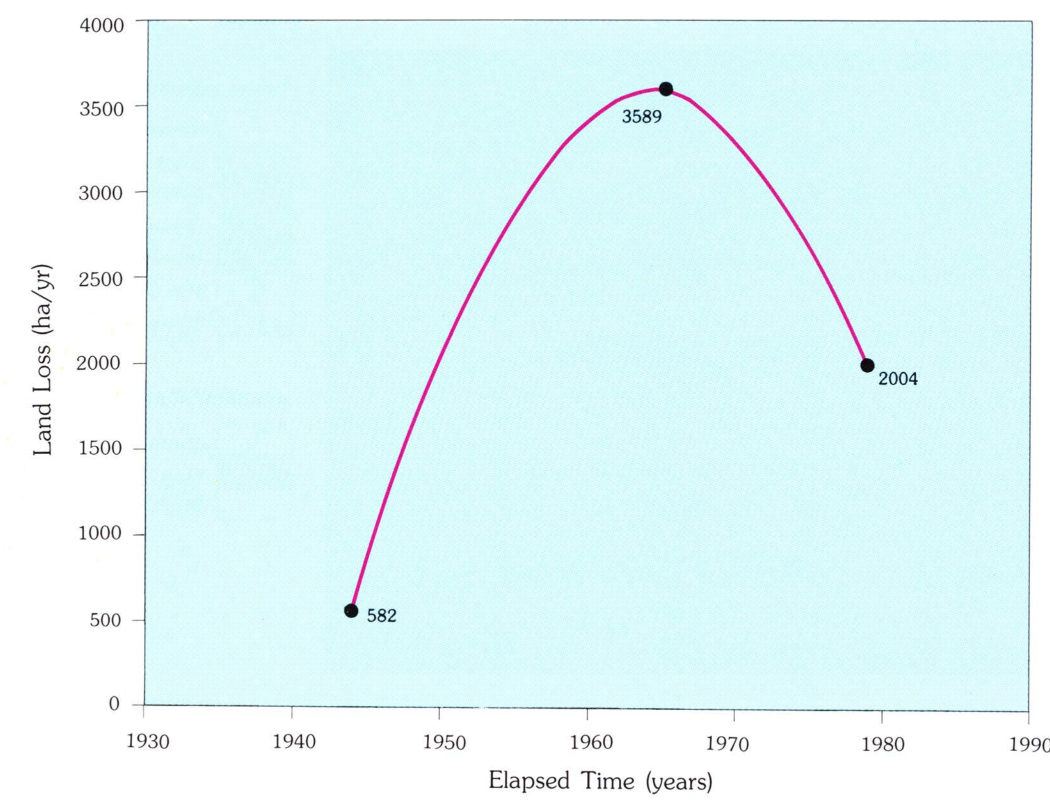


FIGURE 6.— Coastal land loss rate curve for the Mississippi River chenier plain (data from Dunbar and others, 1990, p. 12).

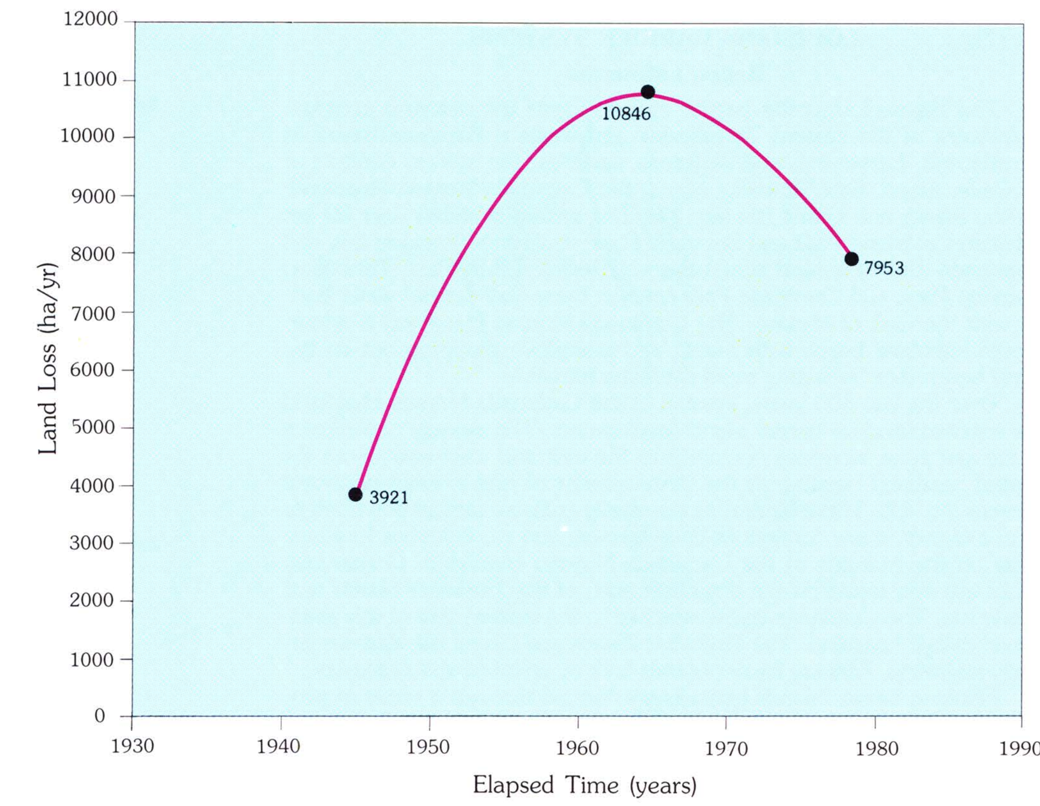


FIGURE 7.— Composite coastal land loss rate curve for the Mississippi River delta and chenier plains in Louisiana (data from Dunbar and others, 1990, p. 14).

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).

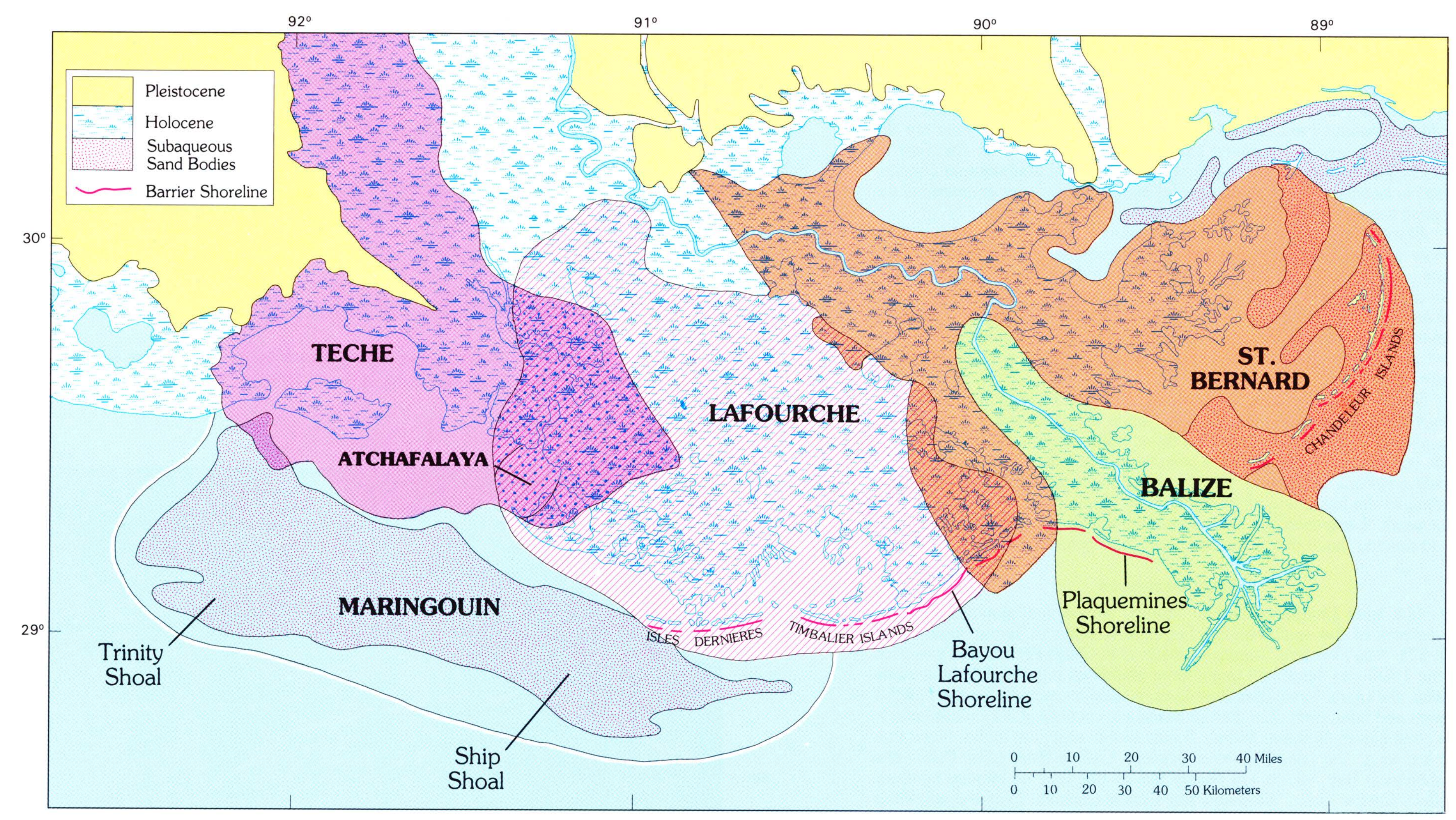


FIGURE 8.— The Mississippi River delta complex, with barrier islands indicated (redrawn and adapted, by permission, from Frazier, 1967, p. 289; © 1967 by the Gulf Coast Association of Geological Societies).

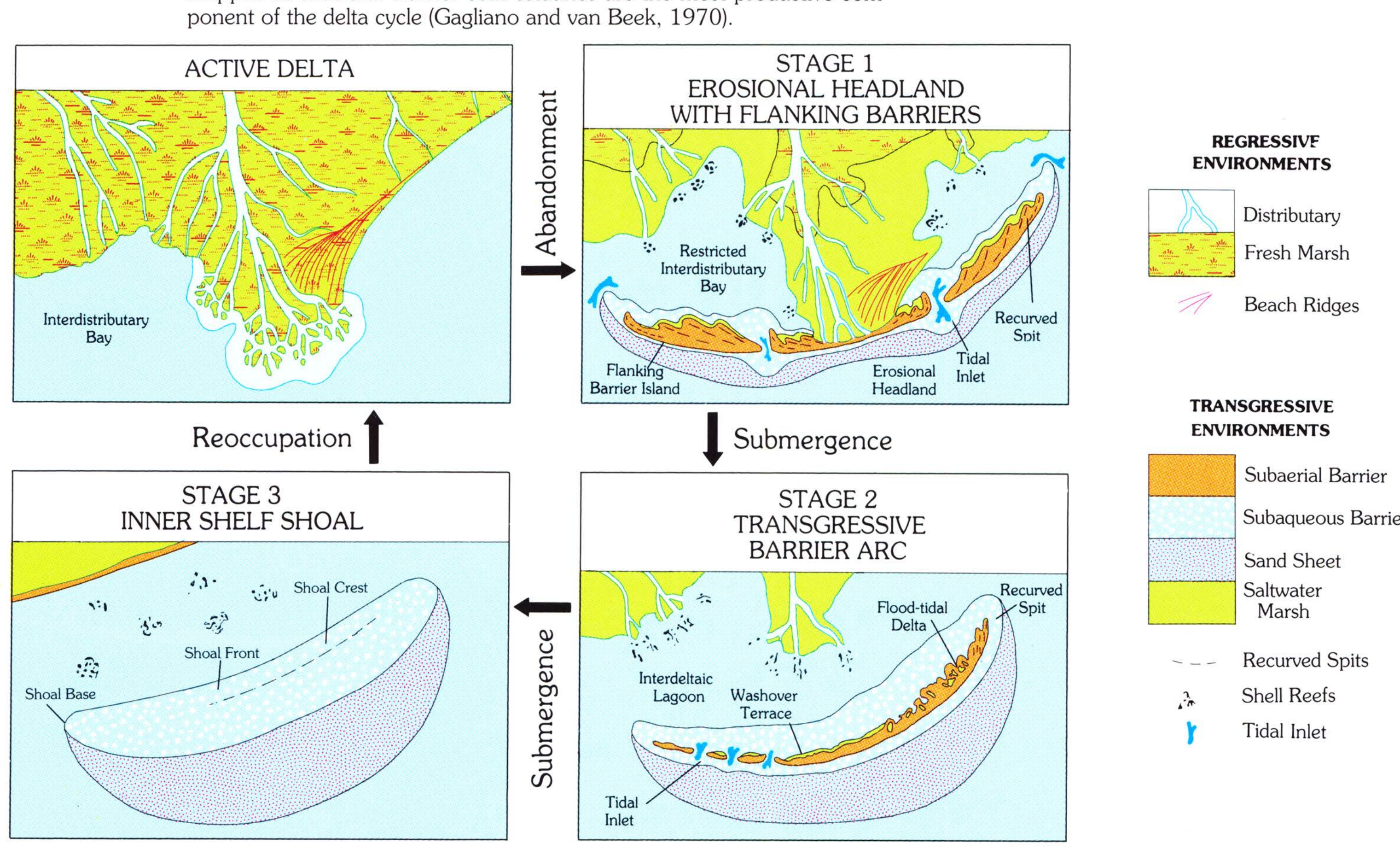


FIGURE 9.— A model of barrier island development (redrawn and adapted, by permission, from Penland and Boyd, 1981, p. 211; © 1981 by IEEE).

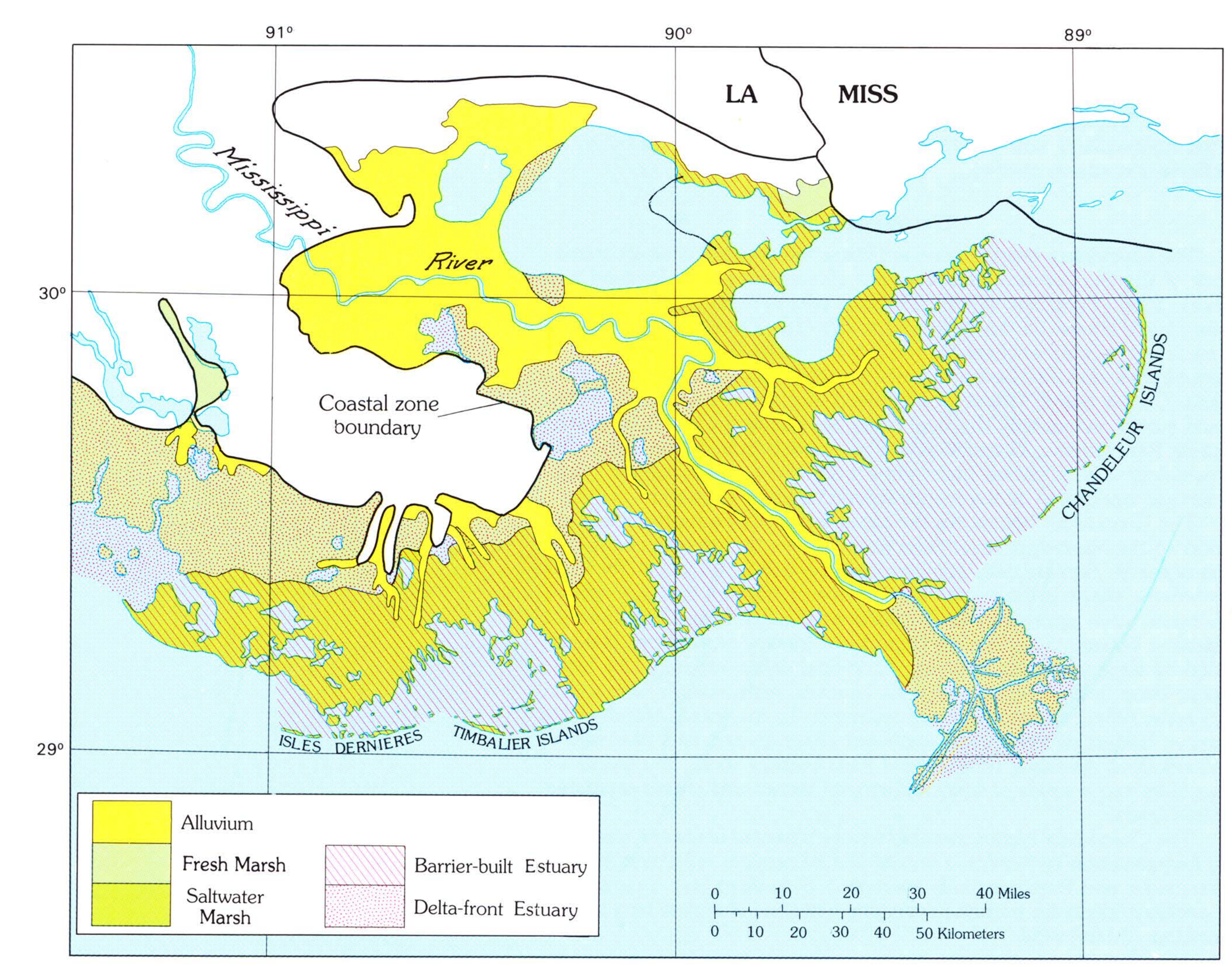


FIGURE 10.— Distribution of barrier-built and delta-front estuaries in the Mississippi River delta plain.

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 Bayoux 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.

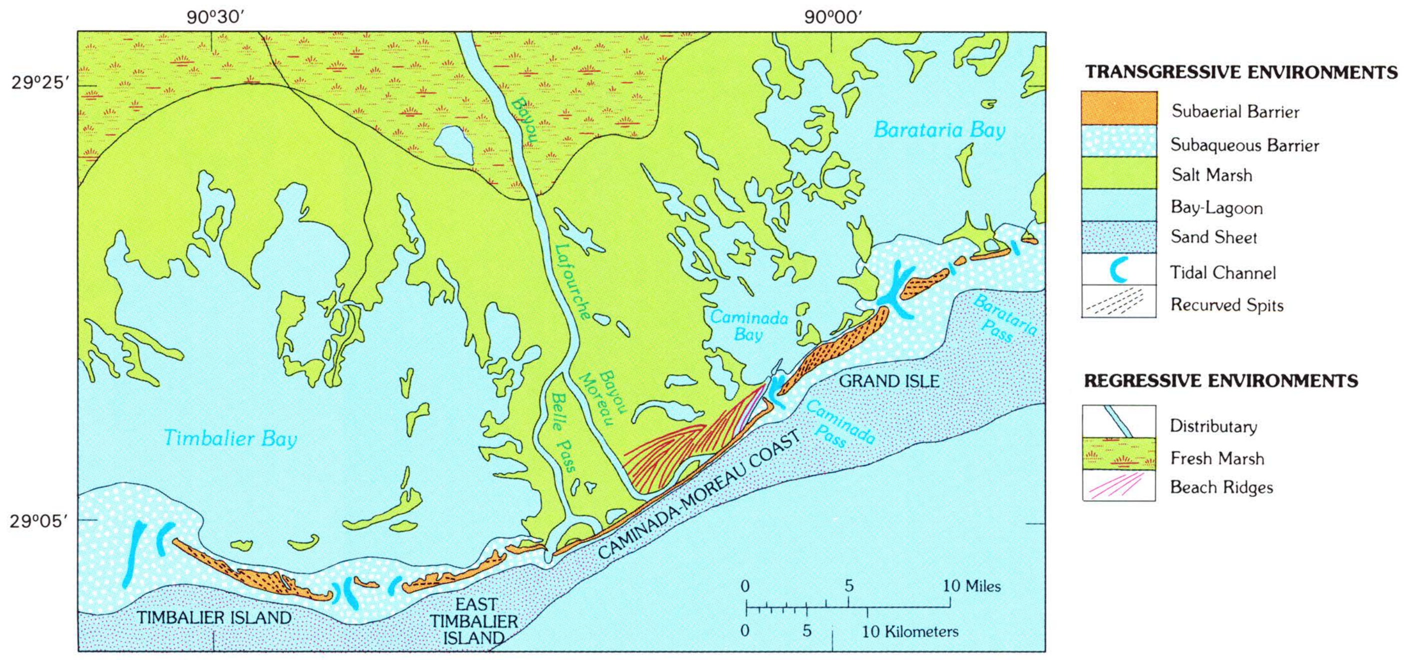


FIGURE 11.— Coastal environments of the Bayou Lafourche barrier system (redrawn from Penland and others, 1988b, p. 19).

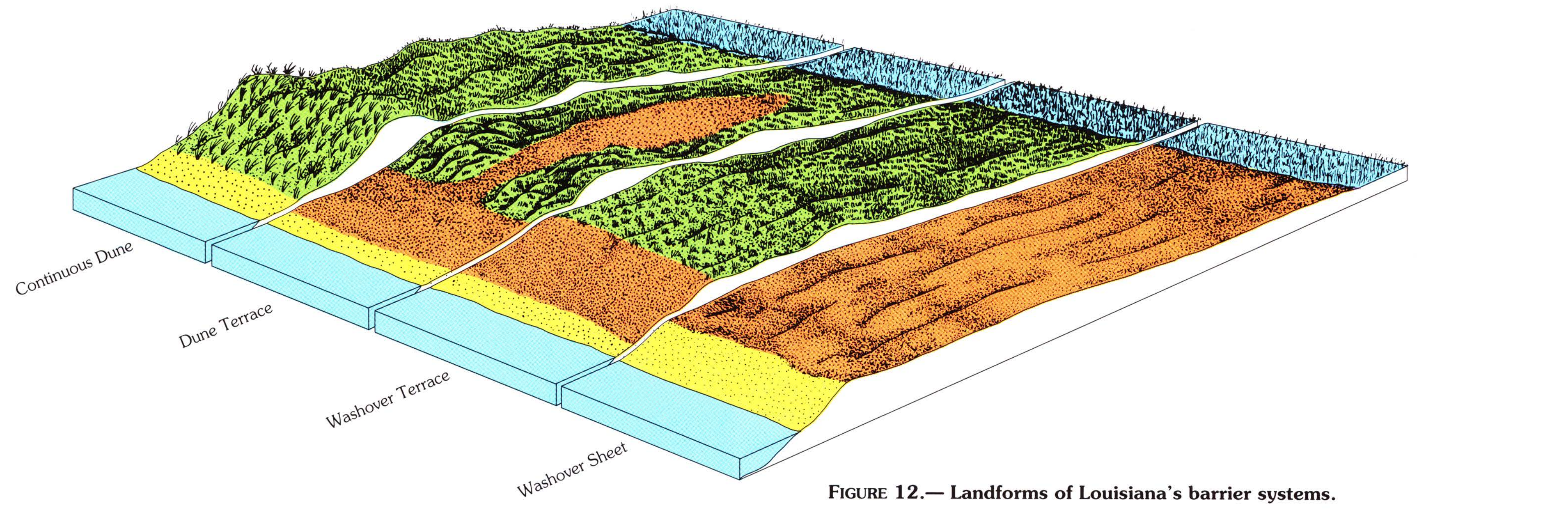


FIGURE 12.— Landforms of Louisiana's barrier systems.

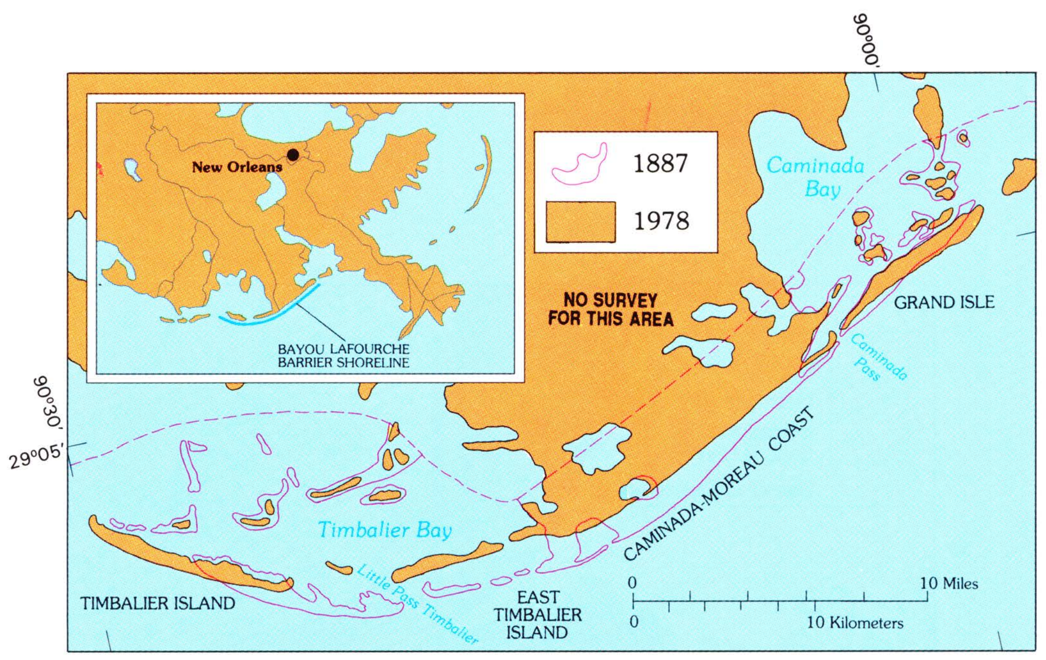


FIGURE 13.— Shoreline change along the Bayou Lafourche barrier system, 1887–1978 (redrawn from Penland and Boyd, 1985, p. 86).

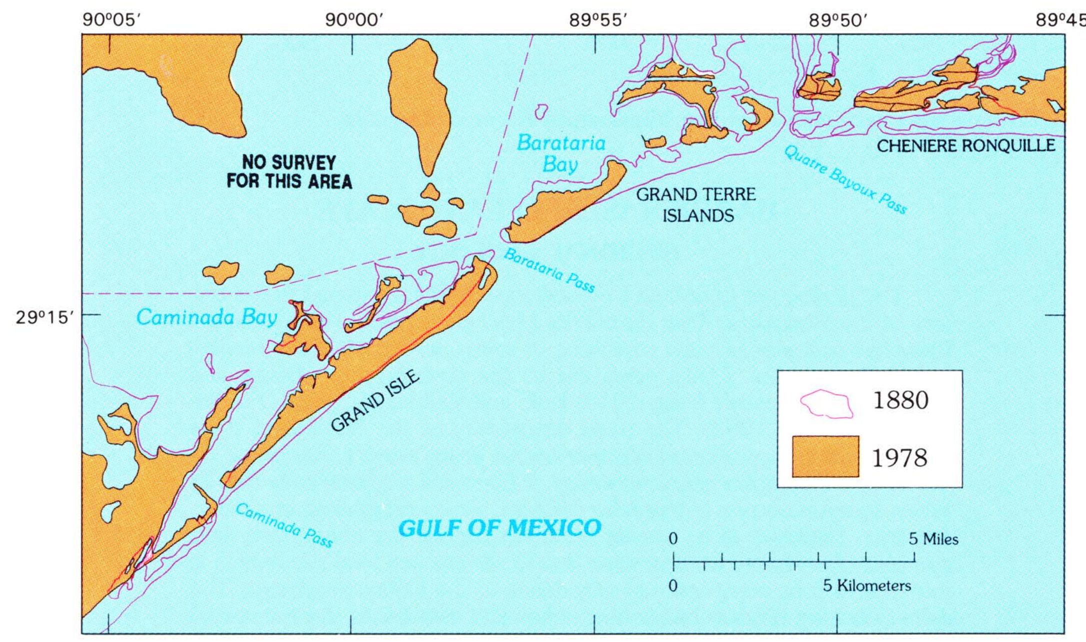


FIGURE 15.— Shoreline change at Grand Terre, 1880–1978 (redrawn, by permission, from Penland and Suter, 1988a, p. 335; © 1988 by the Gulf Coast Association of Geological Societies).

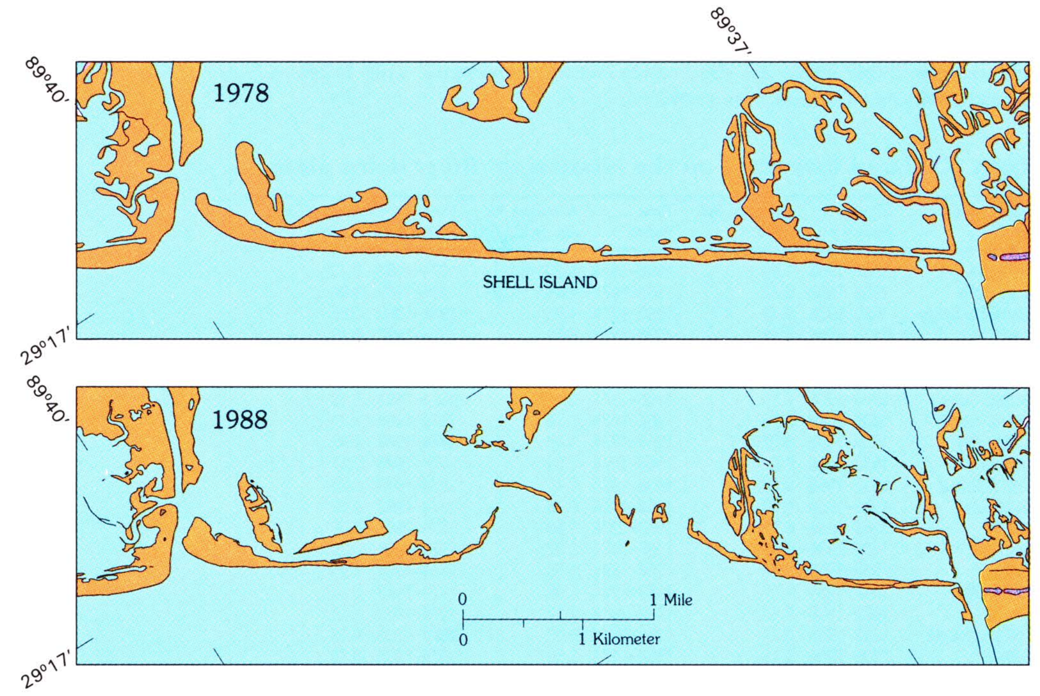


FIGURE 16.— Shoreline change at Shell Island, 1978–1988 (redrawn, by permission, from Penland and Suter, 1988a, p. 337; © 1988 by the Gulf Coast Association of Geological Societies).

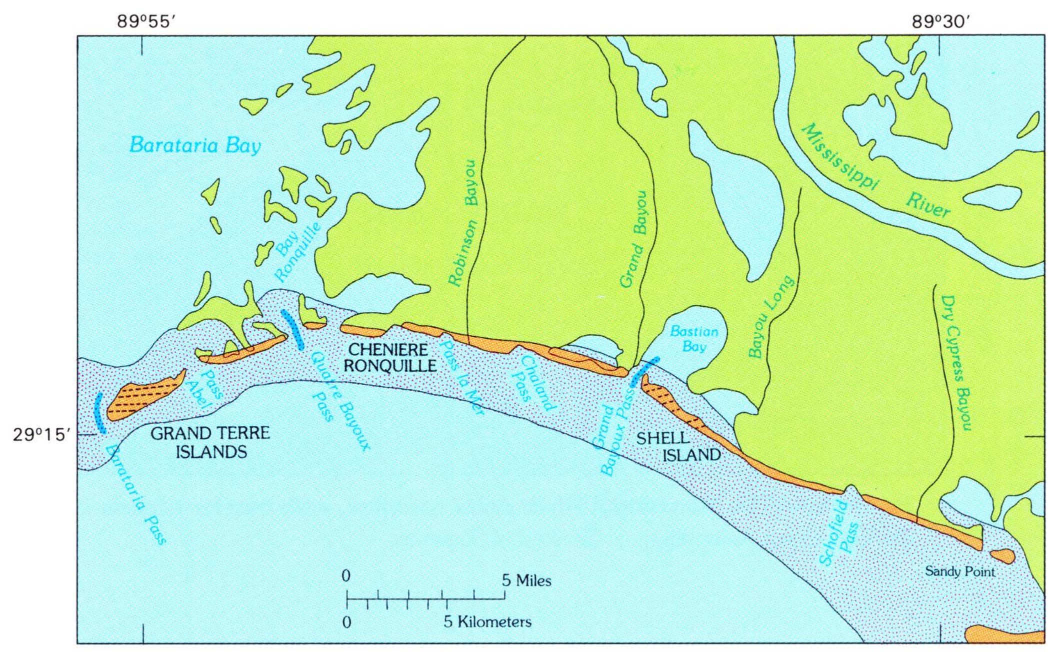


FIGURE 14.— Coastal environments of the Plaquemines barrier system (redrawn, by permission, from Boyd and Penland, 1988, p. 449; © 1988 by the Gulf Coast Association of Geological Societies).

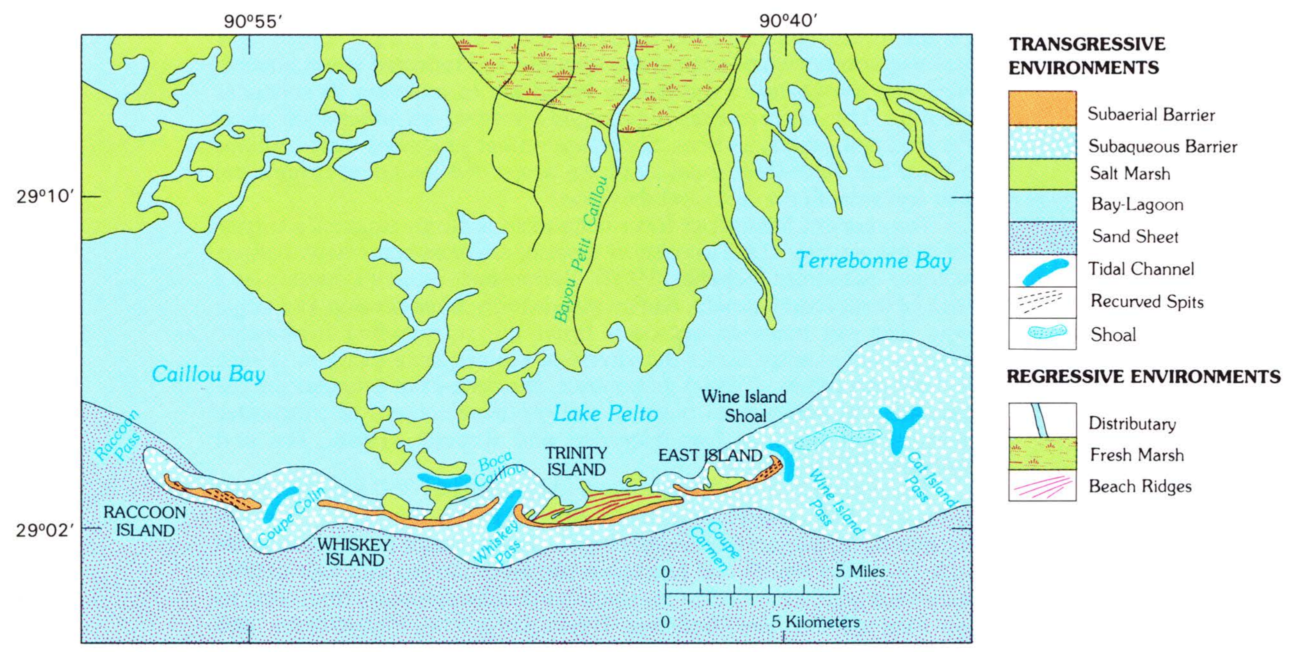


FIGURE 17.— Coastal environments of the Isles Dernieres barrier system (redrawn and adapted, by permission, from Penland and Suter, 1983, p. 370; © 1988 by the Gulf Coast Association of Geological Societies).

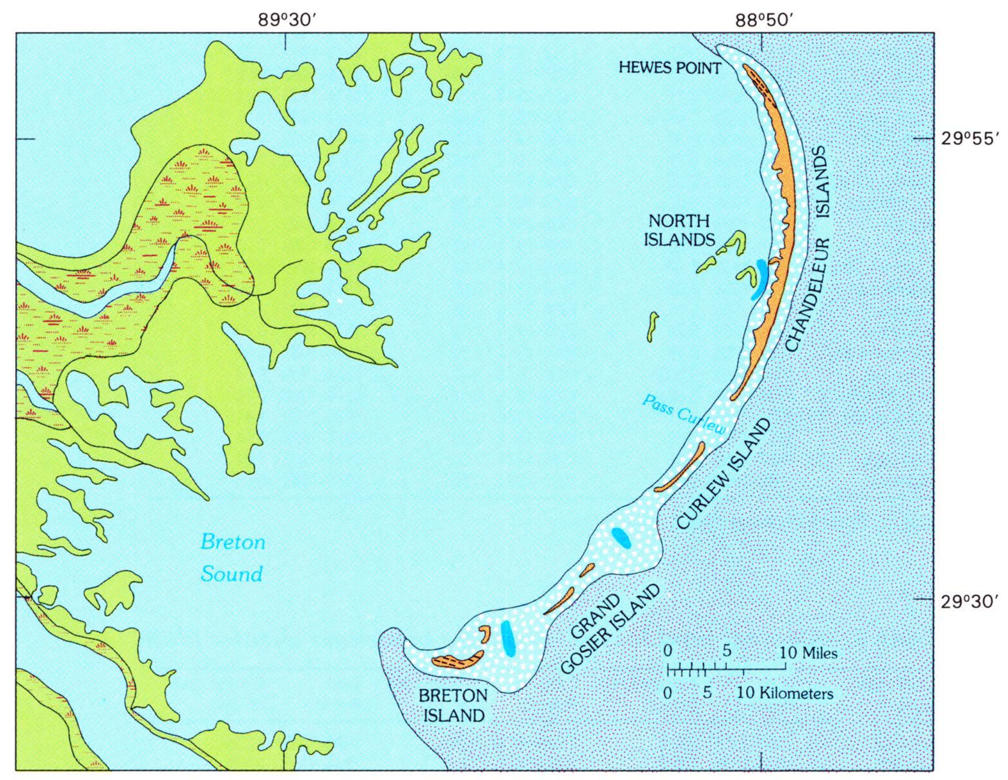


FIGURE 18.— Coastal environments of the Chandeleur barrier system (redrawn, by permission, from Penland and others, 1988a, p. 939; © 1988 by the Society of Economic Paleontologists and Mineralogists).

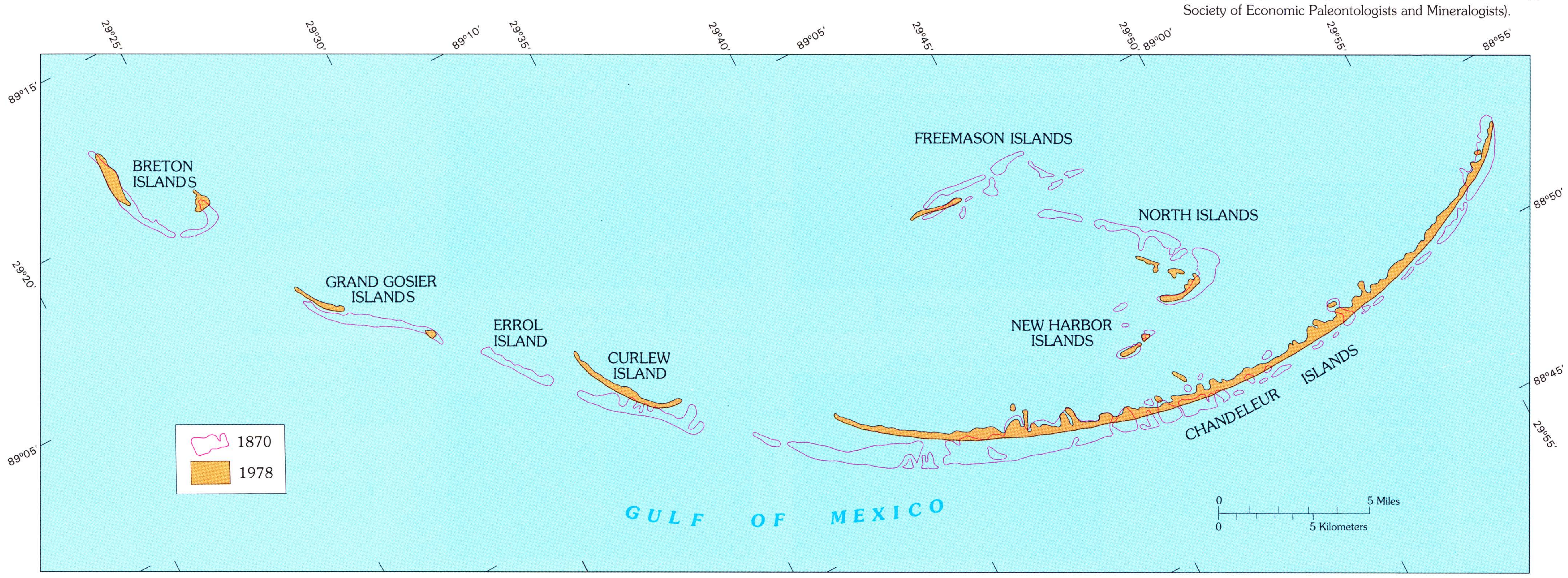


FIGURE 19.— Shoreline change on the Chandeleur Islands, 1870–1978 (redrawn, by permission, from Penland and others, 1985, p. 220; © 1985 by Elsevier Science Publishers).

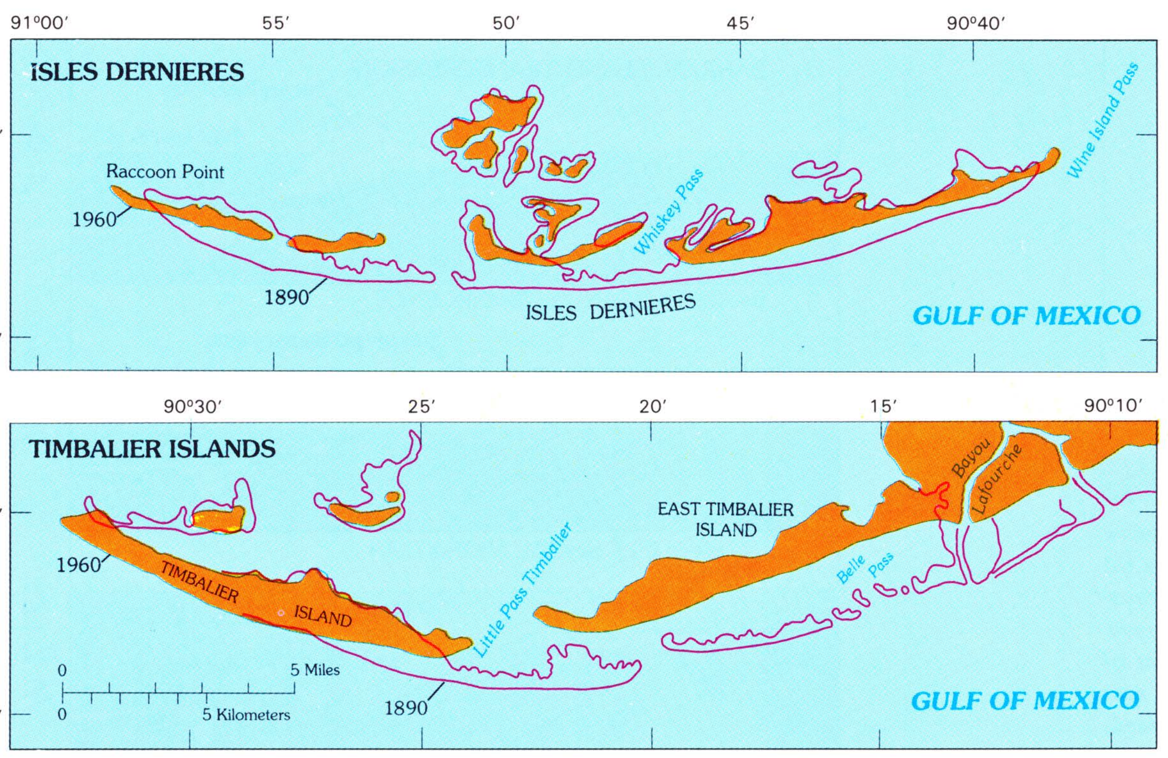


FIGURE 20.— Shoreline change on the Isles Dernieres and Timbalier Islands between 1890 and 1960 (redrawn, by permission, from Peyronnin, 1962; © 1962 by the American Society of Civil Engineers).

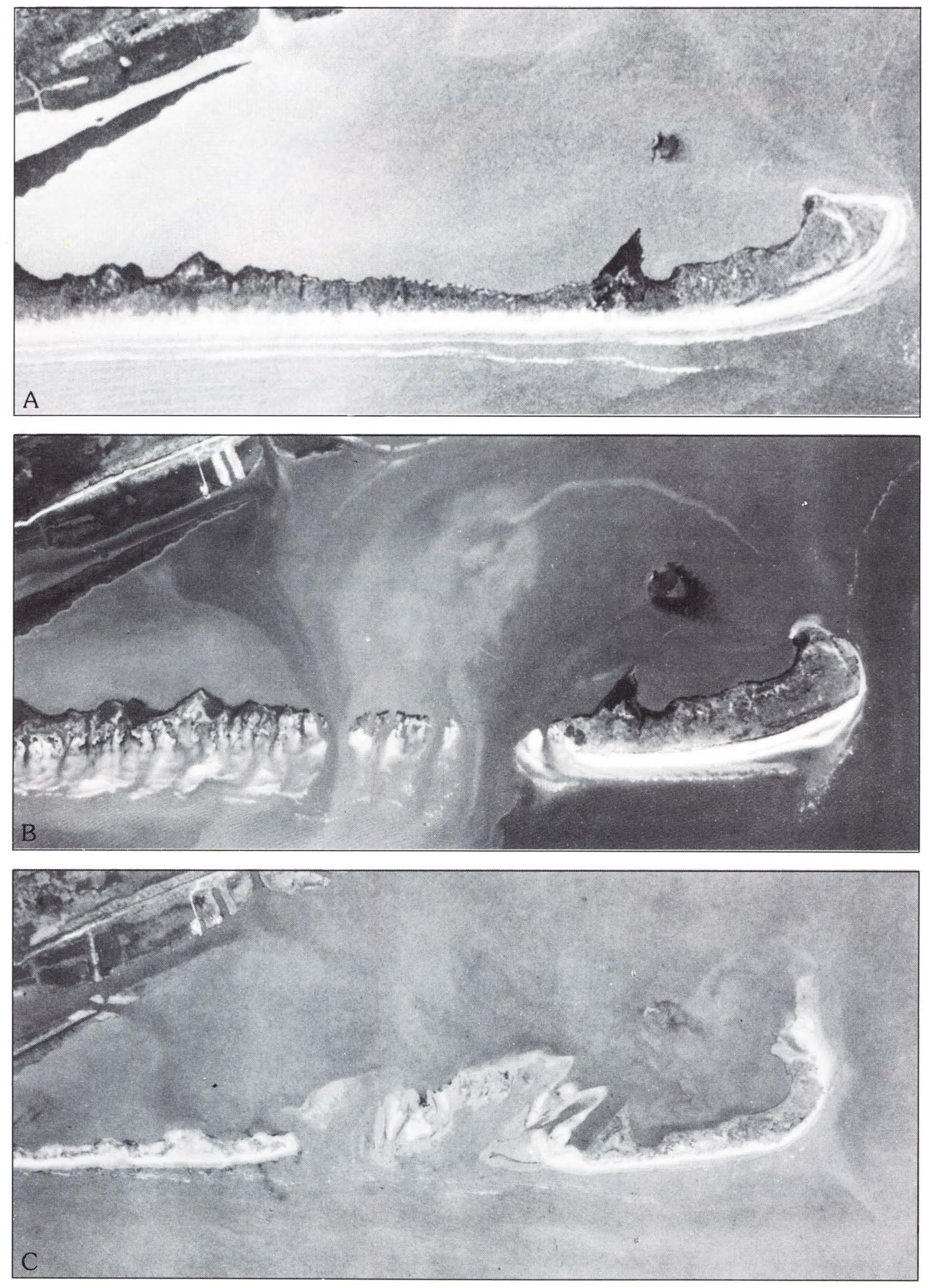


FIGURE 24.— Historical breaching at the Caminada spit. (A) Pre-breach conditions in 1950. (B) After Hurricane Flossy in 1956; note the pattern of seaward-oriented overwash features. (C) After Hurricane Betsy in 1965; note the pattern of landward-oriented overwash features. (Photos from U.S. Army Corps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

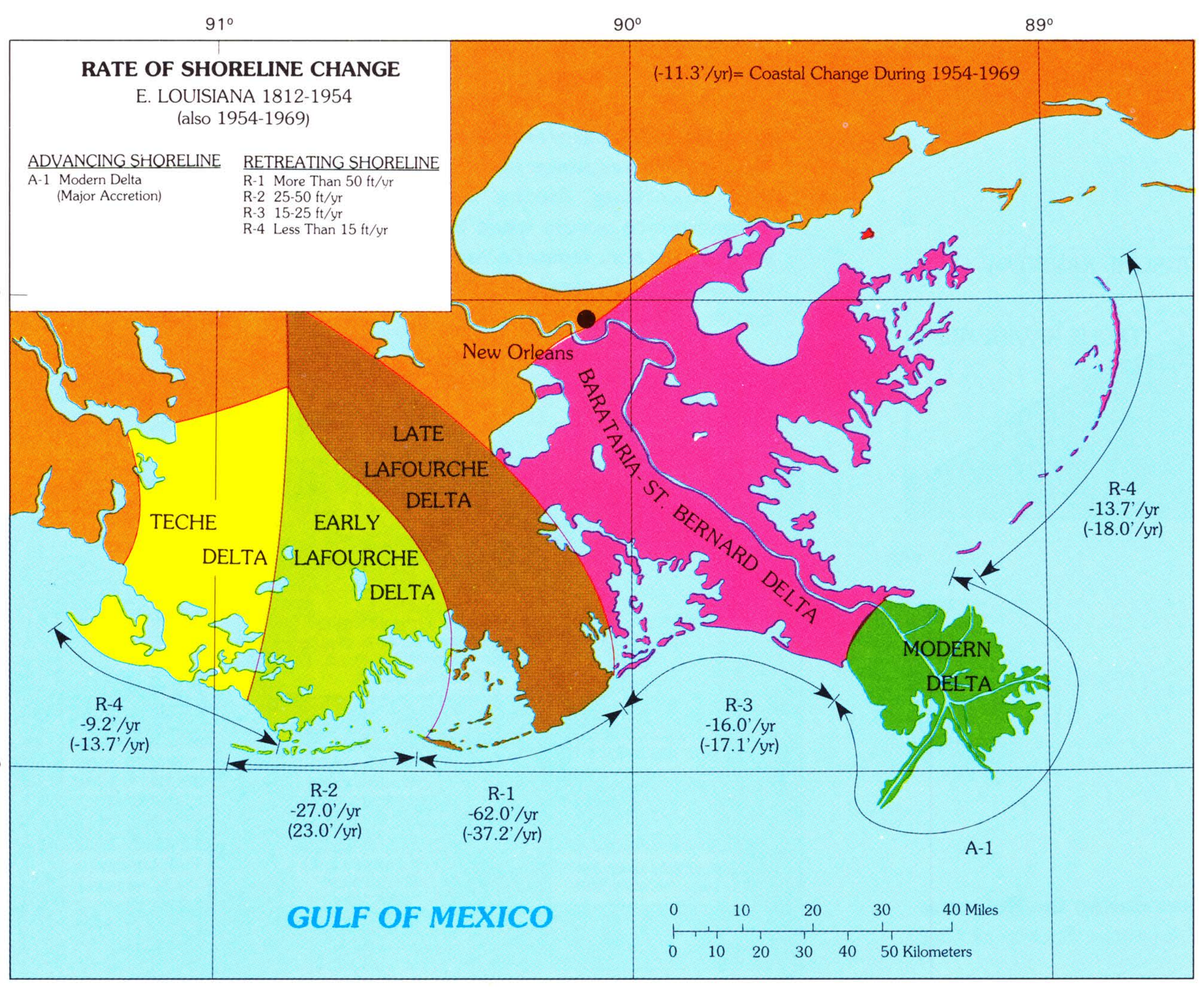


FIGURE 21.— Rate of shoreline change in eastern Louisiana, 1812–1954 and 1954–1969 (redrawn from Morgan and Morgan, 1983, p. 11).

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 were 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 switches 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).

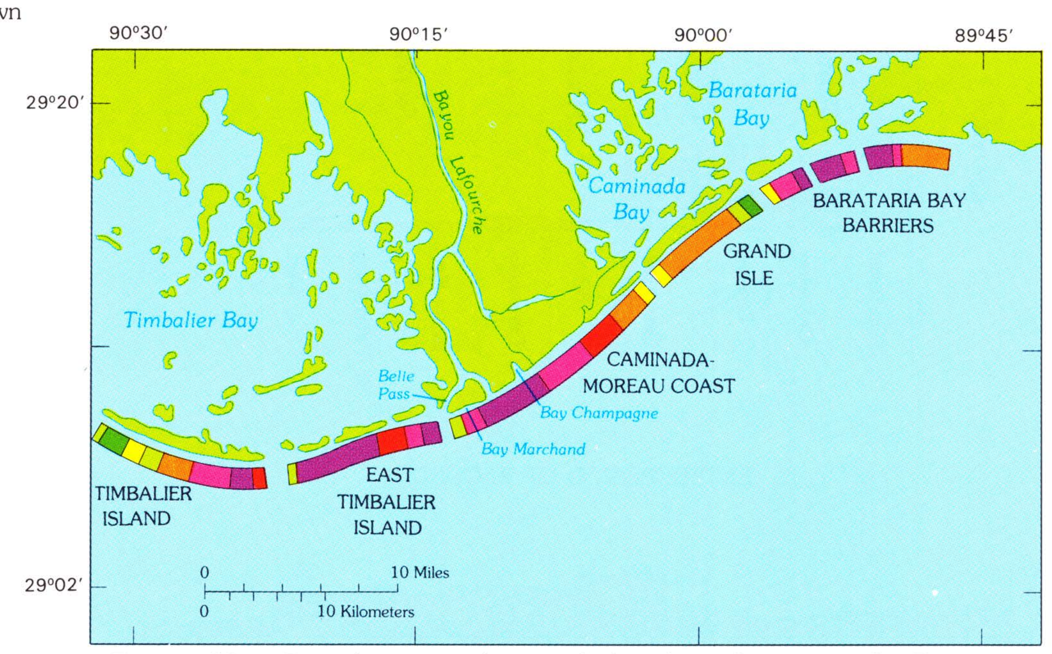
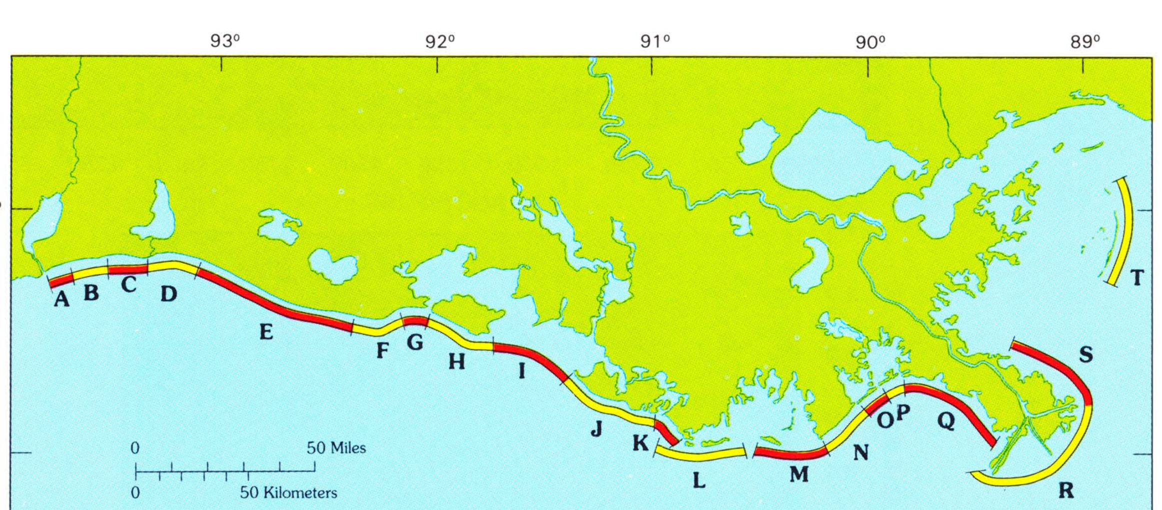


FIGURE 23.— Distribution and rate of shoreline change on the Bayou Lafourche barrier system (redrawn from Penland and Boyd, 1982, p. 25).



SECTOR	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
LIMITS (Latitude or Longitude)	93°50-93°45	93°45-93°34	93°34-93°21	93°21-93°06.8	93°06.8-92°24	92°24-92°12	92°12-92°02.5	92°02.5-91°45.7	91°45.7-91°22	91°21.5-91°00	91°00-90°52.5	90°58-90°37.5	90°32.5-90°14	90°14-90°03	90°03-80°57	89°57-89°51	89°51-89°30	89°30-29°22	89°14-89°00	29°31-30°03
SHORELINE LENGTH (miles)	6	12	13	14	45	13	10	18	27	25	8	21	20	13	7	6	24	—	—	44
EROSION (ft/yr)	0	+3	-3	+11	-32	+12	-14	-10	—	-12	-11	-22	19	-44	0	-18	-13	—	—	-15

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

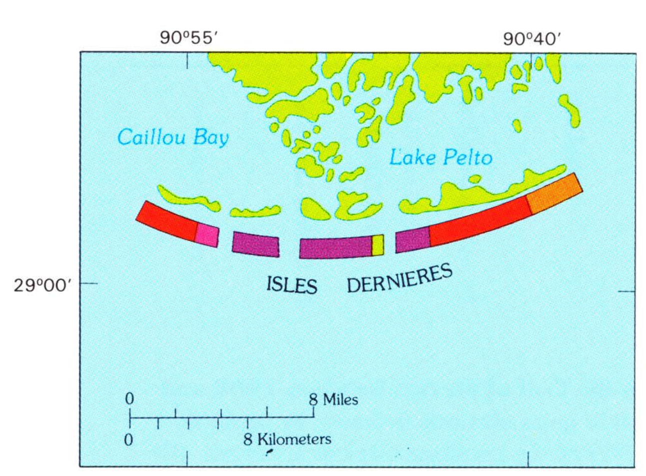
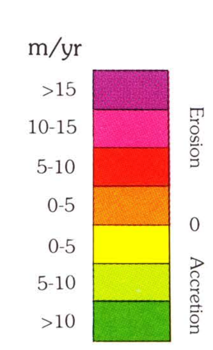


FIGURE 25.— Distribution and rate of shoreline change for the Isles Dernieres barrier system (redrawn from Penland and Boyd, 1982, p. 32).



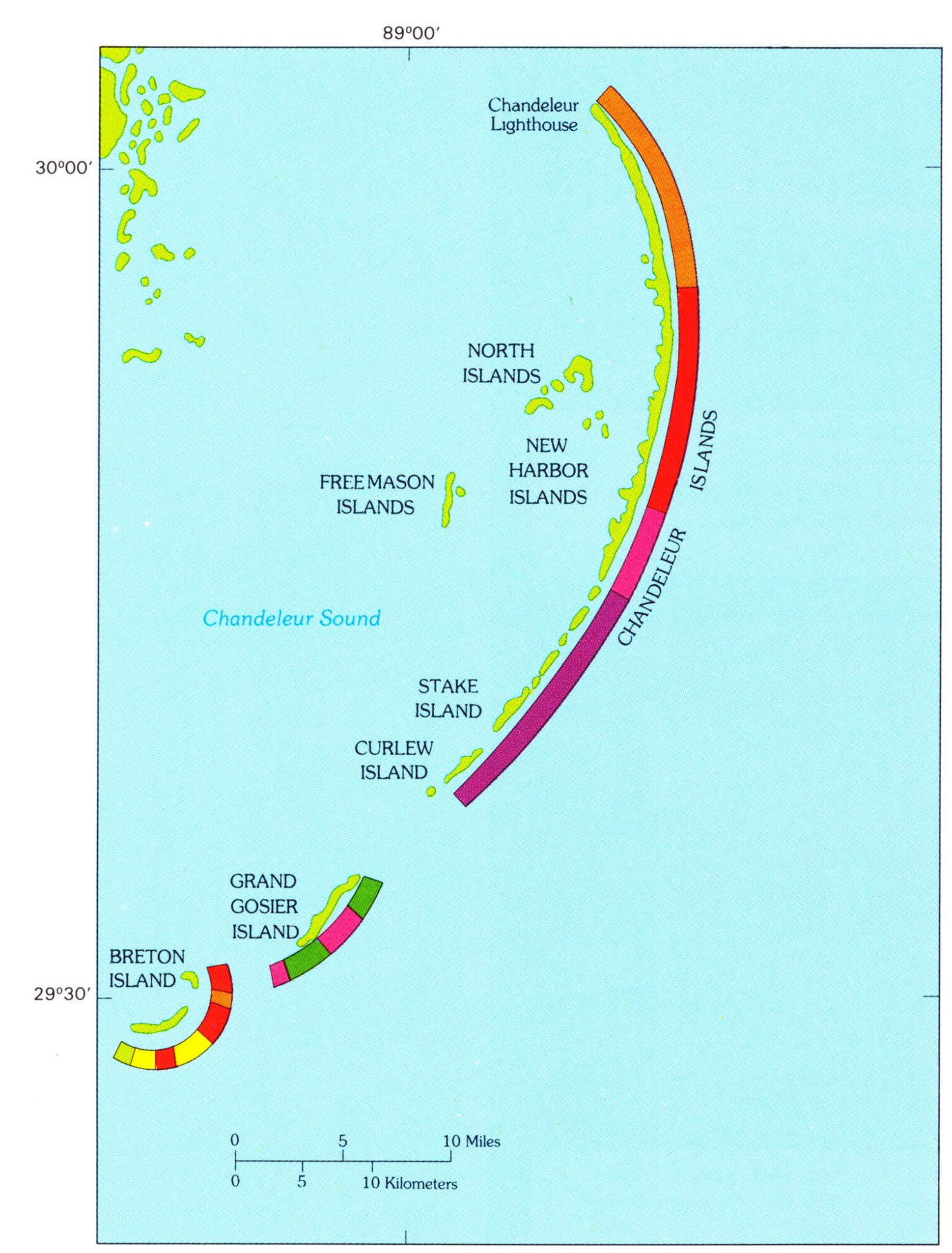


FIGURE 26.— Distribution and rate of shoreline change for the Chandeleur barrier system (redrawn from Penland and Boyd, 1982, p. 34).

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 km^2) 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 Wisconsinan 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 an 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 an 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 an 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 been 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).

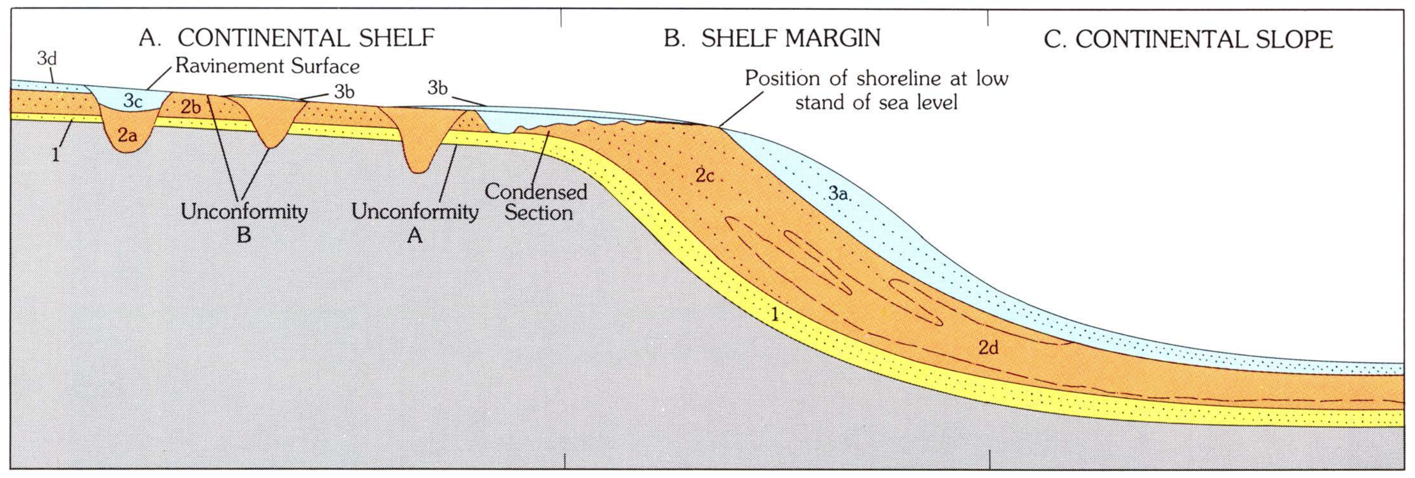


FIGURE 27.— Idealized model of Quaternary facies deposition on the Louisiana continental shelf. (1) Transgressive and aggradational deposits from previous sea-level rise. (2) Sediments associated with regressive phase of cycle: (a) fluvial and distributary channel fill; (b) shelf-phase deltaic deposits; (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 (redrawn, by permission, from Suter and others, 1987, p. 203; © 1987 by the Society of Economic Paleontologists and Mineralogists).

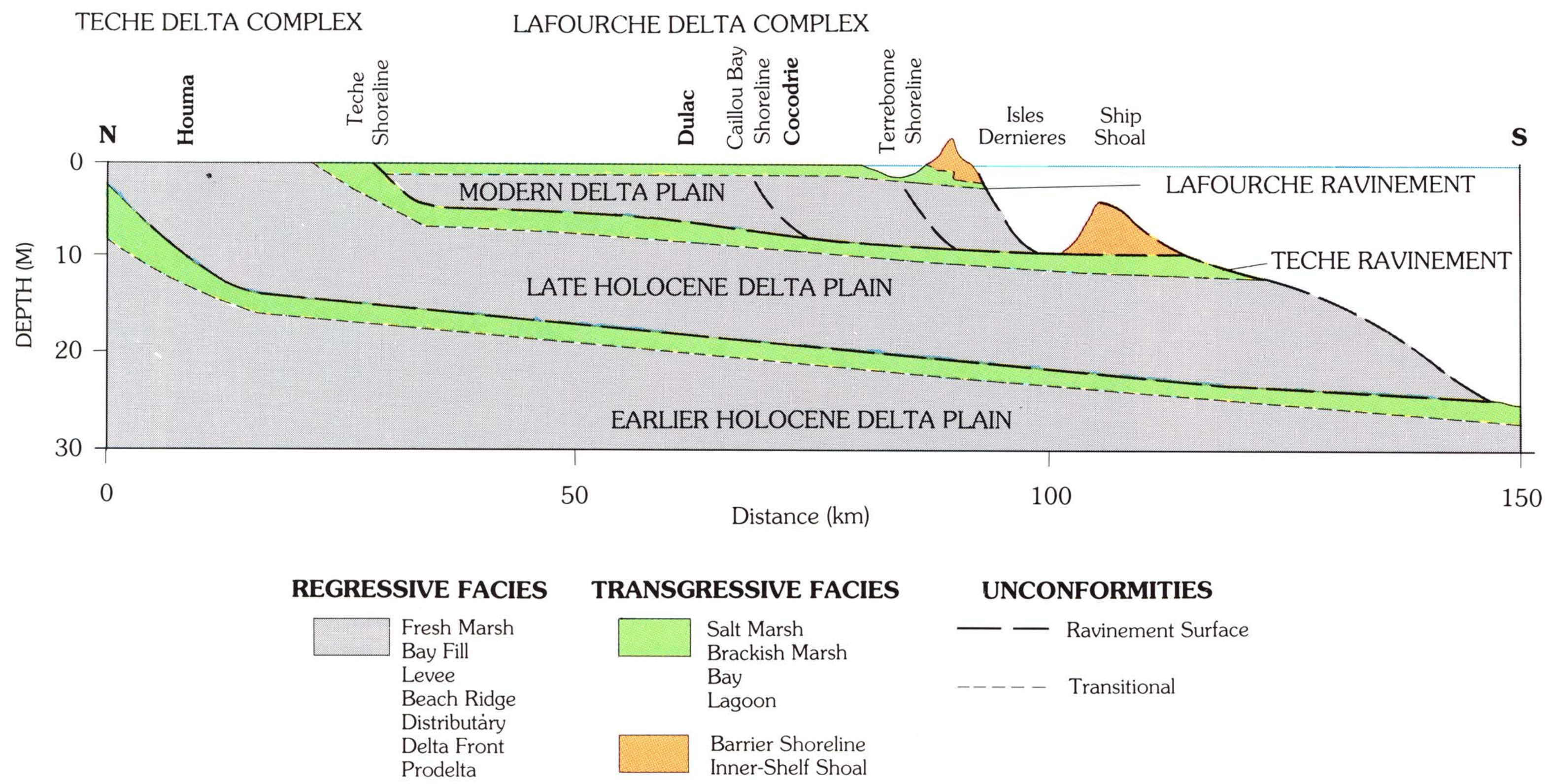


FIGURE 28.— Idealized model of the development of shelf-phase delta plains of the Mississippi River during the Holocene transgression (reprinted, by permission, from Penland and others, 1987a, p. 1696; © 1987 by the American Society of Civil Engineers).

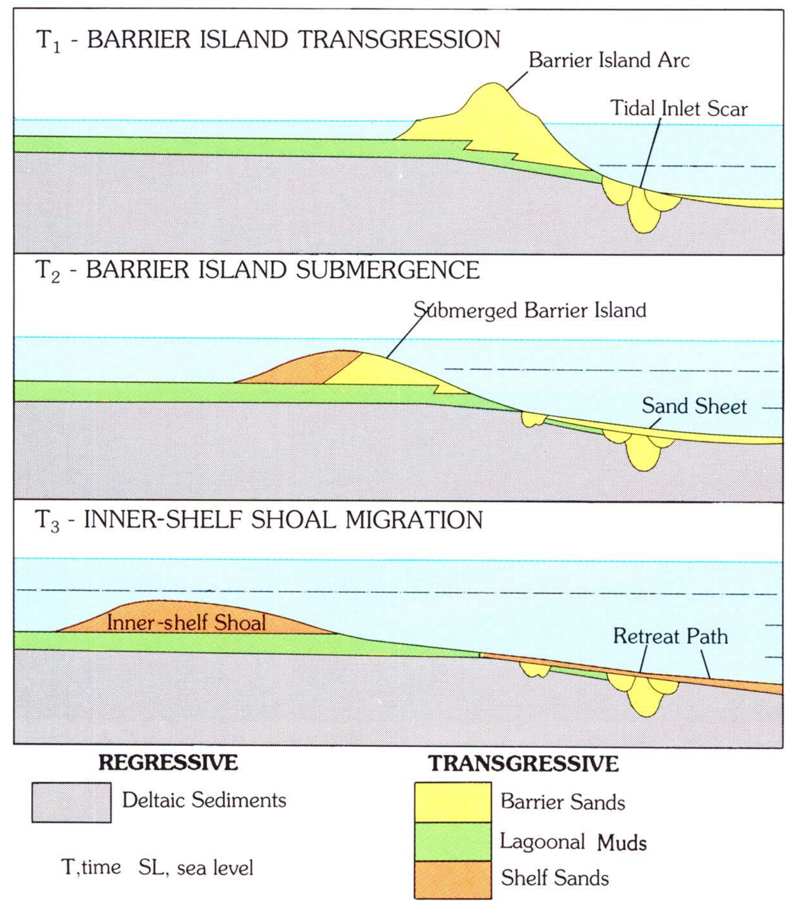


FIGURE 29.— A model of transgressive submergence, the process of shoreline and shelf sand generation on the Mississippi River delta plain. Transgression occurs when the shoreline migrates landward in response to delta abandonment, leading to erosion and reworking during shoreline and shoreface retreat.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

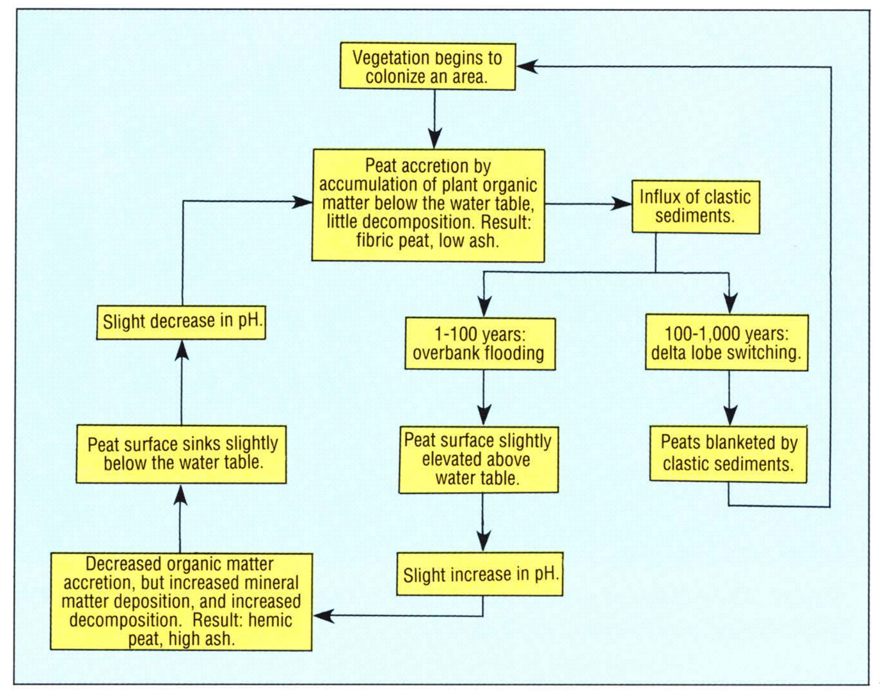


FIGURE 30.— Model of marsh accretion in the Barataria basin (redrawn, by permission, from Kosters, 1989, p. 110; © 1989 by the Society of Sedimentary Geology).

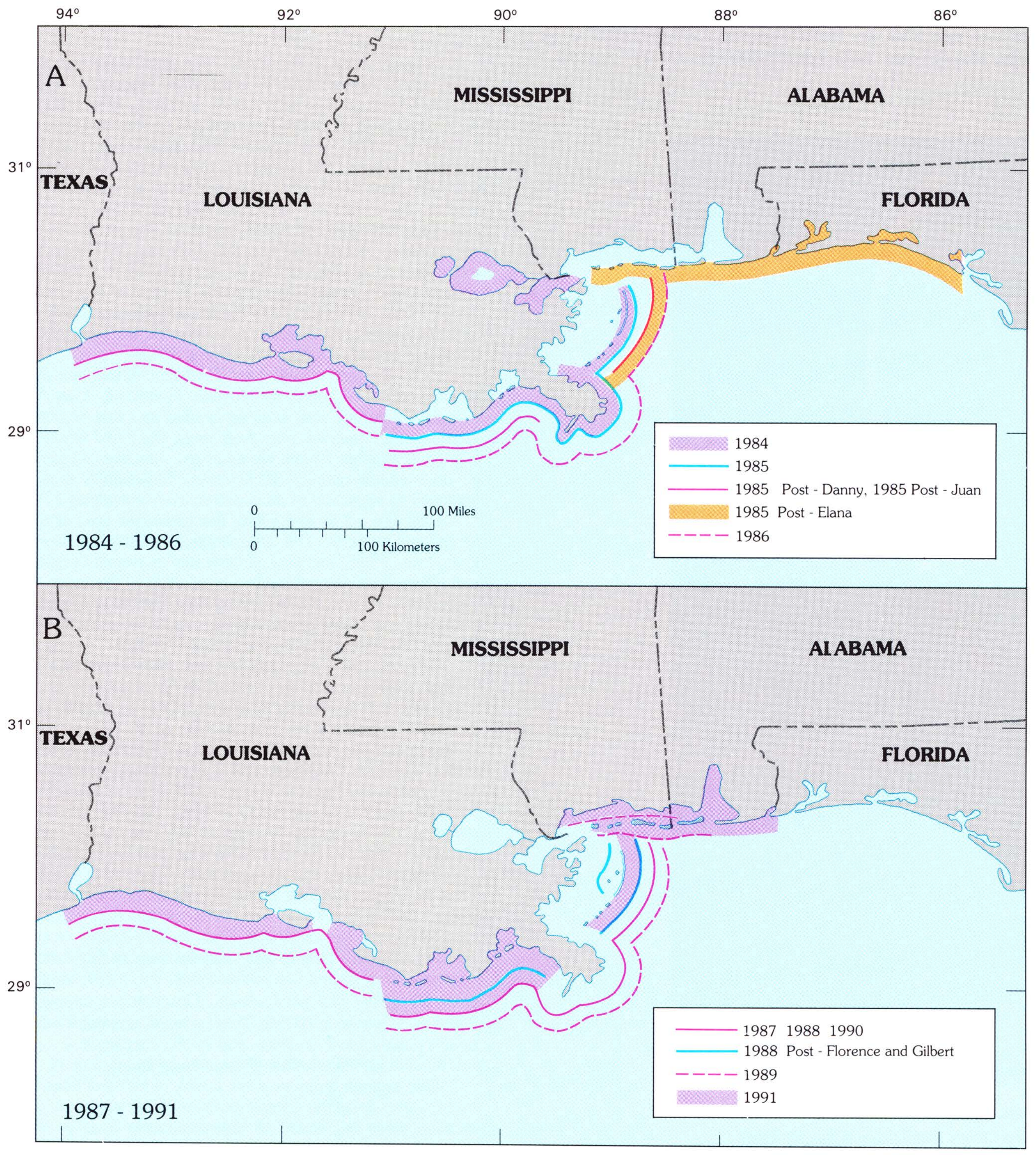


FIGURE 31.— Location of Louisiana Geological Survey aerial videotape surveys in Louisiana and the northern Gulf of Mexico, (A) 1984–1986; (B) 1987–1991.

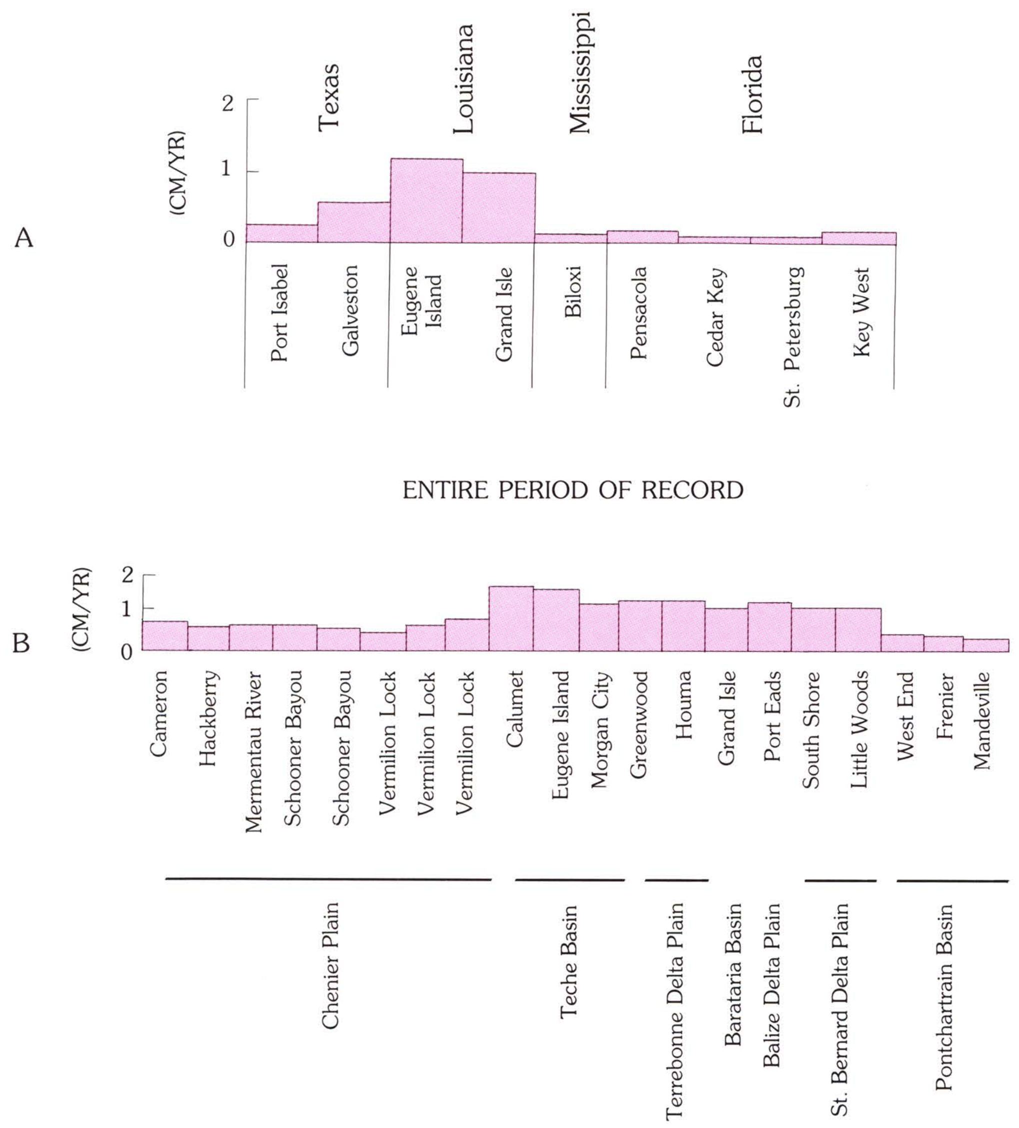


FIGURE 32.— (A) Relative sea level rise in the Gulf of Mexico between 1908 and 1983, based on National Ocean Survey tide gage stations (redrawn, by permission, from Penland and others, 1989e, p. 50; © 1989 by the Louisiana Geological Survey). **(B) Relative sea level rise in Louisiana between 1931 and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

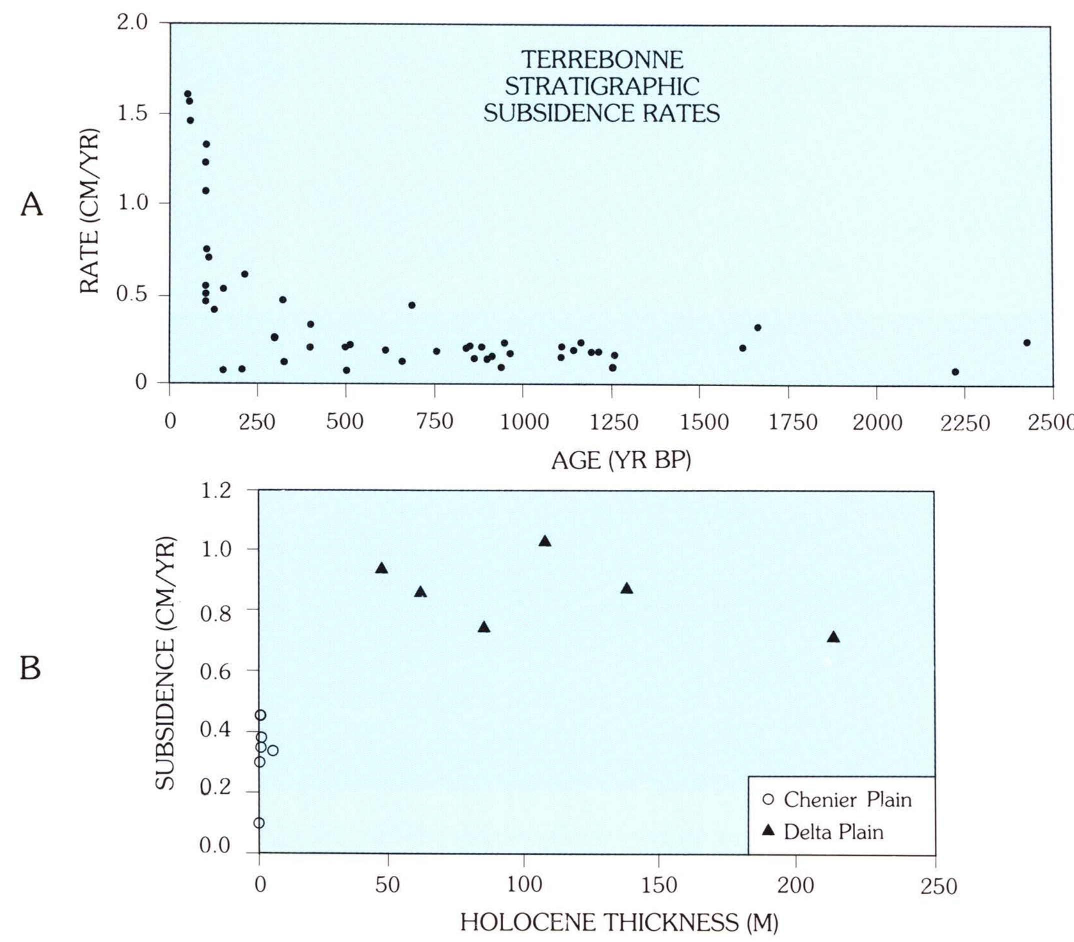


FIGURE 33.— (A) The relationship between sediment age and the rate of stratigraphic subsidence in Terrebonne Parish, Louisiana (redrawn from Penland and others, 1988b, p. 95). **(B) The relationship between rate of relative sea level rise (RSL) based on tide gage records and the thickness of the Holocene 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).

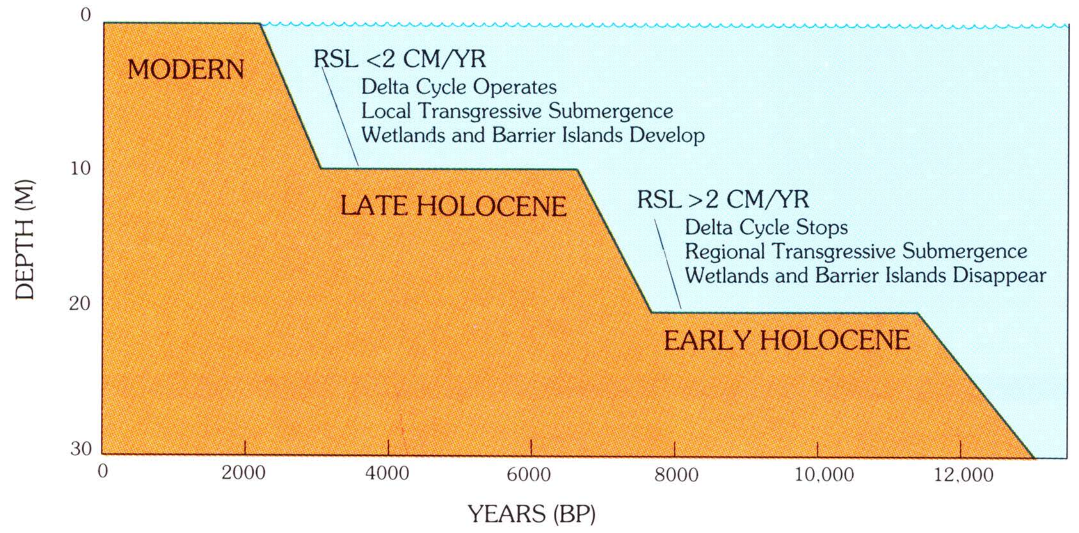


FIGURE 34.— The relationship between changes in relative sea level (RSL) and coastal stability in the Mississippi River delta plain during the last stages of the Holocene transgression.

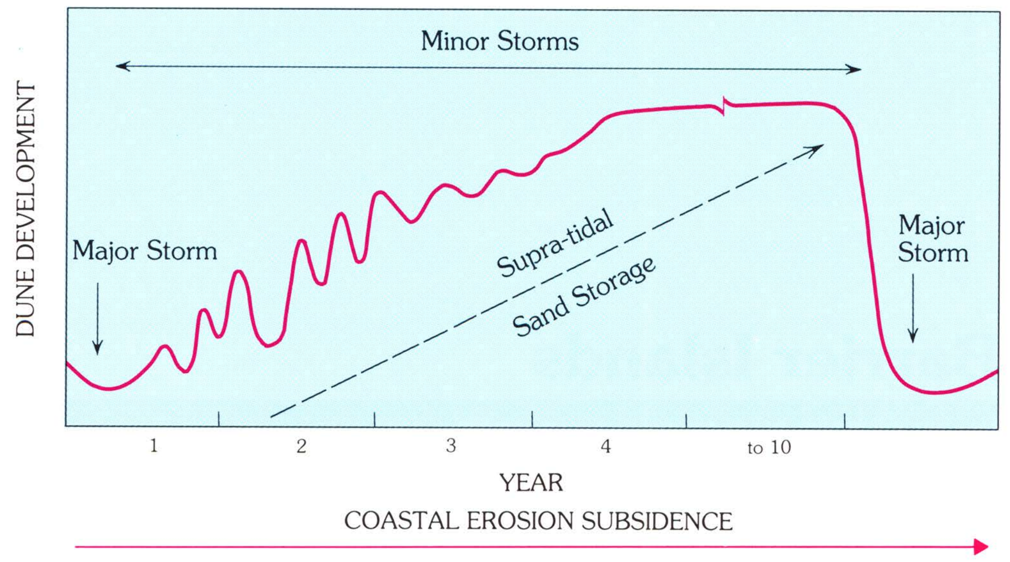


FIGURE 35.— Model of sand dune development in Louisiana as a function of storms and the return period of hurricane impact. Increasing volume of supratidal sand storage leads to dune development and revegetation, increasing the stability of the barrier shoreline. Major storms are hurricanes; minor storms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

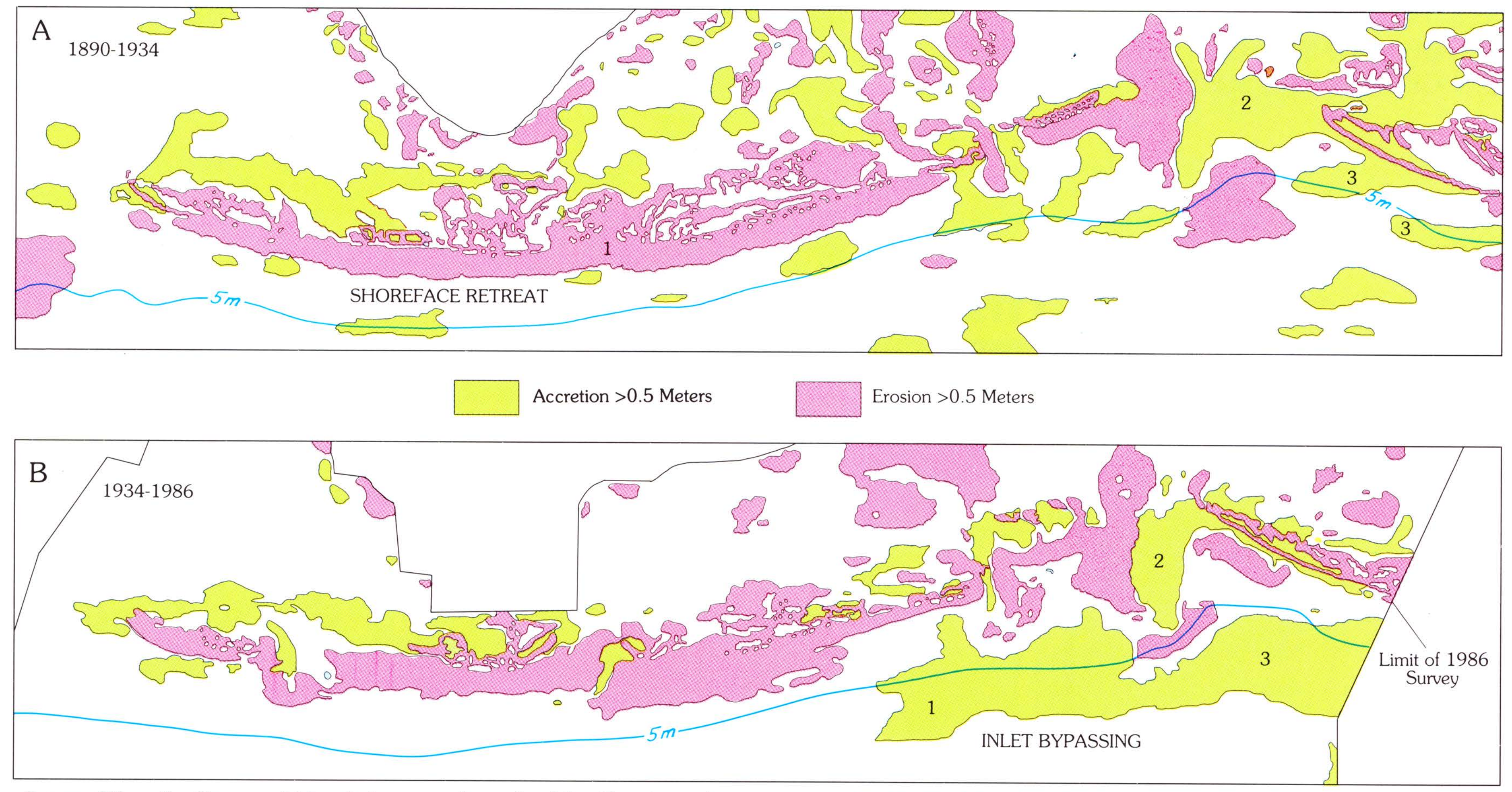


FIGURE 36.— Seafloor and island changes along the Isles Dernieres barrier system (a)1890 -1934; (b)1934 - 1986. (1) Shoreface erosion; (2) sediment deposited from longshore transport in shallow water close to Timbalier Island; (3) sediment deposited from longshore transport offshore of Timbalier Island. 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).

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 (Circé and Holland, 1987, 1988; Circé 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 decisionmakers 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 systems as well as the status of previous research and current USGS-LGS 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).

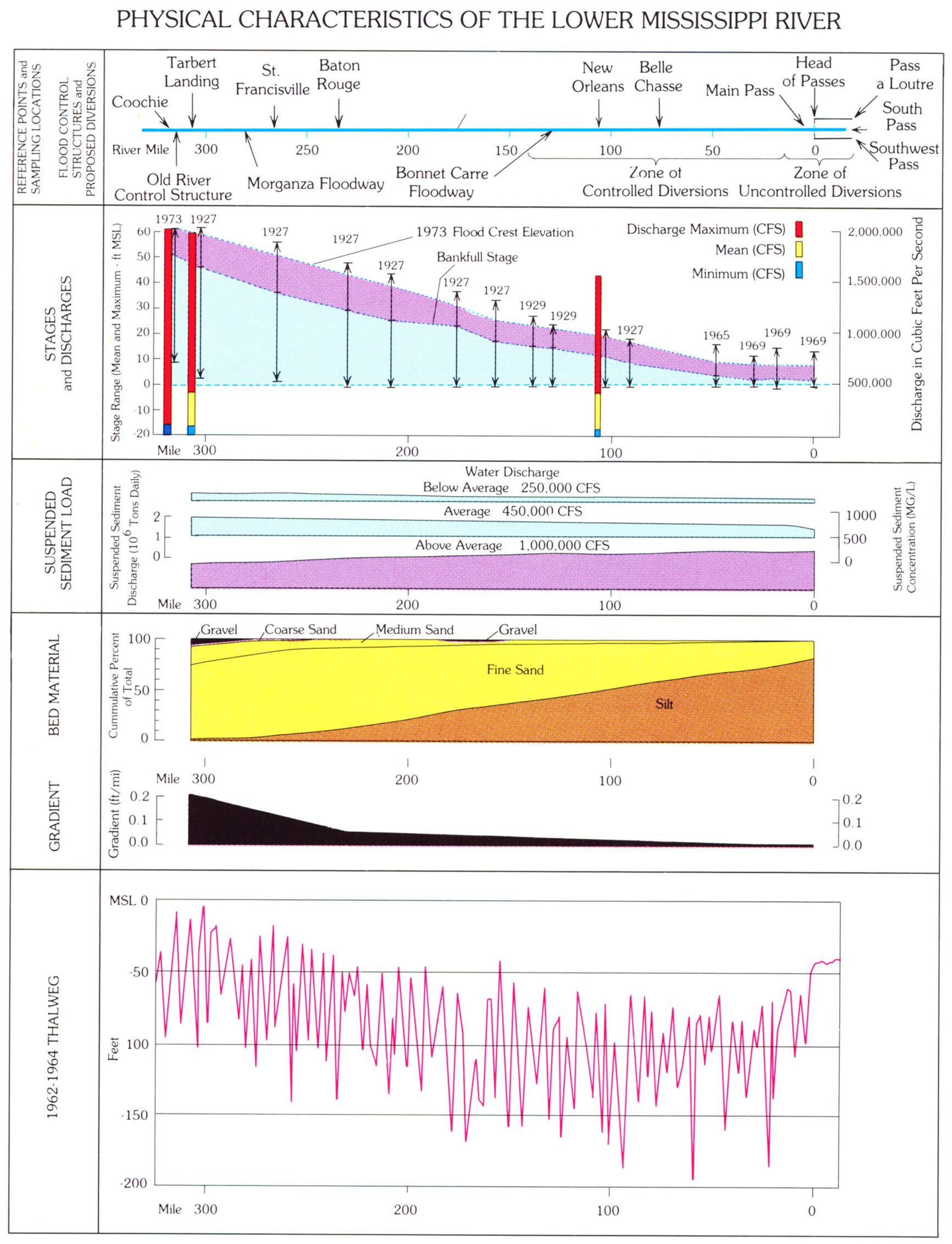


FIGURE 37.— Physical characteristics of the lower Mississippi River alluvial valley and delta plain (redrawn, by permission, from Mossa, 1988, p. 305; © 1988 by the Gulf Coast Association of Geological Societies).

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 associated 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.

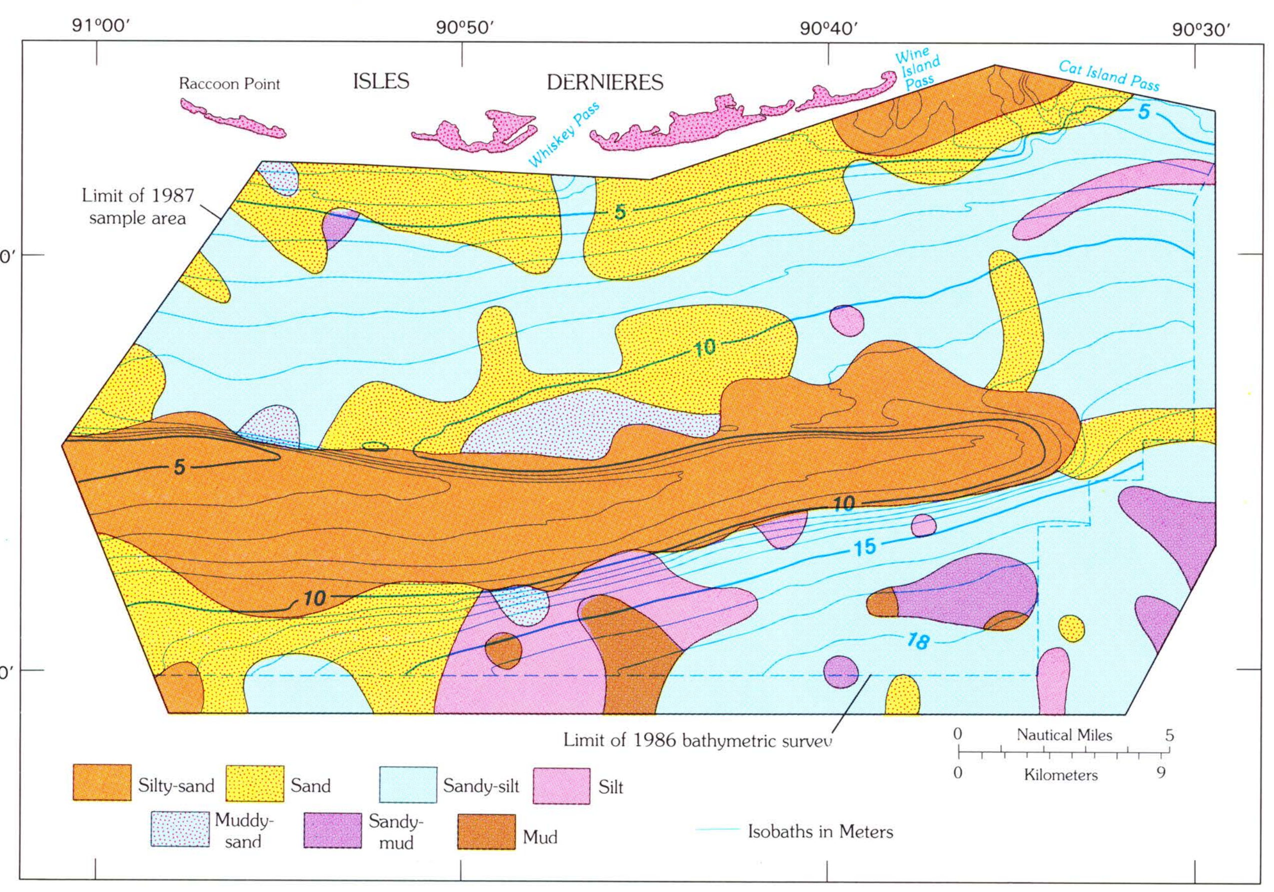


FIGURE 38.— Seven major sediment facies of the inner shelf off south-central Louisiana (redrawn, by permission, from Williams and others, 1989a, p. 573; © 1989 by the Gulf Coast Association of Geological Societies).

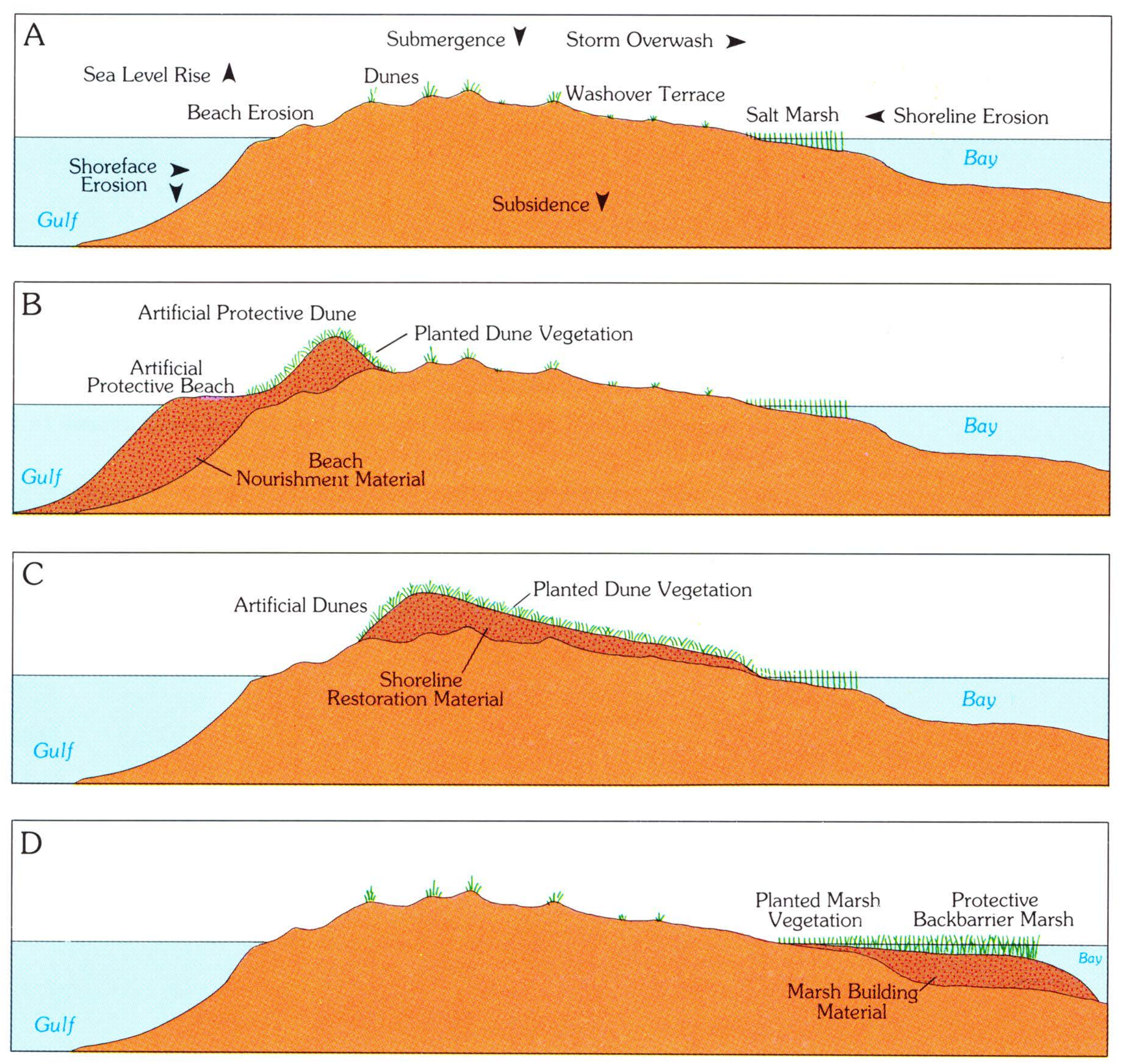


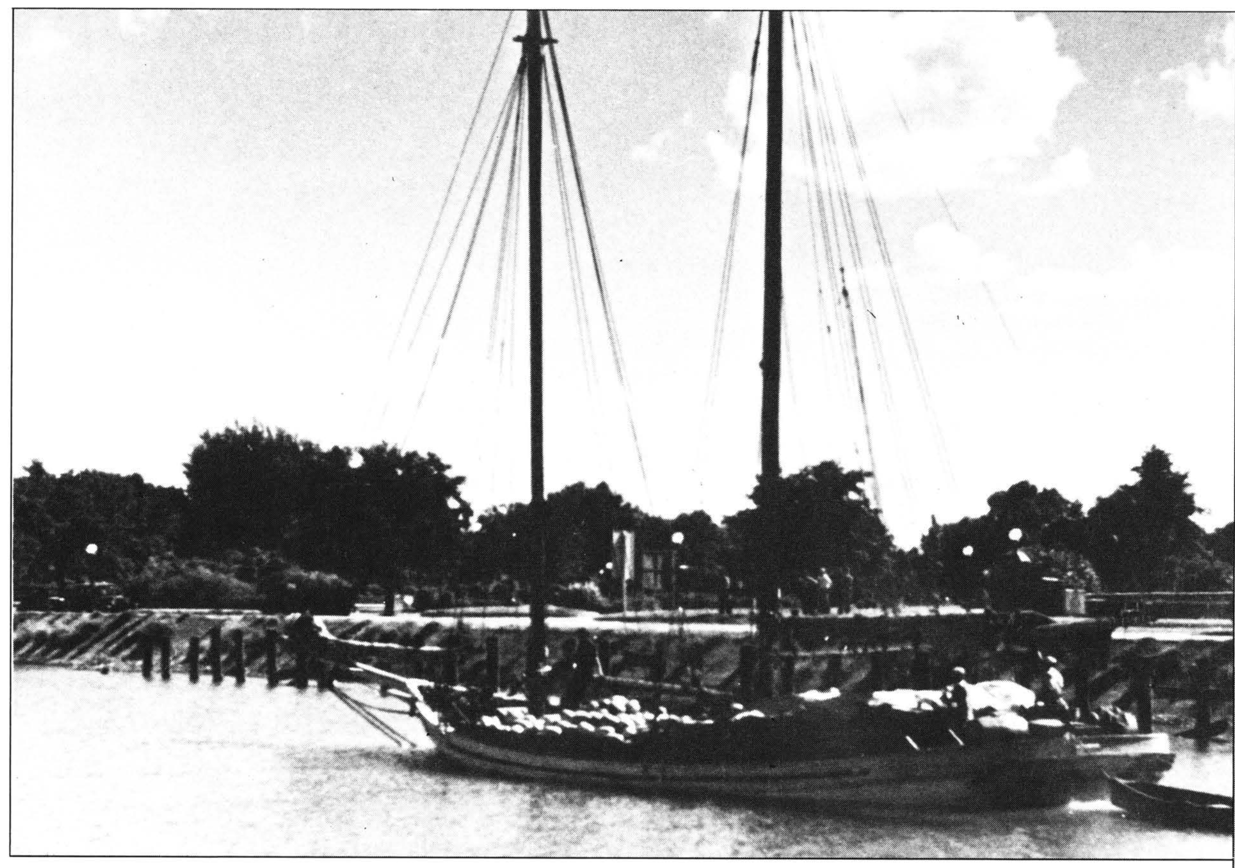
FIGURE 39.— Three designs for using sediment and vegetation to preserve and protect Louisiana's barrier systems. (A) Barrier island erosion problems. (B) Beach nourishment. (C) Barrier island restoration. (D) Back-barrier marsh building.

Recommended citation for this chapter:

Penland, Shea, Williams, S. J., Davis, D. W., Sallenger, A. H., Jr., and Groat, C. G., 1992, Barrier island erosion and wetland loss in Louisiana, *in* Williams, S. J., Penland, Shea, and Sallenger, A. H., Jr., eds., Louisiana barrier island erosion study—atlas of barrier shoreline changes in Louisiana from 1853 to 1989: U.S. Geological Survey Miscellaneous Investigations Series I-2150-A, p. 2-7.

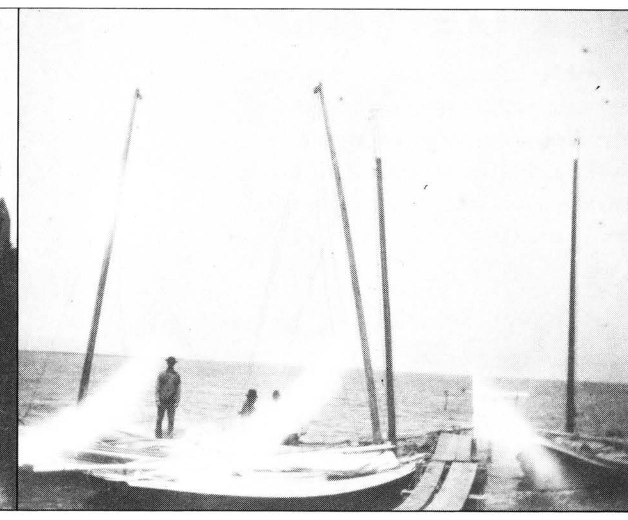
Chapter 2 A Historical and Pictorial Review of Louisiana's Barrier Islands

by *Donald W. Davis*

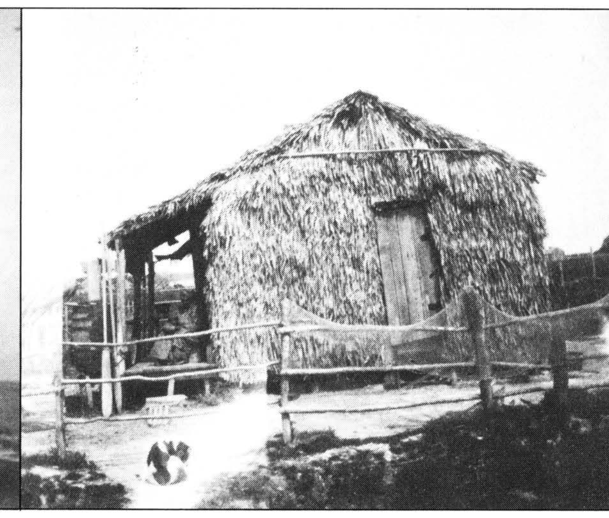


A two-master sailing lugger going to market. Shallow-draft boats often had to be pulled with tow ropes attached to a horse, mule, or man—a process called *cordelling*, ca. 1940: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).

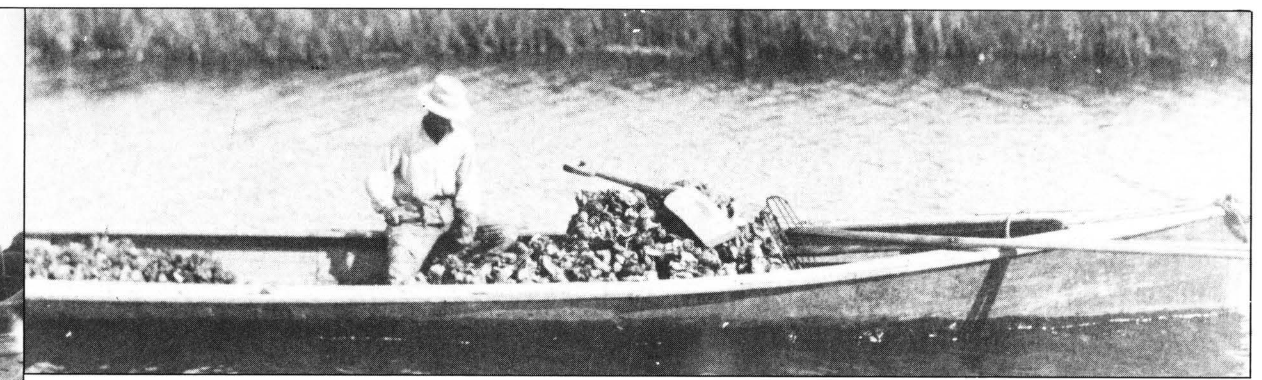
Fisherman's wife baking bread in an outdoor oven *(pain chaud in a bousillage four de campagne)* at Cheniere Caminada, 1891: (National Archives, Negative No. 22-FCD-36).



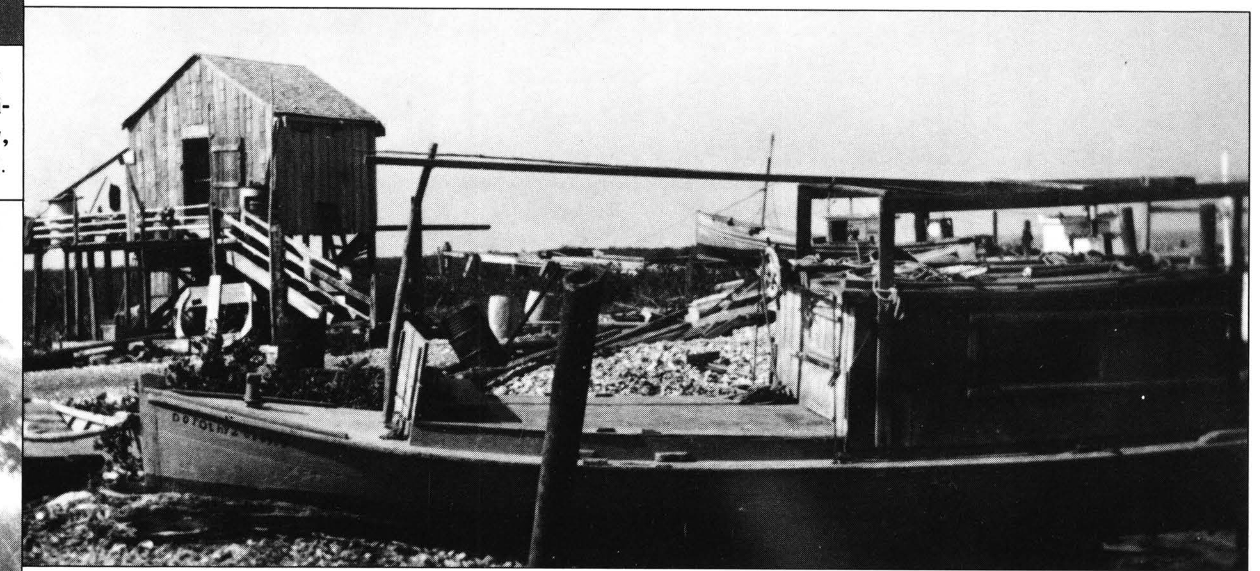
Oyster luggers and skiffs at Grand Isle, 1891: (National Archives, Negative No. 22-FCD-31).



Typical palmetto (*Sabal minor*) house built by the residents of Cheniere Caminada, Louisiana's largest pre-1900 coastal community, 1891: (National Archives, Negative No. 22-FCD-40).



Harvesting oysters from beds in Terrebonne Parish, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).

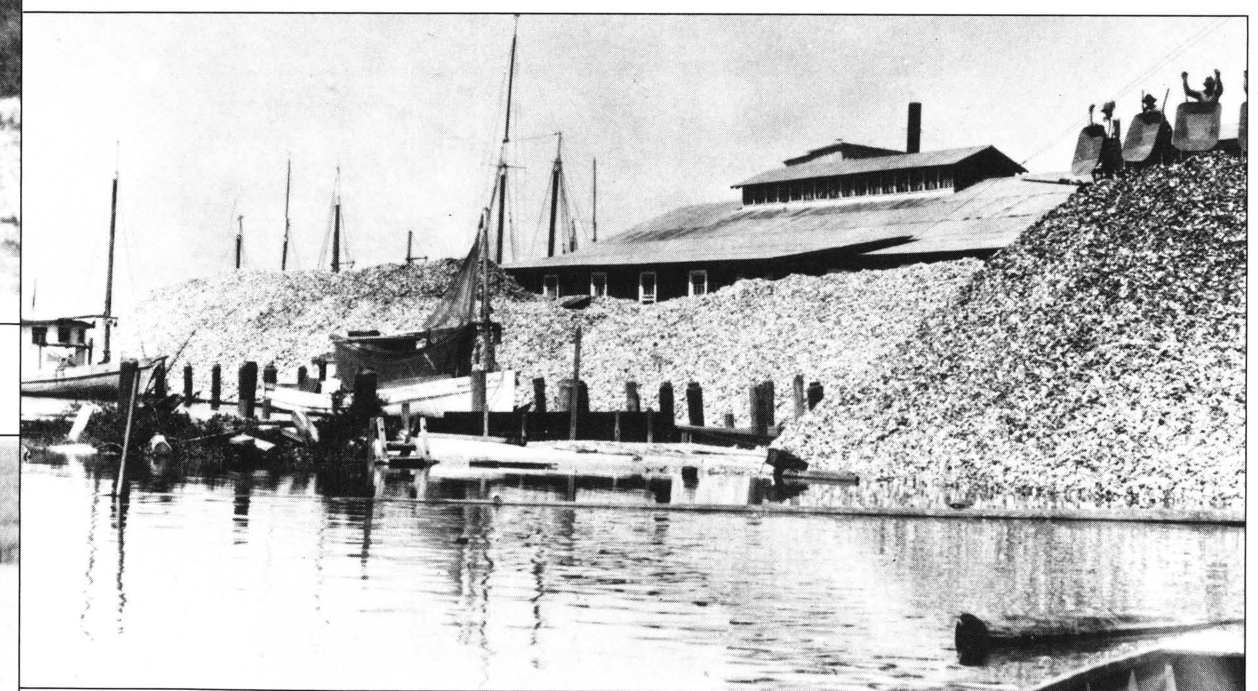


Typical isolated Barataria Bay oyster camp, ca. 1935: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).

Grand Isle children, no date: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).

Many Houma Indians lived in raised structures, close to and facing the bayou. This family's home on Lower Bayou Grand Caillou is one example, no date: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).

The belief that quality furs came only from cold climates was unfounded. Louisiana's marshes were one of North America's preeminent fur-producing regions, ca. 1930: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).



Louisiana's oyster beds were so prolific that oystermen from Mississippi harvested the sites for canning plants at Biloxi, no date: (Anthony V. Ragusin, Louisiana State Library, Louisiana Photographic Archives).

An isolated marsh settlement provided quick and easy access to harvesting areas, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).

Before the arrival of the Yugoslavians, those engaged in the oyster business were Italians and Sicilians, no date: (Fonville Winans, Louisiana State Library, Louisiana Photographic Archives).

Using hand-woven china baskets to unload shrimp at a Terrebonne Parish drying platform, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).

Four large tarpon caught in the inland waters of Terrebonne Parish, ca. 1924: (Randolph Bazet Collection, Houma, Louisiana).

Harvests such as this allowed Louisiana to adopt the nickname "Sportsman's Paradise," ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).

SETTLING LOUISIANA'S COASTAL FRINGE

The Gulf of Mexico's northern coast is dominated by a series of barrier islands separated by water bodies less than 10 meters deep. This 870-kilometer chain parallels the Gulf Coast and represents nearly 35 percent of the United States' barrier islands (Ringold and Clark, 1980).

Most of these islands and adjacent peninsulas have a cross section composed of several shore-parallel environments. Typically, the nearshore zone is identified by a system of bars and troughs parallel to the strandline. The active beach has a moderate sand slope, but grasses cover the dunes that customarily frame the foreshore berms. An island's midsection is frequently a series of beach ridges and intervening swales, covered by salt-tolerant vegetation, scattered shrubs, and clusters of trees. Marsh tidal-flat ecosystems, as well as mangrove communities, lie on the bay-shore side (Vincent and others, 1976; Davis and others, 1987). These features vary in physiography and cross-sectional profile according to the amount and type of eolian material, winds, tides, and the frequency of hurricanes. The same natural laws of beach-barrier dynamics, however, apply equally, regardless of the barrier's location. Unfortunately, human uses do not follow such an orderly pattern; whether in Louisiana, Maine, North Carolina, Florida, or Texas, people introduce to the existing physical and biological systems an additional complex set of variables.

The Gulf of Mexico barrier islands have served humanity since the seventeenth century when farmers discovered that cattle released on barrier islands would forage and reproduce. Eventually, settlers moved onto the barrier islands following an annual-use cycle—making a living using the different renewable resources that were available from season to season. In the late nineteenth and early twentieth centuries, the islands were used for military bases, small settlements, hotels, and other recreation endeavors, such as lavish hunting clubs and camps.

The sea has reclaimed human features repeatedly, but they have been rebuilt. Like lemmings, people continue to move toward the boundary between the land and water to see and hear the ocean, regardless of the consequences. Coastal citizens, especially those on the barrier islands, are at the mercy of hurricanes, northeasters, and other storms.

The conflict that results from the incompatibility of human and natural processes is most evident when the barrier islands are overrun by hurricanes that generate walls of water over six meters high. Often storms hit the shoreline with such intensity that they sweep far inland and destroy homes, businesses, and public buildings; frequently, nothing is spared.

Along the Atlantic and Gulf coasts today, millions of Americans are exposed to hurricanes. Many live on barrier islands; their homes and businesses are particularly vulnerable because they live dangerously close to the water's edge. The citizens of northwest Florida, for example, thought they were immune to dangerous storms; they were incorrect. In 1975, Hurricane Eloise struck the Florida Panhandle; numerous beach-front buildings—believed to be hurricane proof—were "toppled like dominoes" (Frank, 1976, p. 221). Inadequate building codes and improper construction techniques were responsible for the extensive destruction of beach-front property (Frank, 1976).

Two physiographic provinces dominate the natural setting: the chenier and delta plains. The former extends from a site near High Island, Texas, eastward to Marsh Island, Louisiana, and has a relatively smooth and typical shoreline. Near the shoreface, the chenier plain (from the French, *chene*, meaning oak) is fronted by mudflats and backed by marsh with an intervening series of beach ridges capped with live oak trees (*Quercus virginiana*) (Howe and others, 1935). The delta plain is east of Marsh Island; within its boundaries lie more than 7,000 years of deltaic morphology. Numerous bays, lakes, and barrier islands characterize its highly irregular shoreline.

Barrier islands and marshes absorb wave energy and help retard natural or storm-induced erosion. The islands serve as the first line of defense against destructive hurricanes and storms and therefore receive the full force of their impacts. Washover fans, new tidal passes, diminished dunes, rearranged beaches, and general profile changes, via accretion, deposition, and erosion, are by-products of the passage of a hurricane. The islands are in a constant state of change. Moore (1899, p. 73) noted

> The topographical changes in the region between Timbalier and Terrebonne bays are quite extensive and rapid, and islands were observed there in all stages of destruction, some of them cut into pieces, others barely showing above the water, and still others whose former positions were marked merely by shoals or by dead brush projecting above the surface.

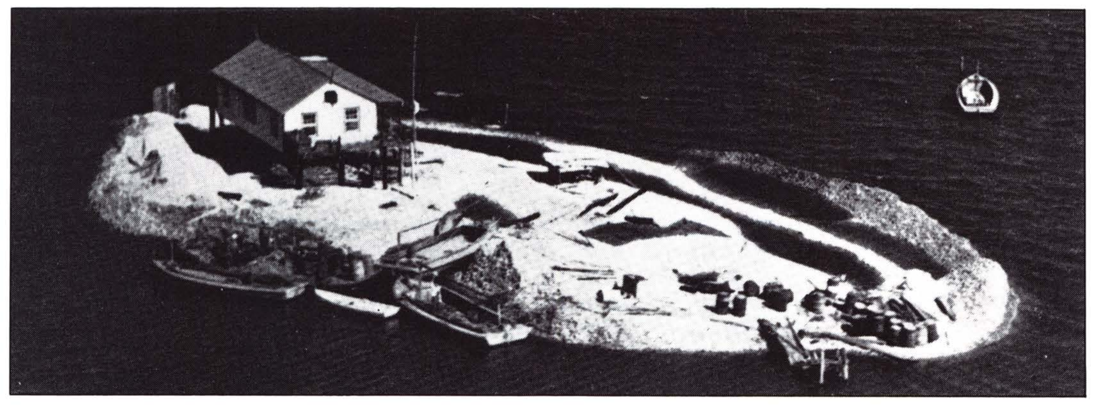
Barrier islands are bulwarks that protect the valuable wetlands and slow a storm's forward momentum, but the damage can still be catastrophic. In fact, since the 1950's over $20 billion in property losses due to hurricanes have been assessed in the United States, with the barrier islands absorbing the initial punishment (Ringold and Clark, 1980; Daily Comet, 1985; Wang, 1990). Although Louisiana's coast does not have a barrier island 50 kilometers long, such as Galveston Island, Texas, the Chandeleurs, Grand Isle, Grand Terre, Timbalier, and Isles Dernieres (Last Island) are important settlement sites.

Unlike those on most coasts, Louisiana's barriers are not completely developed. Grand Isle is the exception; even so, it does not possess an extensive array of hotels, motels, high-rise buildings, or single-family residences. The permanent and seasonal recreational population nevertheless is in danger because Louisiana's coast is particularly sensitive to storm damage. Before 1985, Hurricanes Betsy and Camille severely damaged Louisiana's coast. In 1985, Louisiana became the first state to be struck by three hurricanes in one year—Danny, Elena, and Juan.

Barrier island residents have been susceptible to dangerous weather for over two centuries. Villages, recreational hotels, and scattered trapper-fisher-hunter camps are part of the barrier islands' folklore. Pirates, bootleggers, smugglers, and others have used these islands. Scattered recreational dwellings and petroleum-related industries now dominate the barrier islands' human-made landscape.

LOUISIANA'S COASTAL LOWLANDS

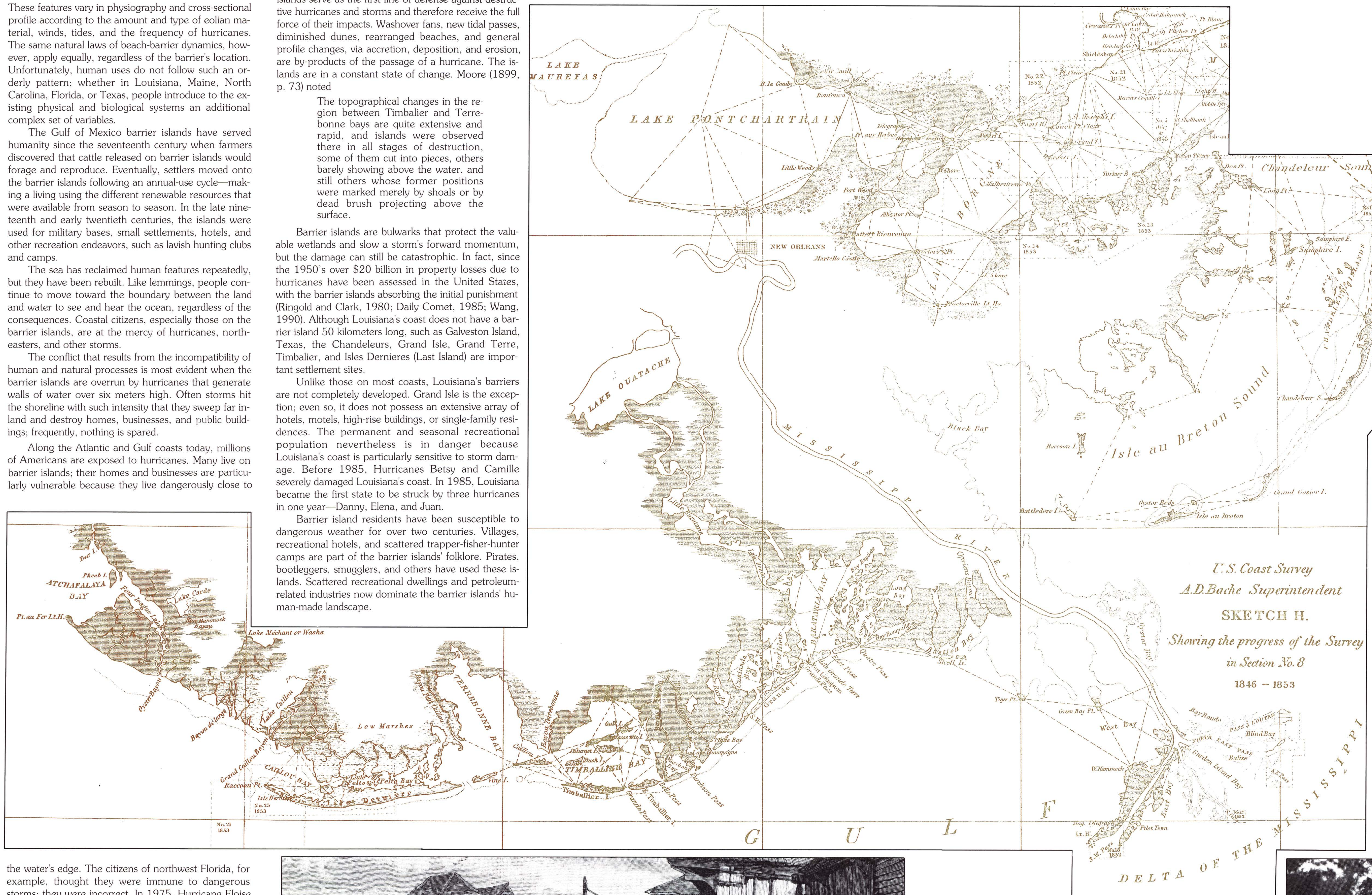
Near-featureless marshes and adjacent water bodies span the Louisiana coast and vary in width from 25 to 80 kilometers. Exposed salt domes are over 40 meters above the sea-level marshes. There is less than a four-meter height difference between the marsh and adjacent natural levees, cheniers, and beaches, and one meter in elevation can provide firm, habitable land.



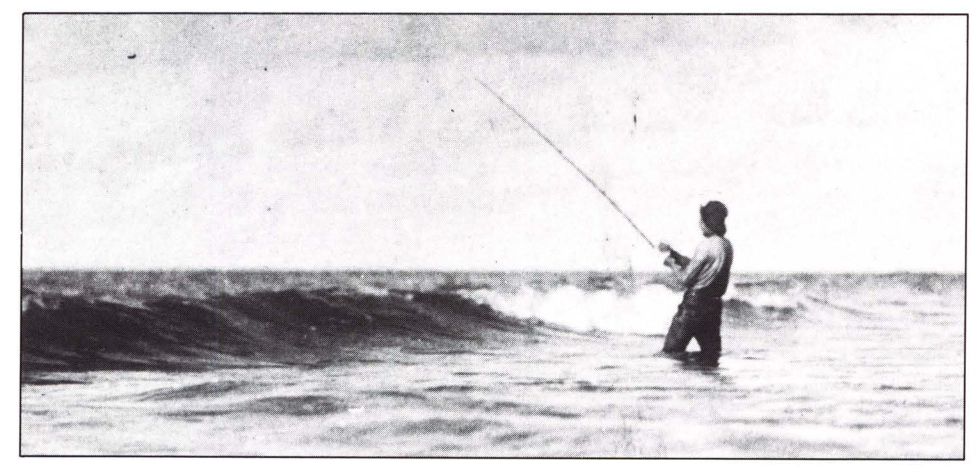
Oystermen often built homes on bird-like wooden legs, two meters above the water; oyster shells thrown around the camp created an artificial island, 1940: (*in* Justin F. Bordenave, ed., *Jefferson Parish Yearly Review*, Special Collections Division, Hill Memorial Library, Louisiana State University Libraries, p. 72).

An oysterman tonging oysters into a *bateau plat*—a flat-bottom boat with a blunt bow and stern, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).

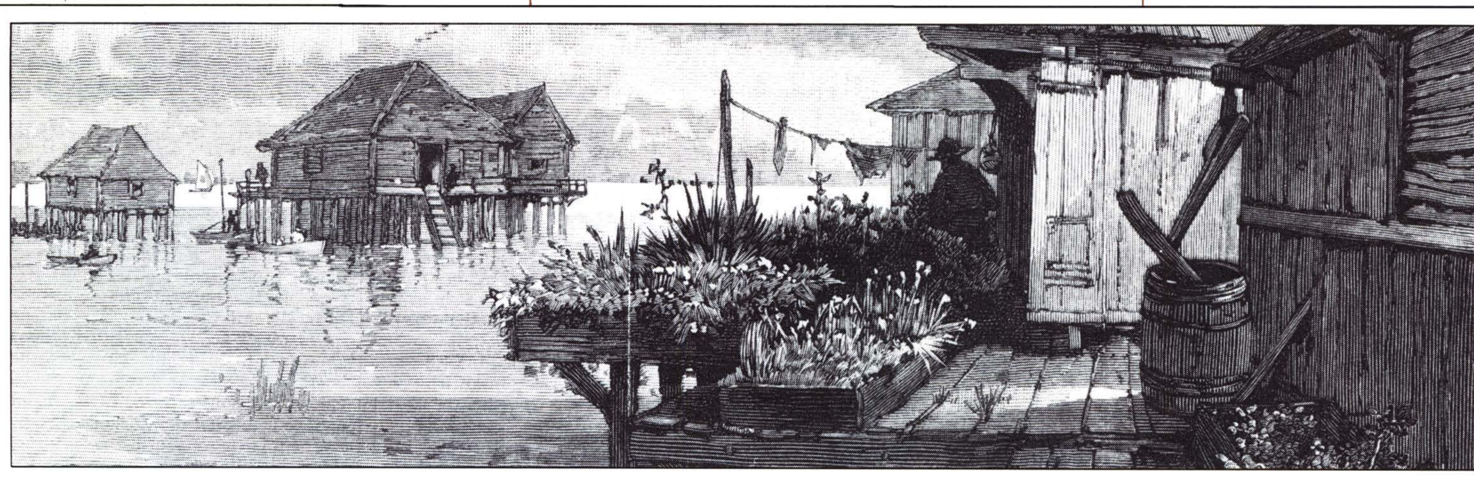
Under full sail, a Louisiana oyster lugger moved easily across the inland waterways, no date: (National Archives, Negative No. 22-FCD-30).



Muskrat and nutria were trapped in Louisiana's marshes to provide nearly 60 percent of the nation's fur harvest, ca. 1930: (Louisiana Department of Wild Life and Fisheries, Photographic Archives).



Louisiana's barrier islands have served as a recreational resource since the early nineteenth century. Surf fishing at Timbalier Island was a popular sport, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).



The St. Bernard Parish community of St. Malo, elevated above the marsh "muck." Asian immigrants used planter boxes and "night soils" to raise fresh vegetables. Rain water from roof drainage was collected in barrels, no date: (*Harper's Weekly*, March 31, 1883, p. 197).

Louisiana's trapper-farmer-fisher folk built their homes from indigenous materials to create functional structures; these were covered with palmetto and equipped with barrel cisterns, ca. 1910: (Swanton Collection, Smithsonian Institution, Photo No. 1536).

LOUISIANA'S SETTLEMENT HISTORY: FROM NATURAL LEVEES TO MARSHES TO BARRIER ISLANDS

Louisiana's coastal lowlands have been occupied for 12,000 to 14,000 years. During that time the adjacent alluvial wetlands have supported a range of cultures and settlements which include prehistoric Indian sites, and Yugoslavian, Chinese, Italian, and Acadian communities (Johnson, 1831). Prehistoric Indians settled the dry land adjacent to many of the region's water bodies. Over 500 of these relic encampments, distinguished by middens (shell mounds), have been located and mapped. The region's settlement and economic history has, in fact, been generally dictated by the availability or unavailability of high ground. From barrier islands to beaches, natural levees, cheniers, coteaux (hills or ridges), bays, and estuaries, people have had to adjust to floods, subsidence, hurricane-induced storm surges, and sea level rise.

Settlement clusters were scattered throughout the wetlands, along the shoreline, and on the barrier islands by the late 1800's. Mauvais Bois, a small community south of Houma, was located on a levee remnant approximately 10 kilometers long and 75 meters wide and supported an economy based on agriculture, fishing, and trapping. At Mauvais Bois and other coastal communities, cattle ranged the open marsh. In contrast, Camardelle inhabitants at Barataria Bay were totally dependent upon seasonal fishing and trapping because there was no space available for agriculture. Camardelle citizens lived on wharves and houseboats and took their homes with them, even if the dwellings had to be dismantled, as seasonal activities changed.

The elevated community of Manila Village was supported entirely by the shrimp industry. Cheniere Caminada was dominated by trapper-hunter-fisher folk, groups who based their subsistence economy on the annual changes in the seasons and who cultivated small gardens to add to the quality of their diet (figure 1). Cheniere Caminada had a school, a church, and several stores, facilities usually unavailable in marsh communities.

By the mid-1800's Louisiana's wetlands supported over 150 communities that were connected to the settlers' resource areas, markets, and supply sources by well-defined routes of circulation—the region's natural and human-made waterways. One of the earliest sites was Cheniere Caminada—a community just across the Caminada Bay from Grand Isle, which served as a harbor for net fishermen.

Because the marshes were devoid of "high" land, the region's narrow riverine strips became the focal point for settlement. A settlement pattern developed from the region's distinctive deltaic morphology. With time, this dense, unorganized network of distributary ridge, wetland, and barrier island communities became a large, isolated, and permanent population. Each settlement was economically homogeneous in that all inhabitants were supported by variations of the same means of making a living. The hamlets' farmer-trapper-fisher folk were aware of their environment and developed skills that allowed them to harvest the local wildlife.

THE ETHNIC MIX

The Spanish, French, Italians, Yugoslavians, Irish, Germans, Cubans, Greeks, Latin Americans, and Chinese settled within Louisiana's coastal lowlands. The foreign fishing population was larger than any other in the Gulf states (Collins and Smith, 1893). Based on its cultural heritage, each group interpreted the environment differently. Louisiana exhibits, therefore, a distinctive ethnic and cultural heterogeneity, but the French are the biggest and oldest ethnic group.

French and German peasant (habitant) farmers first settled along the Mississippi River in the *Cote des Allemands* (German Coast) (American States Papers, 1803). As early as 1718 the area was settled by people enticed into moving to Louisiana from France by the propaganda of John Law's Mississippi Company. They were generally the more prosperous and better educated class living in Louisiana (Bertrand and Beale, 1965). These urban dwellers enjoyed the fine goods offered to them by the privateer Jean Lafitte, whose barrier island fortress was one of the earliest settlements on Louisiana's coast.

After deportation from British-controlled Nova Scotia in September 1755, nearly 4,000 refugee Acadians also migrated to Louisiana and settled the alluvial wetlands. These people continued to arrive in small groups from 1760 to 1790 (Detro and Davis, 1974). The Acadians were accustomed to working the land and settled on the prairies, cheniers, bayous, marshes, swamps, and barrier islands in south central and southeastern Louisiana. They were French-speaking Roman Catholics who provided south Louisiana with its own unique ethnic community. Eventually the Acadians abandoned French as a written language. Their language is no longer spoken in France, and many of the family surnames survive there only in historical literature.

The Acadians enjoyed the isolation provided by south Louisiana's physical geography. Their communities were accessible by means of winding streams called bayous (from the Choctaw *bayuk*, or creek) and close to fishing, hunting, trapping, and agricultural areas. The rich alluvial soil of the Mississippi valley, the area's abundant hide- and fur-bearing animals, and the easily harvested aquatic life were infinitely attractive to the Acadians, who were also trappers and net fishermen (Evans, 1963).

Besides the French, a group of Yugoslavian oyster fishermen settled along the bayous, bays, and lakes southeast of New Orleans. Chinese and Filipinos built shrimp-drying communities in the estuaries. British, French, and Americans settled the barrier islands. By the early 1830's, a relatively dense network of settlements was functioning at isolated points within the marsh. The barrier islands—Grand Isle, Grand Terre, Cheniere Caminada, Isles Dernieres, and the Chandeleur Islands—had established their own identities.

Throughout the wetlands' waterways, red-sailed luggers, isolated palmetto-covered houses, or the rustic, cypress-gray gables of Chinese camps or lake dwellers were a part of the visual landscape (Sampsell, 1893). Although many considered the wetlands valuable only for their intrinsic qualities, Acadians, Yugoslavians, Chinese, Italians, and others recognized the coastal lowlands for their resources and were able to make a living from them through trapping, shrimping, and oystering.

ISLES DERNIERES: LOUISIANA'S FIRST COASTAL RESORT

Isles Dernieres was:

> no ordinary island, but the proudest summering place of the Old South - a private little world dedicated to fine living. Here, to the massive, two-story hotel in the myrtle-shadowed village at the island's western tip, and to the hundreds of graceful houses decorating 25 miles of beach, wealthy planters and merchants, who bore the most illustrious names in all Louisiana, brought their families to escape the summer heat and to live according to the unchanging code of French and Spanish ancestors. (Deutschman, 1949, p. 143)

In the early 1850's Isles Dernieres, known also and especially historically as Last Island and located at the southern fringe of Terrebonne Parish, was about "thirty miles [48 kilometers] long and half a mile [0.9 kilometers] in width" (Daily Delta [New Orleans], 1850). The wooded island was the site of about half a dozen light-framed summer cottages on Village Bayou. Erected on posts stuck in the sand, they were not built to withstand the force of a hurricane, but the visitors were only concerned about enjoying the relaxed atmosphere of the island (Silas, 1890).

> The houses are fine, particularly those of Lawyer Maskell and Captain Muggah. These houses serve for the reception of visitors during the summer season, at which time the enjoyers of elegant leisure flock to the isle in great number, and not as a dernier resort, but for the veritable purpose of enjoying themselves. (Daily Delta [New Orleans], 1850, p. 2)

Isles Dernieres was one of Louisiana's first coastal recreation sites. Families came to swim, fish, hunt, and enjoy the tranquility (Liddell, 1851). Most visitors to the resort were wealthy planters from the Lafourche and Atakapa areas. "It was a delightful place to escape the summer heat, enjoy the sea breeze" (Wailes, 1854), and listen to the "skill and taste of the old German, whose violin furnished … exquisite music" (Pugh 1881, p. 3). The extensive beach served as a shell road where "one's buggy whirls over it with a softness, and airy, swinging motion, that is perfectly intoxicating" (The Daily Picayune [New Orleans], 1852, p. 1). The Village Bayou on the bay side of the island provided a safe place for packet steamers and sailboats to land. In fact, as early as 1848 Louisiana requested its legislative delegation to lobby for a lighthouse at the west end of the island to improve the navigation of the State's western coast (Johnson, 1848).

Two hotels, the Ocean House and Captain Muggah's Hotel, or The Muggah Billiard House, provided rooms for guests. The Ocean House was equipped with a bar, amiable accommodations, a billiard table, and tenpin alley. Captain Muggah built cabins on the beach as alternate facilities to his hotel (Pugh, 1881). A large public livery stable housed the guests' horses and buggies.

THE 1856 LAST ISLAND HURRICANE

Sunday, August 10, 1856, the island resort was destroyed by the Last Island hurricane. During the storm every solid object became a mobile battering ram, destroying nearly all the structures on the island. Many families were lost; about half of the island's population survived. In the legends of coastal Louisiana, over 400 people attended a Sunday ball at the hotel on Village Bayou at which the Creole aristocracy "danced until they died" in the hurricane.

With time, stories of the disaster became part of the region's folklore. For example, through a blend of fact and fiction, the two hotels were visualized as one. Consequently, numerous imaginary embellishments of the Isles Dernieres legend crystallized in Lafcadio Hearn's book, *Chita: A Memory of Last Island*, which purports to document the storm.

Newspaper accounts of the period reported that from 260 to 300 people died (Ellis, no date). Entire families were swept off the island. Some rode out the storm on floating debris and were rescued 24 kilometers from the resort (Schlatre, 1937). Horses, cattle, and fish lay strewn about the island among the human victims. At the center of the island, one small hut and several head of cattle survived the storm (Cole, 1892a). Property loss was estimated at over $100,000 (Ludlum, 1963). Because earlier reports were revised as more survivors were located, the final death toll was about 140 persons (Ludlum, 1963).

> From that time the wind blew a perfect hurricane; every house upon the island giving way, one after another, until nothing remained. At this moment everyone sought the most elevated point on the island, exerting themselves at the same time to avoid the fragments of buildings, which were scattered in every direction by the wind. Many persons were wounded; some mortally. The water at this time (about 2 o'clock P.M.) commenced rising so rapidly from the bay side, that there could no longer be any doubt that the island would be submerged. The scene at this moment forbids description. Men, women, and children were seen running in every direction, in search of some means of salvation. The violence of the wind, together with the rain, which fell like hail, and the sand blinded their eyes, prevented many from reaching the objects they had aimed at. (Ludlum, 1963, p. 166)

> It was a gloomy sight, not a house or shelter standing. The hull of the steamer and a number of sailing boats stranded on the island near where the hotel had stood, and some 260 or 300 people had been drowned … every one was busy all day looking for and burying the bodies which had been drowned, others collecting provisions and getting something to eat, others fixing up things to make it a little more comfortable. In the meantime we had fitted out a boat and dispatched it to the Atchafalaya to report our condition. (Ellis, no date, p. 8)

The steamer *Star* made semi-weekly trips from the railroad station in Bayou Boeuf, down the Atchafalaya River through Four League Bay, to the Isles Dernieres resort. On Sunday morning, August 10, 1856, the *Star* approached Isles Dernieres after a difficult journey from Morgan City, a trip that required two men to steer the vessel. She anchored in Village Bayou behind the Muggah's Hotel. During the hurricane a part of the pier gave way, and the steamer parted her moorings and slowly drifted towards the island. Those on board were ordered below. Soon the steamboat's chimneys, pilot house, and hurricane deck were gone, leaving only the hull (Ellis, no date). The wreck drifted toward the island and lodged itself in a turtle enclosure for the remainder of the storm (The Daily Picayune [New Orleans], 1856b). Approximately 250 to 275 people survived in the hull of the *Star*; without its body, firmly trapped in the sand, more would have perished (The Daily Picayune [New Orleans], 1856a).

The destruction from the Last Island hurricane was complete, but the storm documented the value of the island itself. Isles Dernieres absorbed the storm's winds, waves, and high water; the islands on the backside were protected and did not receive as great an impact. Bayside damage was minimal. At nearby Caillou Island, in Terrebonne Bay, the water only rose about 1.5 meters. The people on these inner islands were saved from the storm's full force. They were inconvenienced but not killed (New Orleans Christian Advocate, 1856).

HURRICANES IN THE COASTAL ZONE

Coastal Louisiana's climate is generally described as humid subtropical: warm summers and mild winters are the rule. Winter extremes, when they occur, are a product of cold fronts that can change the daily weather quickly. In the summer and fall, normal conditions can be dramatically altered by the periodic arrival of hurricanes.

Caribbean history is punctuated by hurricanes; even the name is derived from the Caribbean Indians' storm-god Huracan. By nature, hurricanes are unpredictable and can change direction abruptly. Between May and November, hurricanes move in a north-northwest direction across the Atlantic Ocean. In the Gulf of Mexico, they are most active in August, September, and October.

Hurricanes are always of concern to humans; they carry high winds, extremely low pressures, vast quantities of precipitation, and large storm surges. The Saffir-Simpson scale, originated in 1972 by Herbert Saffir, consulting engineer for Dade County, Florida, and Robert Simpson, former director of the National Hurricane Center, indicates on a scale of 1 to 5 the damage potential from different wind speeds and storm-surge heights (table 1). The 12 deadliest hurricanes of this century were all category 4 or 5 (extreme to catastrophic). Most Louisiana hurricanes are category 2 or 3 (moderate to extensive damage) storms.

TABLE 1.—*Saffir-Simpson scale of damage-potential.*

Scale Number	Central Pressure (Millibars)	Winds (km/hr)	Surge (meters)	Damage
1	≥980	119-153	1.2-1.5	Minimal
2	965-979	154-177	1.6-2.4	Moderate
3	945-964	178-209	2.5-3.6	Extensive
4	920-944	210-250	3.7-5.4	Extreme
5	<920	>250	>5.4	Catastrophic

In reports of hurricane damages, two Louisiana storms are mentioned repeatedly: Betsy (1965) and Camille (1969). When Betsy struck the Louisiana coast, it had already left in its wake $119 million in damages to Florida. This fast-moving storm was highly erratic; it could not be predicted accurately because it changed course frequently. Because of this, officials took the precaution of evacuating an estimated 250,000 residents from unprotected areas. Betsy's 200 km/hr winds approached shore, its waves battering Grand Isle; approximately 90 percent of southeastern Louisiana's residents evacuated.

The storm's aftermath resulted in at least $700 million in insured damages—$650 million in Louisiana, the remainder in Florida, Mississippi, and Alabama. Uninsured flood damages pushed the final figure over the $1 billion mark. Seventy-four people died in Louisiana, most from drowning.

Four years later, Hurricane Camille, one of only three category 5 hurricanes to enter the Gulf of Mexico in this century, took aim on the Louisiana-Mississippi coast. Camille was a compact storm, only 80 kilometers wide, with 320 km/hr winds, a six-meter storm surge and 75 centimeters of rain. This system made landfall near Pass Christian and Bay St. Louis, Mississippi. Its destructive intensity established financial and wind-speed records. Camille left 259 people dead and $1 billion in property damage.

Before Betsy and Camille, two catastrophic storms occurred in the barrier islands. The first, in 1856, destroyed the recreation-oriented community at Isles Dernieres, and the second, in 1893, displaced nearly 1,500 families at Cheniere Caminada.

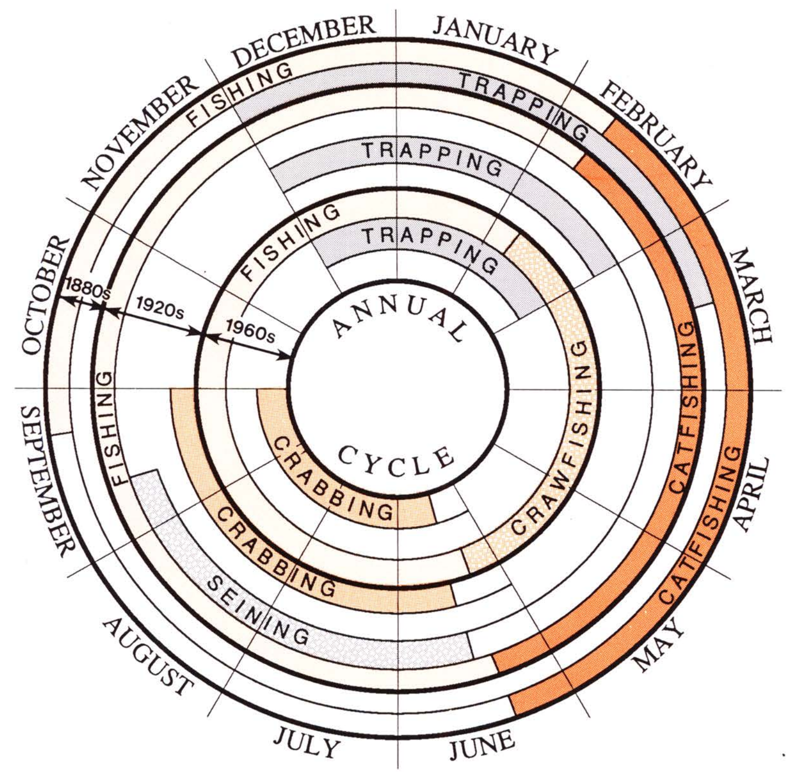
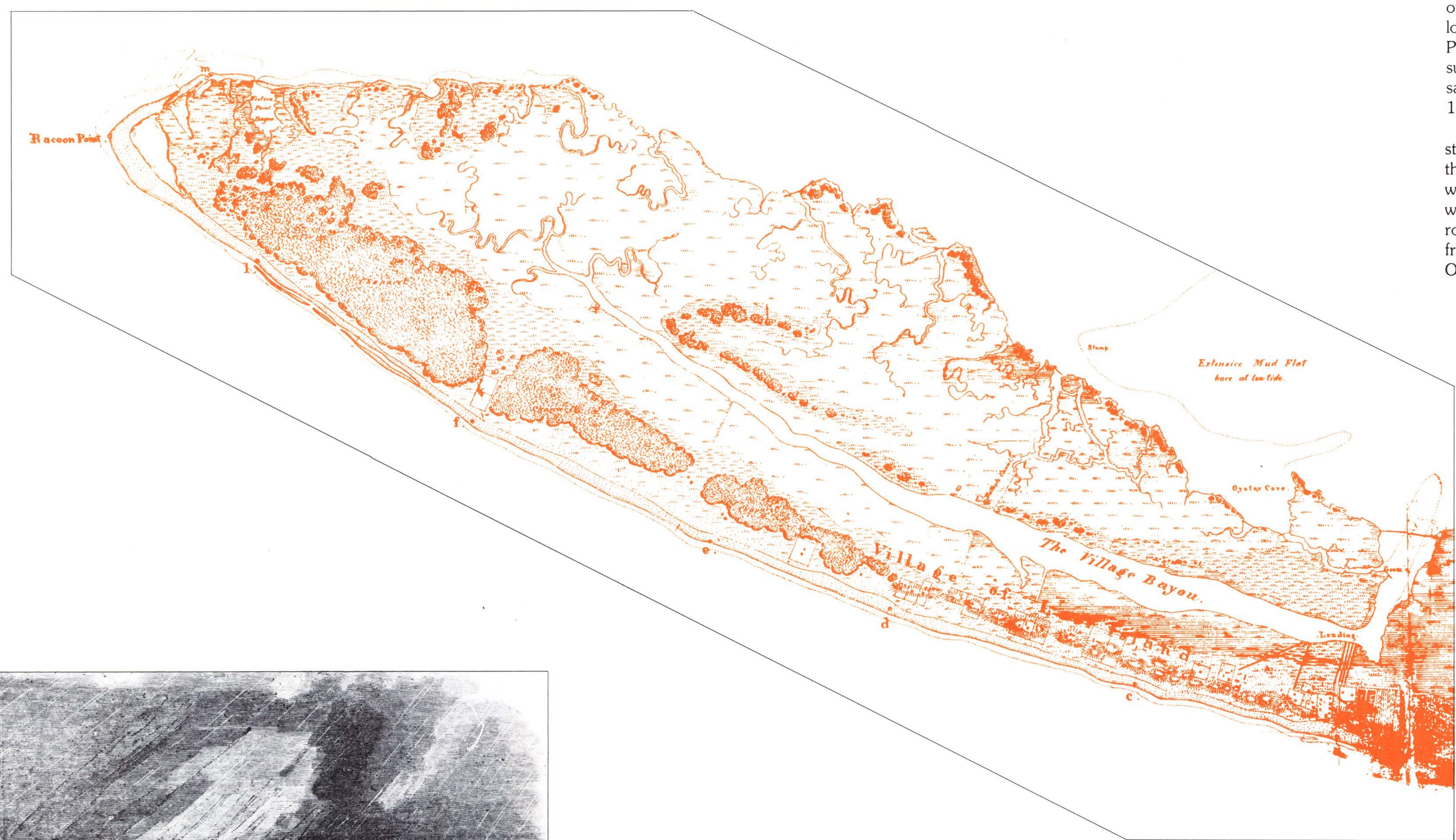
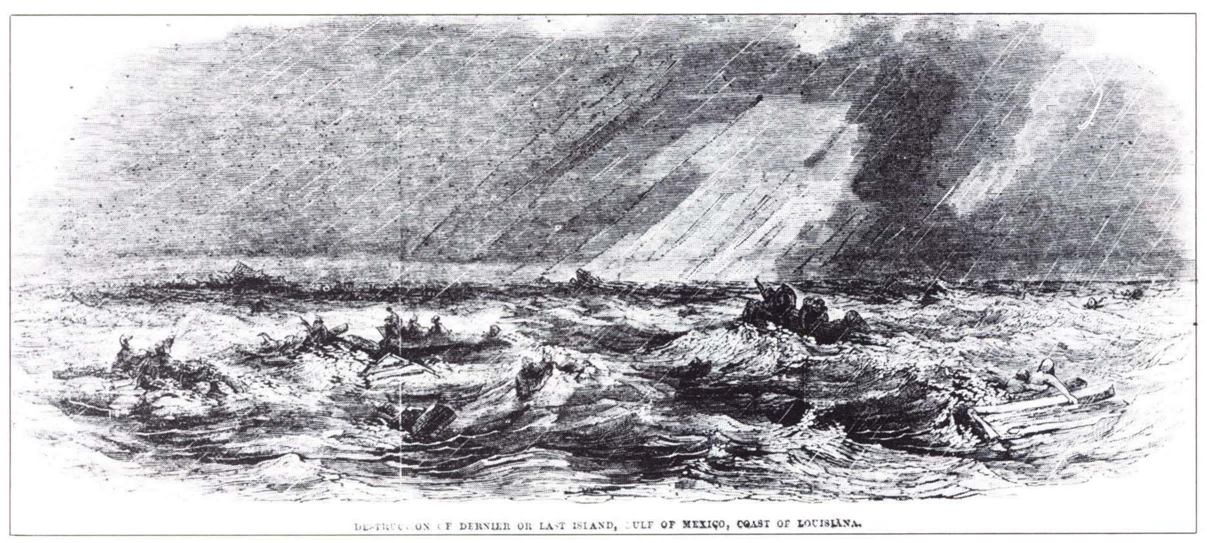


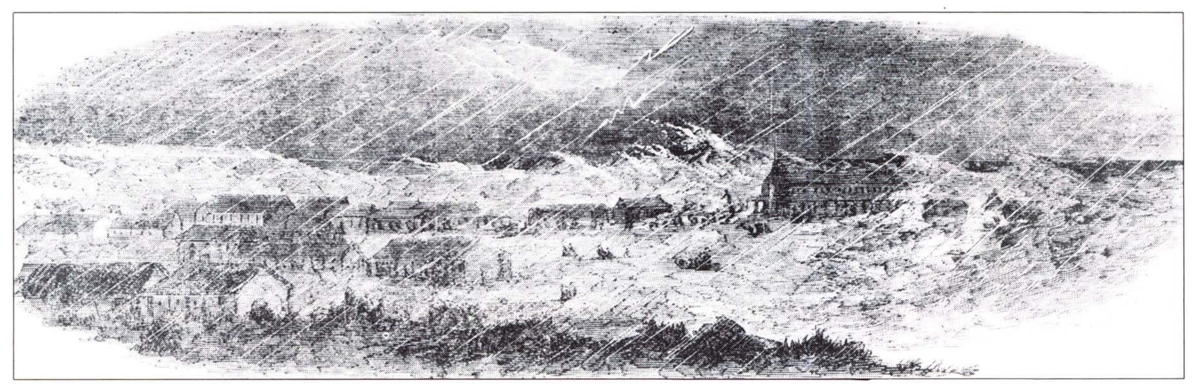
FIGURE 1.—Annual-use cycle of marshlands people in Louisiana. The fishing season included oystering and shrimping as well: Modified from Comeaux, 1972.



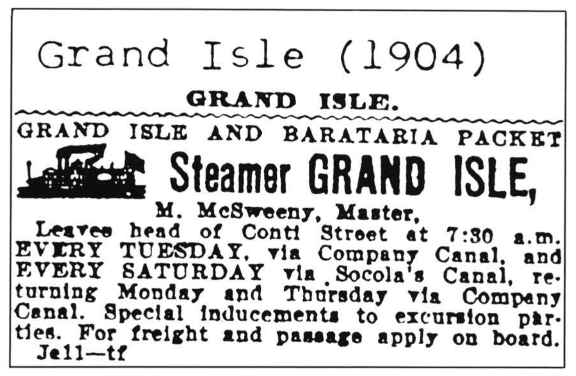
United States Coast Survey, A. D. Bache, Superintendent, Western Part of the *Isles Dernieres*, February 1853 by F. H. Gerdes, scale 1:10,000.



In 1853 Isles Dernieres' (Last Island) Village Bayou was destroyed by a hurricane that inundated Louisiana's first coastal recreation site, ca. 1856: (Frank Leslie's Illustrated Weekly, Historic New Orleans Collection, Museum/Research Center, Accession No. 1974.25.4.66).



Two hotels, the Ocean House and The Muggah Billiard House, were lost because the wind and water rose from the 1856 hurricane, ca. 1856: (Frank Leslie's Illustrated Weekly, Historic New Orleans Collection, Museum/Research Center, Accession No. 1974.25.4.65).


Grand Isle (1904)

GRAND ISLE.

GRAND ISLE AND BARATARIA PACKET

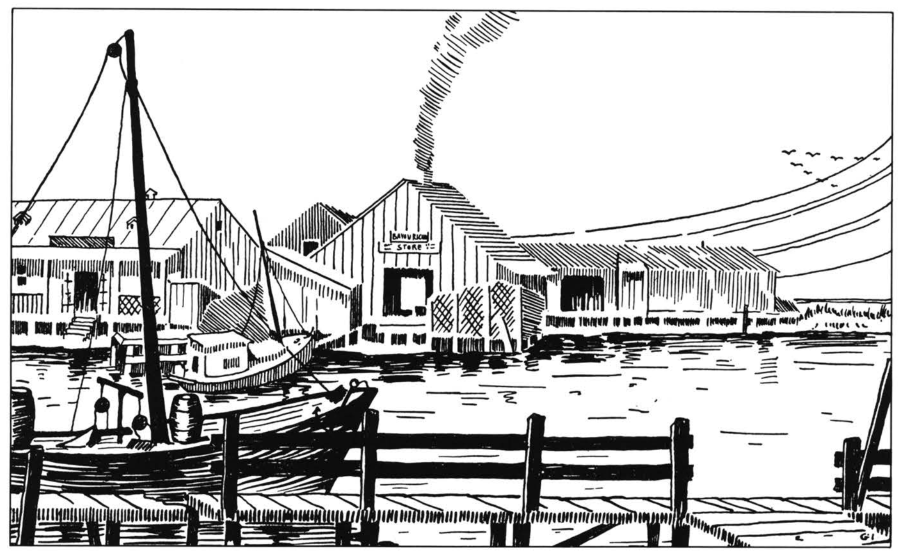
Steamer GRAND ISLE,

M. McSweeny, Master.

Leaves head of Conti Street at 7:30 a.m. EVERY TUESDAY, via Company Canal, and EVERY SATURDAY via Socola's Canal, returning Monday and Thursday via Company Canal. Special inducements to excursion parties. For freight and passage apply on board.

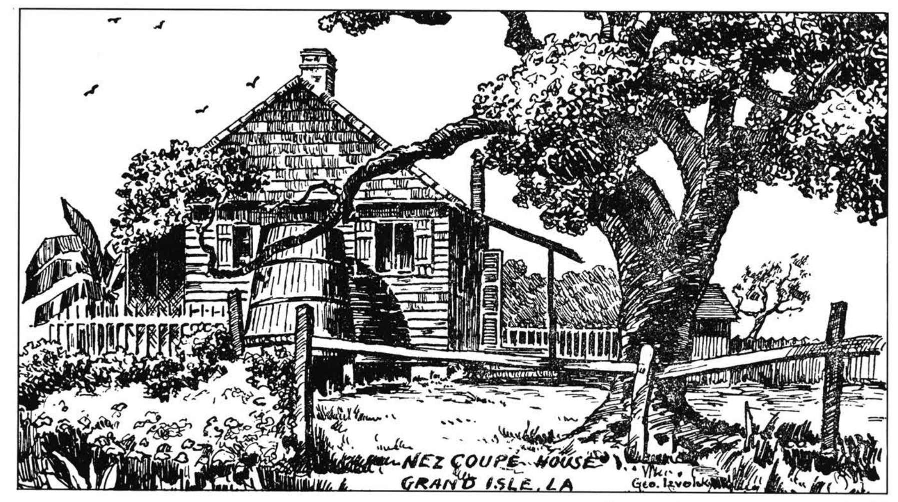
Je11—tf

Huber, Leonard, 1959, *Advertisements of Lower Mississippi River Steamboats, 1812-1920*, West Barrington, Rhode Island, The Steamship Historical Society of America, p. 29.

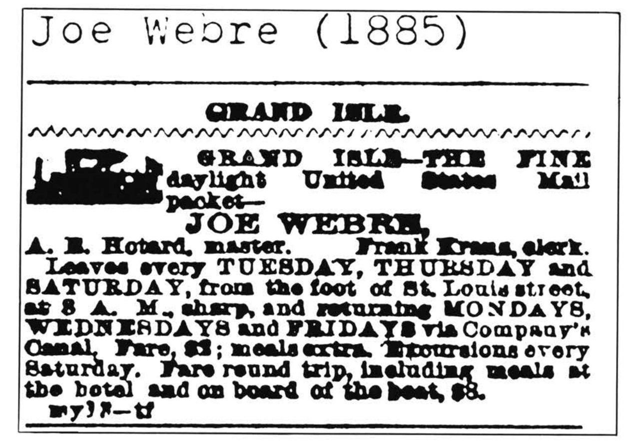


Bayou Rigaud landing at Grand Isle, ca. 1933: (Pen and ink postcard drawing by George Izvolsky).

Ca. 1933: (Pen and ink postcard drawing by George Izvolsky).



Home of Nez Coupe, descendant of one of Jean Lafitte's lieutenants, ca. 1933: (Pen and ink postcard drawing by George Izvolsky).


Joe Webre (1885)

GRAND ISLE.

GRAND ISLE—THE FINE daylight United States Mail packet—

JOE WEBRE,

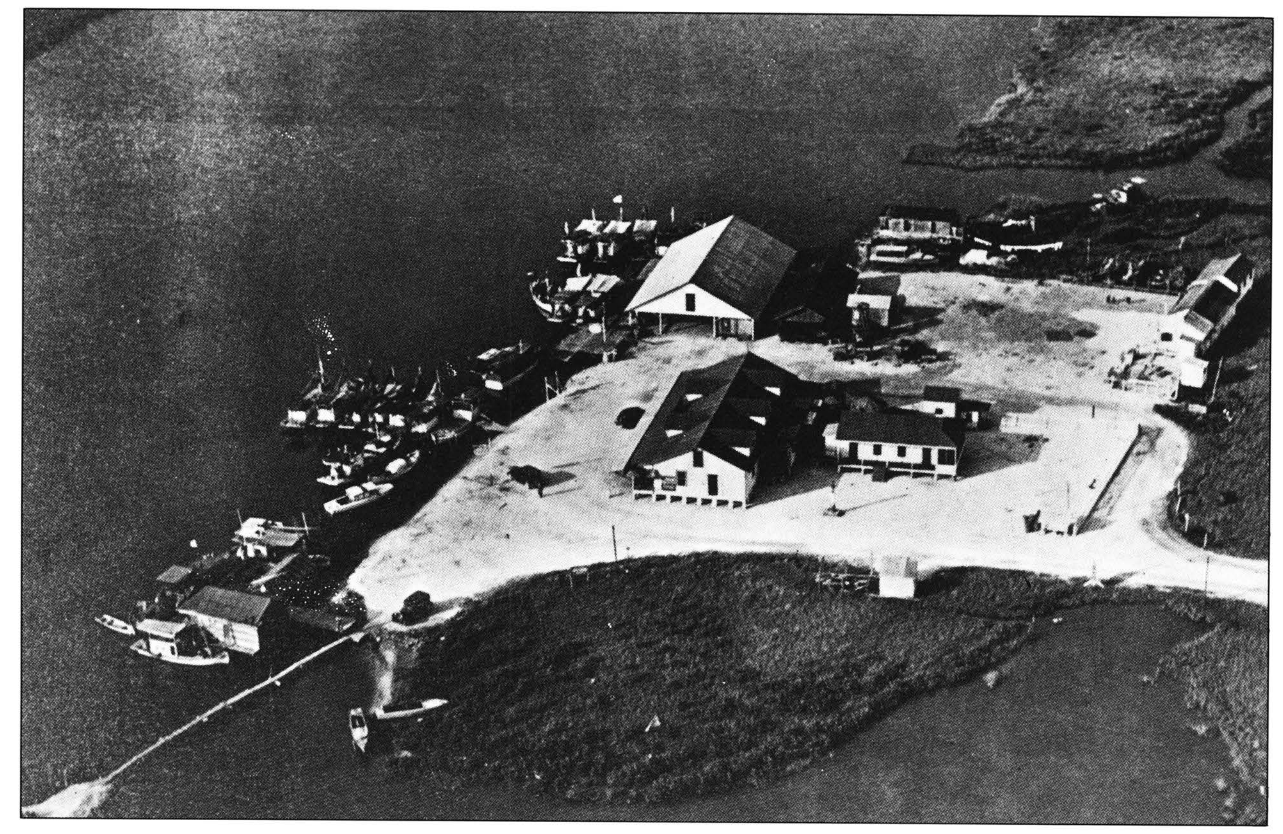
A. E. Hotard, master. Frank Krams, clerk.

Leaves every TUESDAY, THURSDAY and SATURDAY, from the foot of St. Louis street, at 8 A. M., sharp, and returning MONDAYS, WEDNESDAYS and FRIDAYS via Company's Canal. Fare, $3; meals extra. Excursions every Saturday. Fare round trip, including meals at the hotel and on board of the boat, $8.

my17—tf

Huber, Leonard, 1959, *Advertisements of Lower Mississippi River Steamboats, 1812-1920*, West Barrington, Rhode Island, The Steamship Historical Society of America, p. 36.

Typical early Grand Isle home, built on the highest portion of the island for added hurricane protection, no date: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).



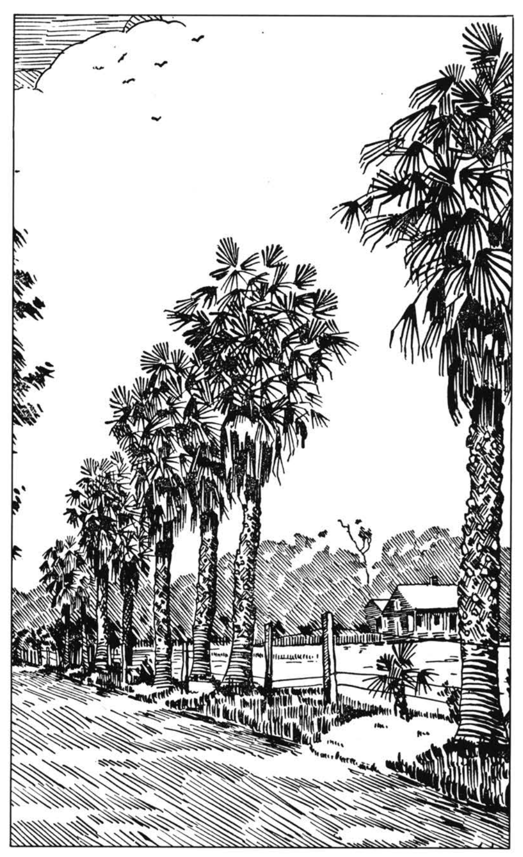
Bayou Rigaud provided a safe and convenient harbor for the working and sporting boats looking for a safe anchorage at Grand Isle, ca. 1939: (in Justin F. Bordenave, ed., *Jefferson Parish Yearly Review*, Special Collections Division, Hill Memorial Library, Louisiana State University Libraries, p. 54).

Horse-drawn carts were the principal means of transportation on Grand Isle, no date: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).

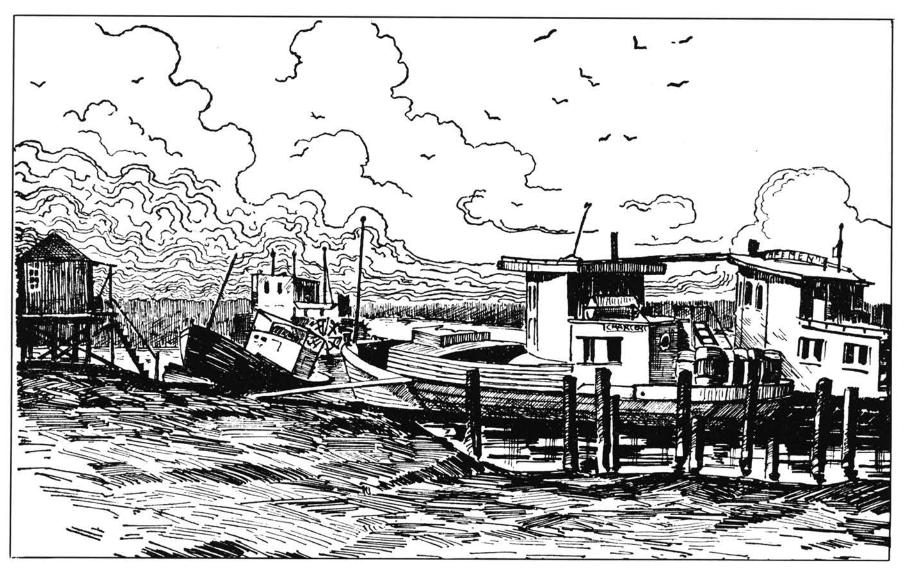
When a road and bridge were completed to Grand Isle, it became a favorite summer and weekend resort, July 4, 1938: (Fonville Winans, Louisiana State Library, Louisiana Photographic Archives).

A day at the beach on Grand Isle, no date: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).

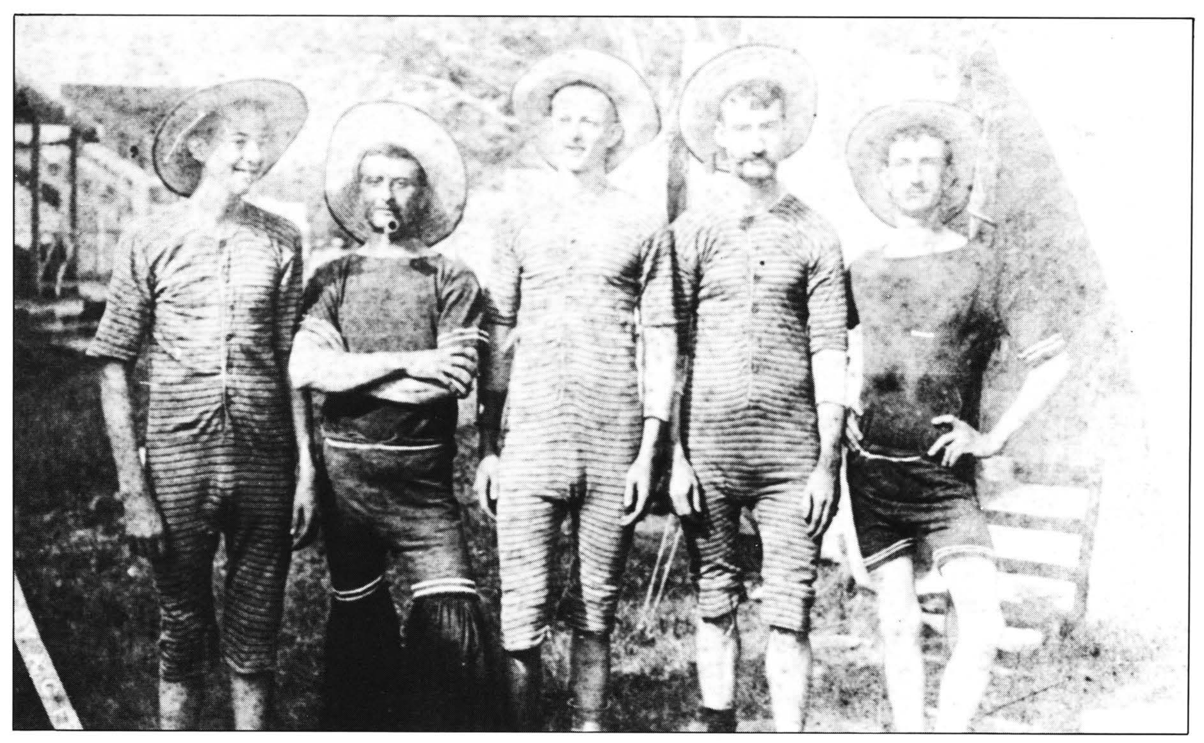
Grand Isle bathers leave their cars at the water's edge on hard packed sands, while they enjoy playing in the surf, 1940: (in Justin F. Bordenave, ed., *Jefferson Parish Yearly Review*, Special Collections Division, Hill Memorial Library, Louisiana State University Libraries, p. 77).



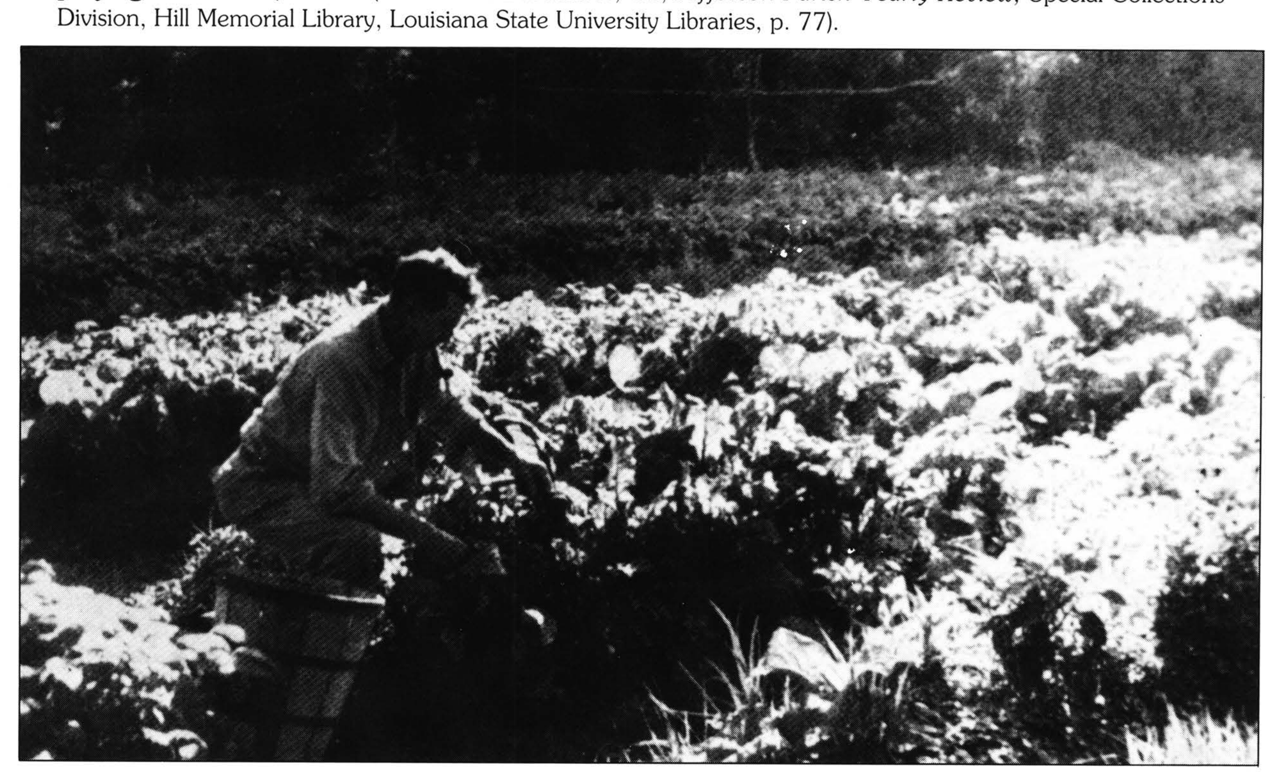
Palm-lined Ludwig's Lane on Grand Isle, ca. 1933: (Pen and ink postcard drawing by George Izvolsky).



Grand Isle oyster boats, ca. 1933: (Pen and ink postcard drawing by George Izvolsky).



A group of Grand Isle bathers modeling the latest in swimwear, ca. 1890: (Historic New Orleans Collection, Museum/Research Center, Accession No. 1981.238.14).



Within the oak thicket at the center of Grand Isle, the local farm community established orange groves, cauliflower fields, and blackberry patches, 1943: (in Justin F. Bordenave, ed., *Jefferson Parish Yearly Review*, Special Collections Division, Hill Memorial Library, Louisiana State University Libraries).

GRAND ISLE: A POTPOURRI OF USES

The history of Grand Isle is not as spectacular as that of Isles Dernieres, Cheniere Caminada, or Grand Terre. It was, like all of south Louisiana's coastal settlements, isolated. To survive economically, the island's inhabitants supported themselves through various industries that included seafood canning, agriculture, and turtle farming (Davis, 1990).

Grand Isle's first major economic activity was the sugar business. By 1830, four sugar plantations were in operation; this established the island as an agricultural base. These plantations were owned by Samuel Britton Bennett, Alexander and Charles Lesseps and John B. Lepretre, Pleasant Branch Cocke, and Francois Rigaud (House Document, 1832).

The center of the island had always been protected to some degree from the full force of a hurricane and was therefore of agricultural interest. The eastern end of the island was under the ownership of Francois Rigaud (House Document, 1832). The island's western end was claimed in 1833 by Samuel Britton Bennett (Swanson, 1975). The middle was divided between the Lesseps/Lepretre and Cocke interests.

A sugarhouse, mills, small homes, carpenter shop, stables, draining machine, cotton gin and press, blacksmith shop, slave quarters, and other buildings were a part of the island's plantation morphology. Sugar and cotton were the principal crops, but sugar was always primary (Swanson, 1975).

Grand Isle citizens lived in wood-framed cottages without electricity, modern plumbing, or evening newspaper, but the fishermen and vegetable farmers considered them comfortable. These were simple folk houses with little wasted space. Below the window sill on many homes there was a sloping shelf called a *tablettes a chaudiere*, or "dish-washing shelf," large enough to hold a stout dish pan. While washing the dishes, *Maman* kept her eye on everything that happened in the yard and on the road.

The oriental pink-to-faded-red-sailed fishing boats called luggers were a common sight in the Barataria estuary and were steered with a rudder by Malay fishermen or French oystermen (Sampsell, 1893). Piled on board the vessels were big bell-shaped bamboo baskets covered with Spanish moss (*Tillandsia usenoides*), lashed with ribbons of latania (palmetto), and filled with the day's harvest of shrimp, oysters, fish, or crabs (Cole, 1892a). As a rule, fishermen received about half the retail price for their catch. Grand Isle, one of the fishermen's supply points, eventually developed into an important recreational site. Spanish moss, itself an important regional product, was collected, ginned, and sold for furniture or mattress stuffing. There was, in fact, a large trade in the moss along the area's inland waterways (Saxon, 1942).

THE RECREATIONAL RESORT

After the Civil War, Grand Isle became a mecca for fishing, recreation, and farming; visitors endured untold hardships because getting to the island was difficult. It took 12 or more hours to reach it through narrow canals scarcely wider than the passenger steamboat. This problem was resolved upon completion of the New Orleans, Fort Jackson and Grand Island Railroad, which travelled down the Mississippi's west bank to Socola's Canal at Myrtle Grove plantation. Passengers were loaded onto a steamboat that carried them the rest of the way. The entire trip took about five hours (Ross, 1889a). Although there was some thought of building a railroad to the island to lessen the travel time, this idea never materialized.

Excursion packets from New Orleans were available aboard numerous steamboats of the era. For $7.50 per person, a room could be reserved for an overnight packet (New Orleans Times, 1866). By 1861, there was daily service to the island via the *Emma McSweeny* and the Fort Jackson and Grand Isle Railroad (The Times-Democrat [New Orleans], 1891b). A well-established pattern of summer visitation evolved. Plans were made to expand the island's facilities and make it even more attractive for guests (Meyer-Arendt, 1985). In addition, the steamer *St. Nicholas* provided passenger service three times a week from New Orleans to the island (Tieys, 1867).

In the late nineteenth century, Grand Isle attracted summer vacationers who wanted to enjoy the island's beaches and escape the heat and "yellow jack" (malaria) that plagued New Orleans. The epidemic of 1878 caused numerous families to take refuge on Grand Isle (Ross, 1889a).

THE ISLAND'S ECONOMIC BASE

Within the oak thicket at the center of the island, the local farm community eventually established orange groves, cauliflower fields, and blackberry patches. John Ludwig, one of the island's earliest leaders, recognized that the sandy loam soil could be used to produce melons, cucumbers, cauliflower, and other commodities (House Document, 1917). The soil, however, could not be cultivated by conventional means, so Ludwig introduced the idea of using high hills with deep furrows to ensure proper drainage. To utilize Ludwig's technique, the islanders built new levees on the island's bay side and repaired those that had been damaged by storms. To keep out salt water, flood gates were installed.

Grand Isle citizens went into the truck-farming business and used shrimp bran to fertilize the new fields (Swanson, 1975). These farms were quite successful and often shipped to northern markets between 35,000 and 50,000 bushels of cucumbers a year (Thompson, 1944). Orange groves were planted so close to the Gulf they rarely froze, and the island's cauliflower reached northern markets before that of any other producing region.

Even though farms were established, farmers still endured the uncertainty of getting their products to market before other producers. Heavy losses were often incurred because perishable items could not be shipped to New Orleans during sustained periods of low water (House Document, 1917).

The Grand Isle and Yugoslavian fishermen gained some notoriety for the oyster beds established in Barataria Bay. On Bayou Brule, a packing plant was constructed from a renovated building used by the New Orleans' World Exposition in 1884. Unfortunately, the enterprise failed, and the harvest was sent to "Lugger Bay," a small area of water on the Mississippi River across from the French market in New Orleans.

By the early 1900's, the island was served by a large number of stern-wheel gasoline boats. The *Tulane, Hazel, Nevada*, and *J. S. & B.* made the New Orleans-Grand Isle run once or twice a week to carry freight and passengers to the island. These boats and the local luggers carried shrimp, dried shrimp, shrimp bran, crabs, fish, diamond-back terrapin, game, cucumbers, squash, beans, tomatoes, oysters, corn, and furs to the New Orleans market (House Document, 1917).

THE ISLAND'S RESIDENT TURTLE HERD

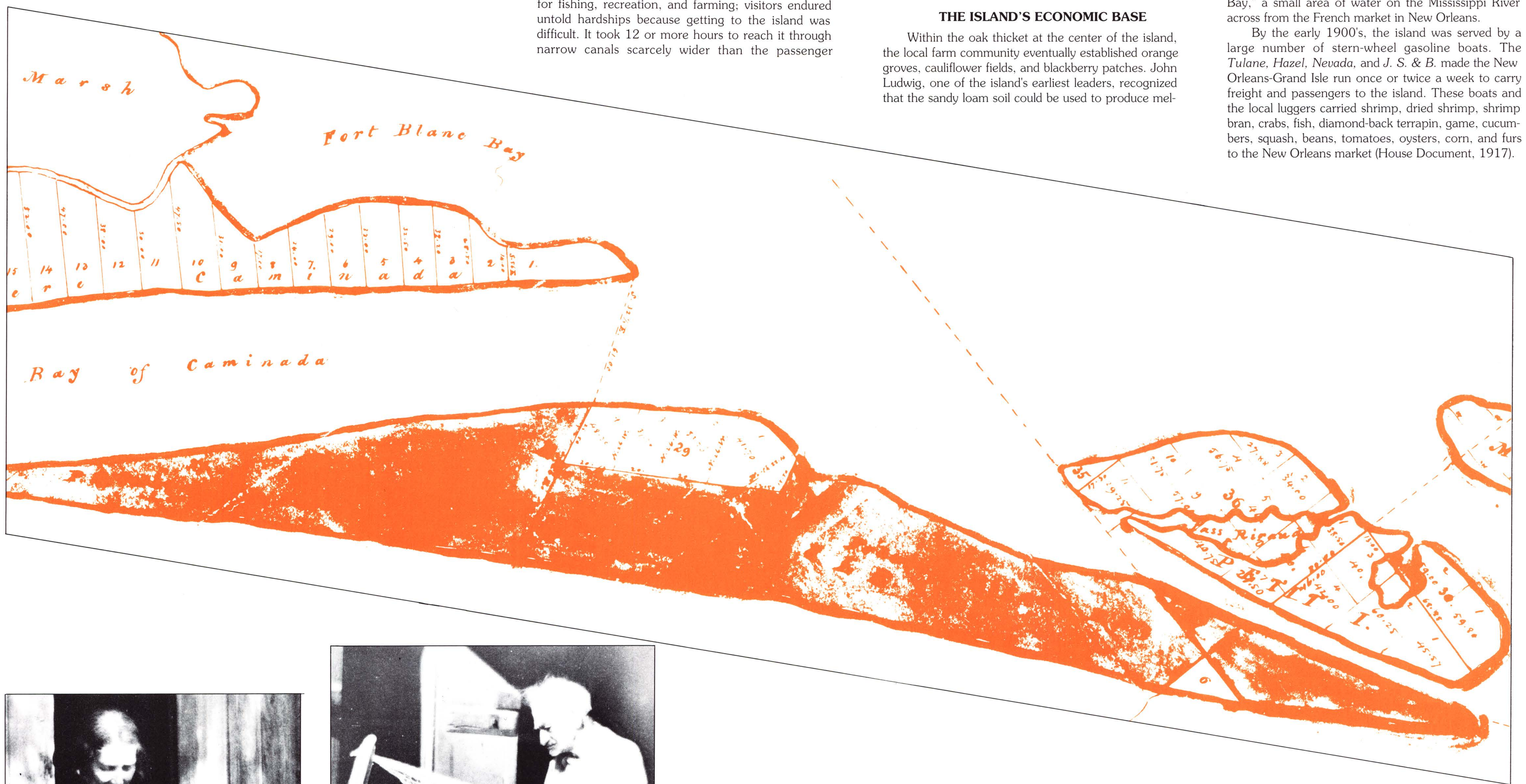
In the 1890's, John Ludwig, Jr., established on Grand Isle what was reputed to have been the world's largest terrapin farm, valued at over $50,000 (House Document, 1917). The turtle business was established to meet the needs of the restaurant trade (True, 1884b). The diamond-back terrapin (*Malacoclemmys palustris*) was a highly prized food and was cooked according to a Maryland or Philadelphia recipe for a stew garnished with vegetables and spices. Nationwide, the best market was Philadelphia, but turtles were sold in large numbers in many other cities (True, 1884b). Grand Isle turtles were sold to customers in New York, Baltimore, Washington D.C., and Boston (Housley, 1913).

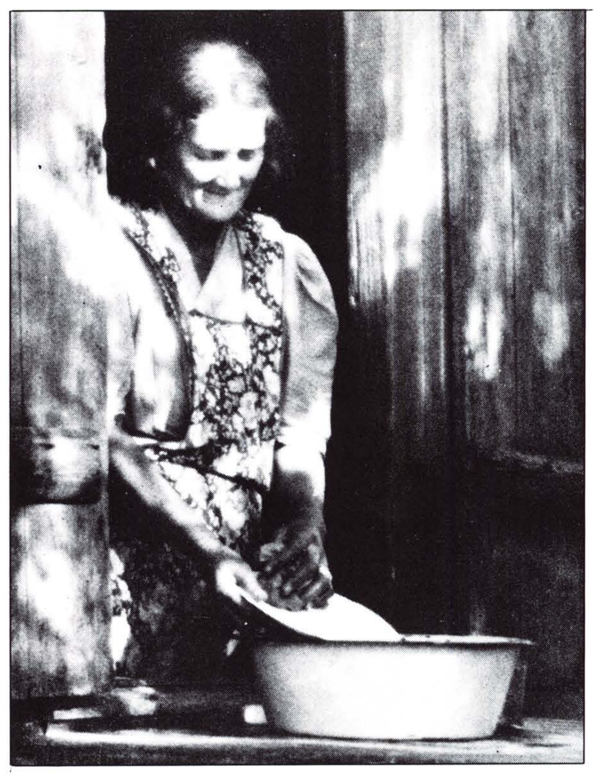
Fishermen caught the animals in their nets, but to meet the industry's needs, a consistent source of diamond-back terrapin was needed. The turtle farm, "three low barns, separated by a road … [that] look almost identical with the barns of a well-appointed race track" (Housley, 1913, p. 1), solved this problem. The barns had a low silhouette with protective latticework on the ends, a hinged roof, and floors covered with less than one-half meter of water. Encircling the ponds were small earthen levees designed to let the turtles sun themselves (Housley, 1913).

These pens, or stables, housed about 20,000 female and 5,000 male turtles. The females were used for breeding and market, while the males' only worth was breeding. When the female's bottom shell was 15 centimeters long, her market value would be from $1.00 to $1.50, while the male's was rarely over 25 cents (Housley, 1913). Turtles were of some commercial value for their meat and eggs. One turtle, for example, could weigh over 200 kilograms and yield 1,000 eggs (Fountain, 1966).

Although others went into the industry, Ludwig bought them out and controlled the business in Louisiana. Grand Isle was the major source for terrapin, but the industry was widespread. In 1900, one dealer on Deer Island, Mississippi, had a herd of over 5,000.

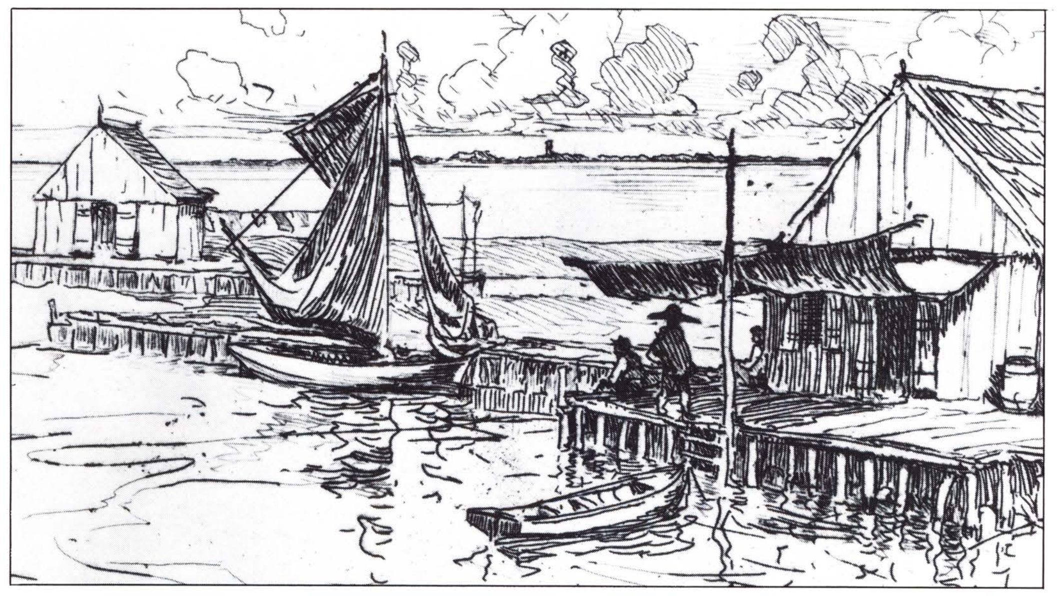
At Grand Isle, many families collected turtles for Ludwig's farm. Often dogs were used to point to where the terrapin were hiding. Besides raising his own locally caught turtles, Ludwig kept turtles shipped from other wholesalers. Dealers in New York and Philadelphia shipped their terrapins south in the fall because the cold northern winters were often fatal. A barrel of turtles could be stabled at the Ludwig farm for $10 a season (Housley, 1913).





This open-air *tablettes a chaudiere*, or dish-washing shelf, was strong enough to hold a stout dish pan, ca. 1947: (in Justin F. Bordenave, ed., *Jefferson Parish Yearly Review*, Special Collections Division, Hill Memorial Library, Louisiana State University Libraries, p. 68).

A net being repaired on Grand Isle, ca. 1947: (in Justin F. Bordenave, ed., *Jefferson Parish Yearly Review*, Special Collections Division, Hill Memorial Library, Louisiana State University Libraries, p. 69).



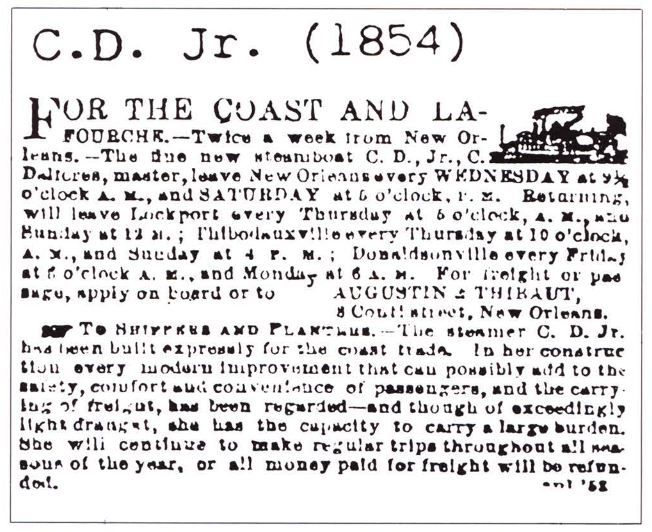
Grand Isle harbor scene, ca. 1940: (Historic New Orleans Collection, Museum/Research Center, Accession No. 1976.22.3).

Col. D.S. Cage (1870)

GRAND ISLE.

For Grand Isle.
The swift passenger steamer
COL. D. S. CAGE,
LOUIS FLATAU, Master; DELL ROPER, Clerk;
Will make semi-weekly trips to the above popular watering place, leaving the head of Harvey's Canal on TUESDAYS, and SATURDAYS at 8 o'clock A. M. Passengers and shippers can rely on this steamer leaving punctually as advertised For freight or passage appl on board. P. HIGGINS, Advertising Agent

Huber, Leonard, 1959, *Advertisements of Lower Mississippi River Steamboats, 1812-1920*, West Barrington, Rhode Island, The Steamship Historical Society of America, p. 13.

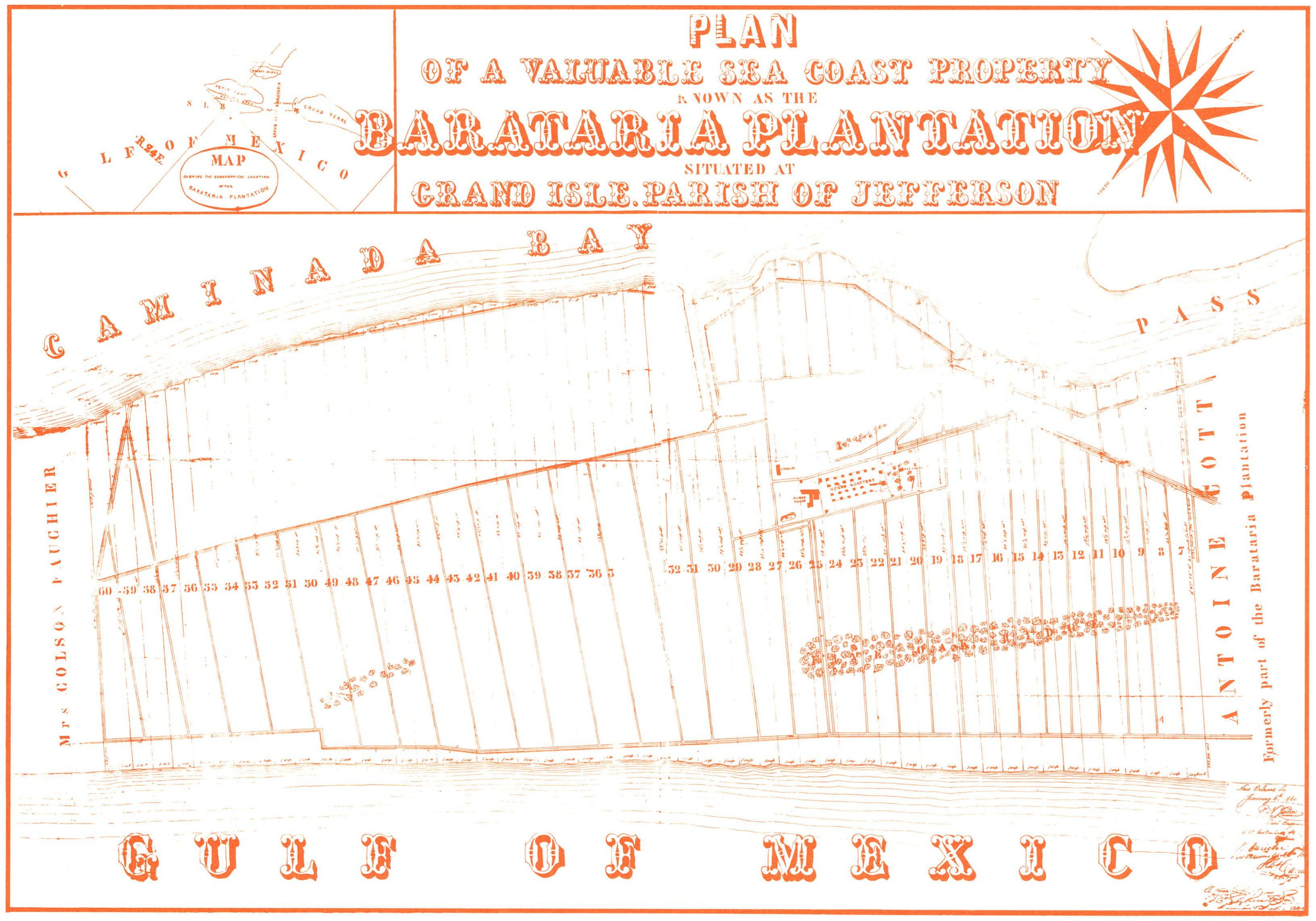


C.D. Jr. (1854)

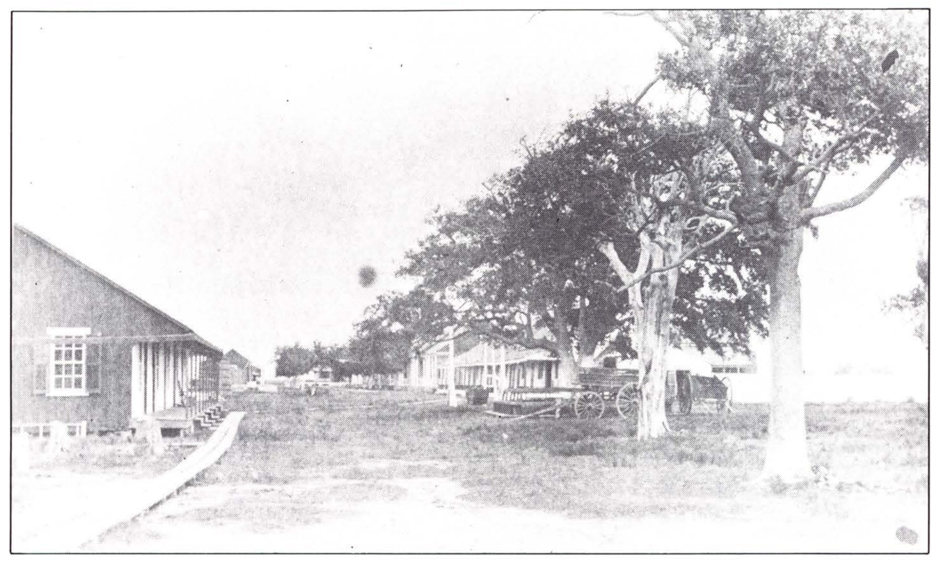
FOR THE COAST AND LAFOURCHE.—Twice a week from New Orleans.—The fine new steamboat C. D., Jr., C. Dalferes, master, leave New Orleans every WEDNESDAY at 9½ o'clock A. M., and SATURDAY at 6 o'clock, P. M. Returning, will leave Lockport every Thursday at 6 o'clock, A. M., and Sunday at 12 M.; Thibodauxville every Thursday at 10 o'clock, A. M., and Sunday at 4 P. M.; Donaldsonville every Friday at 6 o'clock A. M., and Monday at 6 A. M. For freight or passage, apply on board or to AUGUSTIN & THIBAUT, 8 Conti street, New Orleans.

TO SHIPPERS AND PLANTERS.—The steamer C. D. Jr. has been built expressly for the coast trade. In her construction every modern improvement that can possibly add to the safety, comfort and convenience of passengers, and the carrying of freight, has been regarded—and though of exceedingly light draught, she has the capacity to carry a large burden. She will continue to make regular trips throughout all seasons of the year, or all money paid for freight will be refunded.

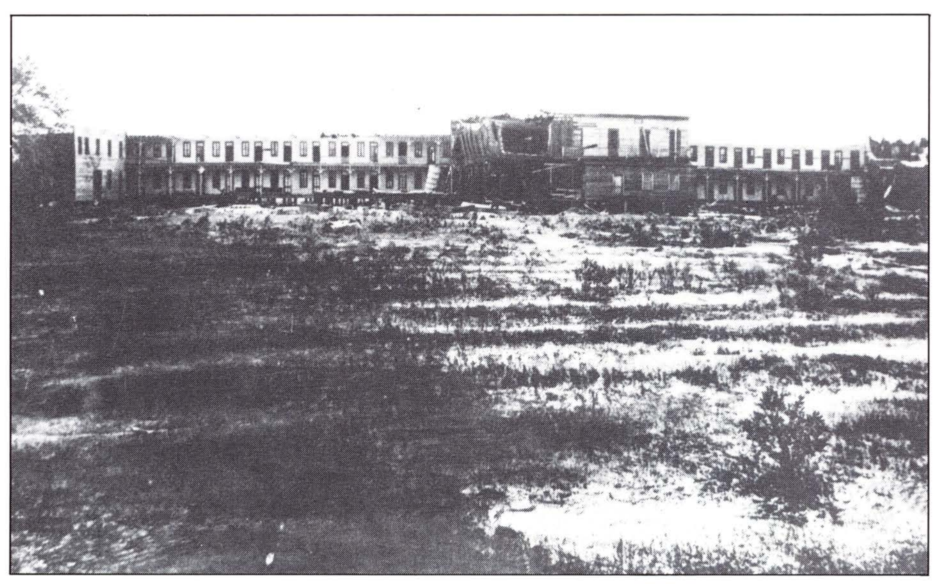
Huber, Leonard, 1959, *Advertisements of Lower Mississippi River Steamboats, 1812-1920*, West Barrington, Rhode Island, The Steamship Historical Society of America, p. 16.



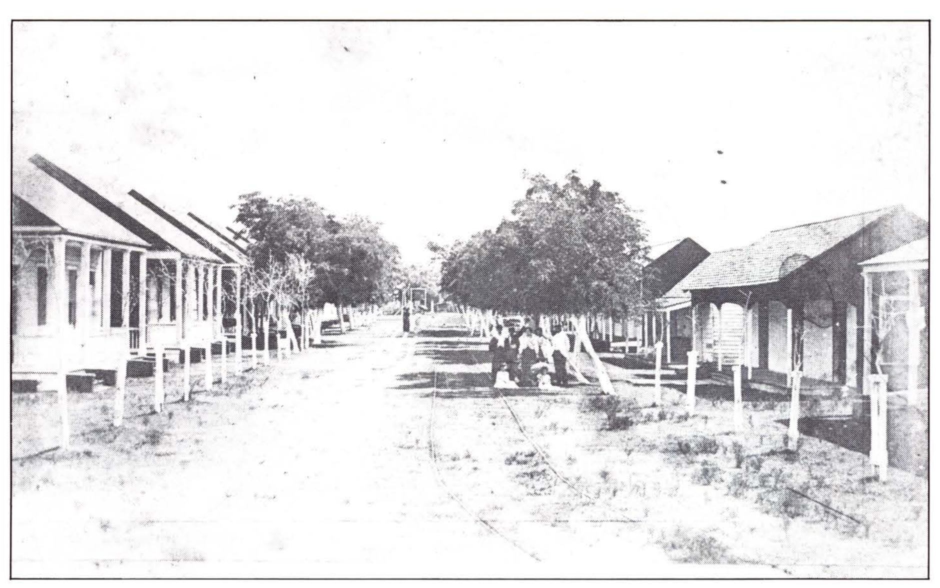
The Kranz Hotel was partially destroyed in the 1893 hurricane, ca. 1893: (Historic New Orleans Collection, Museum/Research Center, Accession No. 1981.238.17).



The row cottages that made up the Kranz Hotel, no date: (Historic New Orleans Collection, Museum/Research Center, Accession No. 1981.251.13).



The 1893 hurricane severely damaged The Ocean Club. Built for an estimated $100,000, the facility was never rebuilt in its original grand manner, ca. 1893: (in Mark Forrest, *Wasted by Wind and Water: a Historical and Pictorial Sketch of the Gulf Disaster*, Milwaukee, Art Gravure and Etching Company, Louisiana Lower Mississippi Valley Collections, Hill Memorial Library, Louisiana State University Libraries).



The main avenue of the Kranz Hotel complex showing the rail line used by mule carts to move people to the beach and the steamboat landing, ca. 1890: (Historic New Orleans Collection, Museum/Research Center, Accession No. 1982.86.2).

GRAND ISLE HOTELS AND HURRICANES

There were three hotels on Grand Isle during the late 1800's: the Kranz Hotel, Hotel Herwig, and the Ocean Club. As is the case today, the beach was the focus of the island's tourist trade, but the island's shoreline was in motion then also. An 1878 survey indicated the island's shoreface was subject to intermittent erosion and accretion. Besides that, there was also a constant threat from hurricanes (see appendix A). All the hotels were wrecked by the storm of 1893. In addition, the steamer Joe Webre, which made regular runs to the island, washed onto the island and "crashed to her death squarely across the tracks of the streetcar line that ran from the Kranz's Grand Isle Hotel to the beach" (Van Pelt, 1943, p. 8)—"a mass of broken timbers, fit only for firewood" (Forrest, no date, p. 6). Of the estimated 650 people on the island, 25 were killed (Sampsell, 1893).

THE KRANZ HOTEL

At Grand Isle's west end lay the Kranz hotel and its associated cottages. The villa was about one kilometer from the Gulf. Cole (1892a, p. 12) described the island's first hotel as an

> old, popular, well known resort, built like a plantation quarters, in a series of [38] cottages along a grassy street. At one end a ballroom, at the other a dinning hall ... One is out of sight of the surf and the sea; but three times a day a tram car runs down to the beach where the bathhouses are.

Mule carts were used to unload the steamers that made regular trips to Grand Isle, and to convoy guests to the beach during prescribed bathing hours—5:00 a.m., noon, and 6:00 p.m. (Ross, 1889a). A partial inventory of the hotel's property reveals there were three carts used in this shuttle service (Grand Isle Hotel, no date).

In a report in the *Daily Picayune,* Mr. Kranz (The Daily Picayune [New Orleans], 1893) stated:

> I am 70 years old, and for many years have owned the Grand Isle Hotel. I am a widower with four children. On the night of the storm I was at home. I did not expect that anything serious would happen. The wind rose ... and blew hard. At 11 o'clock it changed and blew from ... northwest to southwest at intervals of fifteen minutes thereafter. In about half an hour the water on the grounds around the hotel was fully five feet deep. A terrible gust of wind struck the house and knocked it over. A portion of the guiding fell on me, and for a time I thought our last hour had come. Fortunately, the water continued to rise, and in about ten minutes I felt the weight pressing heavily upon my body gradually removed. I was lying on a beam. It was [w]ashed away from under the house, the water carrying me with it for a distance of twenty-five feet. I was struck and became unconscious, for several hours I did not know what had occurred to me. When I regained consciousness ... I was still clinging to the beam ... I received very serious injuries. In my feeble condition I returned to what had been the hotel, but out of the thirty-eight cottages which formerly stood there only twenty were left. There was not a particle of food to be found, everything had been washed away, including all the wearing apparel. I estimate my loss at from $75,000 to $100,000.

THE OCEAN CLUB

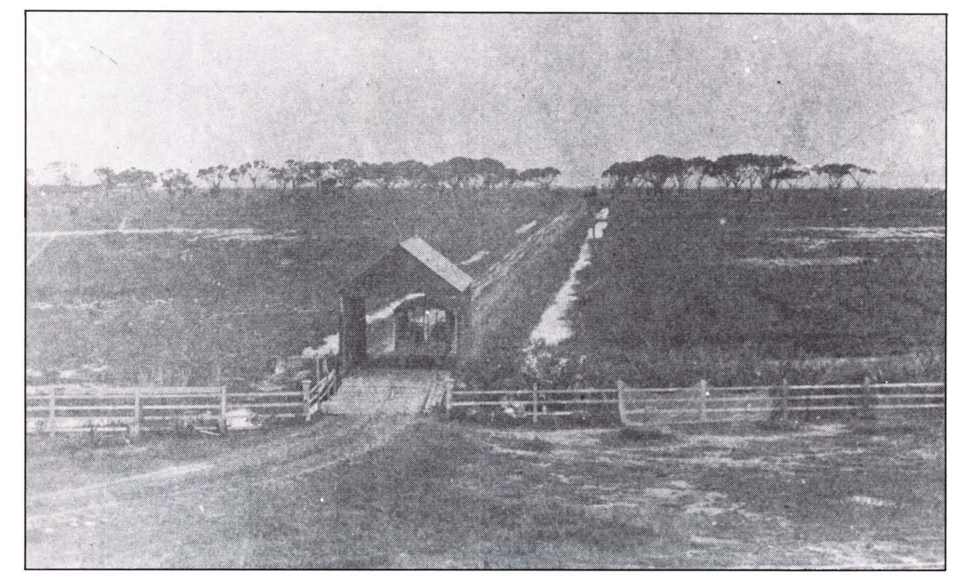
The Ocean Club hotel, built for an estimated $100,000, lay broadside to the Gulf. Investors had grand plans for the property. The hotel was designed to be one of the "most commodious and imposing buildings along the Gulf" (Grand Isle, 1891, p. 3) and to rival or surpass the resort hotels at Newport, Saratoga, and Niagara Falls (The Daily Picayune-New Orleans, 1866). Photographs from the period indicate the investors met their goal; it was a most impressive structure. The hotel, in fact, marked the beginning of the island's resort cycle (Meyer-Arendt, 1985). Three times a week the steamer *St. Nicholas* carried to the island people interested in leisure-time pursuits (Tieys, 1867).

The two-story building took the shape of a large letter "E" (New Orleans Daily Picayune, 1891). With the hotel's long axis parallel to the Gulf, all rooms faced the surf zone. Supported by nearly 300 pilings, the hotel contained 160 bedrooms, two parlors, two dining halls, a billiard hall, a card room, a reading room, pantries, kitchen, and a laundry, and was illuminated by 320 gas lights. The dining hall alone could accommodate 250 guests. The middle section of the "E" was the "en" suite for the hotel's stockholders and was described as "most luxurious" (New Orleans Daily Picayune, 1891; The Times-Democrat [New Orleans], 1891a). The building was constructed with double framing that required over 180,000 meters of lumber. Like Fort Livingston, the Ocean Club served as a landmark for fishermen returning to the island (New Orleans Daily Picayune, 1891).

A two-story addition to the front of the building was planned. This structure would have been at right angles to the main building and extended to the beach. A 40-meter hall would have connected the main building to an immense over-water pavilion, which would have provided a covered walk to the Gulf. Bathrooms were designed into the first floor. The new structure was expected to increase the hotel's capacity to 1,000 guests (New Orleans Daily Picayune, 1891). However, the 1893 hurricane ruined these plans permanently. Like the hotels on Isles Dernieres, it was damaged severely—never to be rebuilt in its original grand manner.

A storm in 1888 partially inundated the island. Stories circulated around New Orleans that Grand Isle's residents took refuge in Fort Livingston. The storm was described as being the most violent since the Last Island hurricane of 1856. When news of the storm's damage reached New Orleans, reporters wrote: "The rain fell in torrents and the hurricane was as severe as can be imagined" (The Daily Picayune [New Orleans], 1888, p. 1). The hotel and its associated cottages survived. Beach bathhouses were demolished and washed away, but quickly rebuilt (The Picayune [New Orleans], 1888; Cole, 1892a). Within days after the storm, the resort was back in operation with the *Joe Webre* bringing guests to the island on a regular basis. Five years after the 1888 storm, the enterprise had to be abandoned. Transportation to the island was not quick and easy. Those who could afford the $50 a month room rate were unaccustomed to enduring the hardships of the long rail and boat trip to the resort (Cole, 1892a).

The Kranz Hotel was Grand Isle's first major hotel and was described as an "old, popular, well known resort, built like a plantation quarters, in a series of [38] cottages along a grassy street" (Cole, 1892a, p. 12), no date: (Historic New Orleans Collection, Museum/Research Center, Accession No. 1981.251.11).



Grand Isle tram clearly visible in a small, covered bridge, ca. 1890: (Historic New Orleans Collection, Museum/Research Center, Accession No. 1981.251.14).

The Grand Isle steamer *Joe Webre* lay across the tracks of the Kranz Hotel's streetcar line after the 1893 hurricane, ca. 1893: (in Mark Forrest, *Wasted by Wind and Water: a Historical and Pictorial Sketch of the Gulf Disaster*, Milwaukee, Art Gravure and Etching Company, Louisiana and Lower Mississippi Valley Collections, Hill Memorial Library, Louisiana State University Libraries).

Fort Livingston saw no military action, but from its inception in the 1840's, it was at war with the elements, ca. 1935: (Fonville Winans, Louisiana State Library, Louisiana Photographic Archives).

GRAND TERRE: HOME OF PIRATES AND PLANTATIONS

THE HOME OF JEAN LAFITTE THE PIRATE

In the 1800's, Louisiana's coastal lowlands were ideally suited for smugglers. The land was inadequately mapped; consequently, government agents who were unfamiliar with the Barataria Bay water system easily became lost, and a skilled smuggler could outmaneuver his pursuers. Isolated ridges, or Indian middens, were utilized to unload contraband. Louisiana's geographical position was nearly perfect for the storage and movement of illicit foreign merchandise (Davis, 1990).

The privateer Jean Lafitte established a base on Grand Terre. By 1810, New Orleans newspapers reported that the privateers had captured a "richly laden" Spanish ship, removed her guns, and built a shore battery to protect their base of operations (The Louisiana Gazette-New Orleans, 1810). These beach cannon emplacements fortified the site. The "first smugglers' convention [was] held there [Grand Terre] in 1805" (DeGrummond, 1961, p. 4).

Over 30 privateer captains called Grand Terre, Grand Isle, and Cheniere Caminada their home. With 120- to 130-ton brigs and schooners, manned by crews of 90 to 200 men, the island's population often swelled to 3,000 (DeGrummond, 1961). Lafitte also had a base at Cat Island, the home of from 500 to 600 men who were protected by a 14-gun brig sunk in the pass (Gilbert, 1814). In 1814, there was a force of five or six armed vessels at Cat Island, each carrying from 12 to 14 guns and 60 to 90 men.

The region profited from the "legalized" pillage practiced by the Barataria pirates. The harbor at Grand Terre served as a rallying point for the Gulf privateers' fast-sailing schooners, which were armed for victory over their adversaries. Newspapers reported that numerous New Orleans businessmen sailed to the island to acquire good bargains (The Louisiana Gazette-New Orleans, 1814a). Several huts and a storehouse were constructed to display the captured booty.

As the English closed the French-controlled Caribbean ports, more contraband was shipped to Grand Terre. Great quantities of foreign merchandise accumulated on the island and were distributed to the New Orleans' market. To meet the demand for storage space, Lafitte acquired a warehouse in New Orleans and built one in Donaldsonville. At Grand Terre, 40 warehouses were built along with slave pens, dwellings, a hospital, and an improved fort (DeGrummond, 1961).

At times, the only prudent means of disposing of merchandise was to hold a public auction (Gilbert, 1814). The warehouses attracted merchants and traders who used large pirogues to make the three-day journey to Lafitte's market at Grand Terre. The entrepreneurs purchased their goods cheaply, then retailed them at a large profit; the privateers were better with sword, cutlass, and cannon than with matters of business.

A fleet of small vessels was constantly moving these resold goods into the "Crescent City." The practice was "illegal" but ignored by most of the authorities (Daily Delta [New Orleans], 1854). Hard currency was scarce in New Orleans, so these goods became part of the city's barter economy.

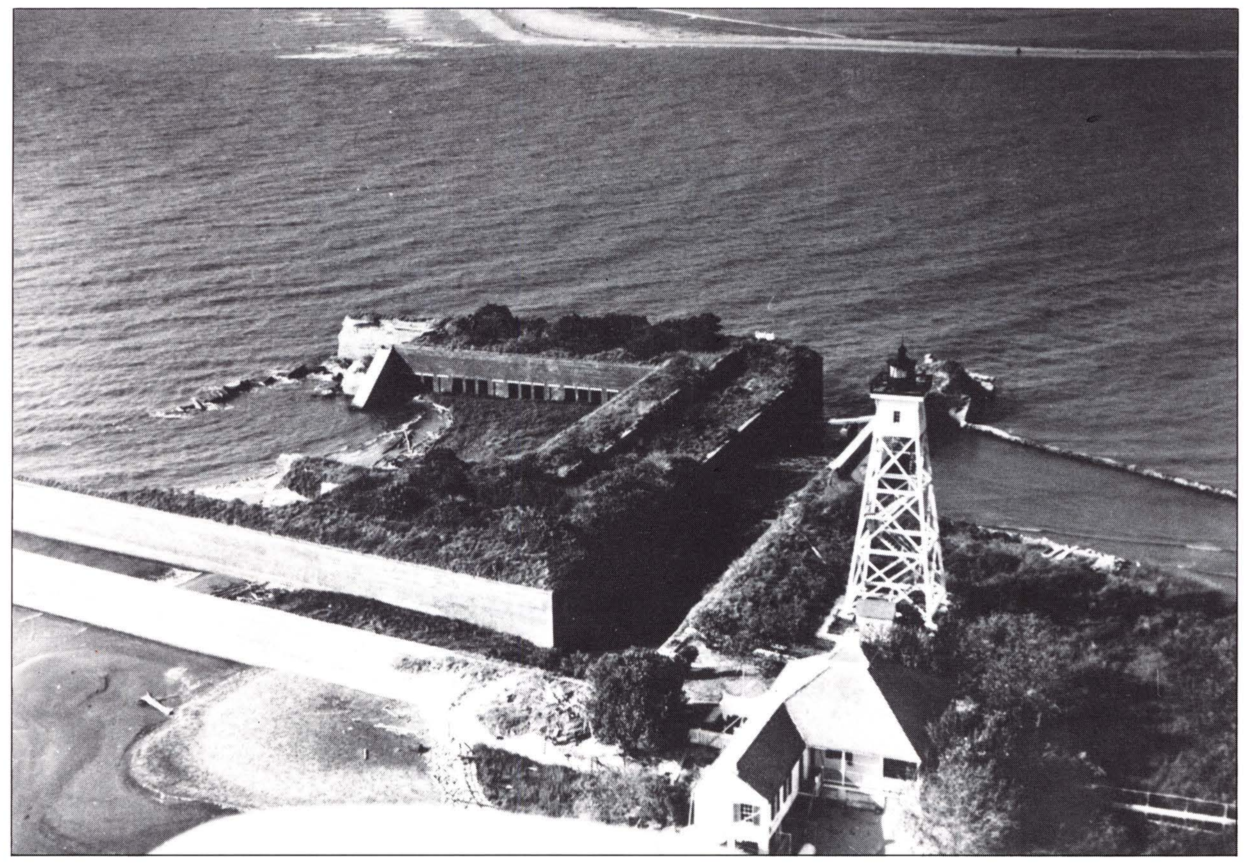
In 1814, the United States Navy sent an expedition to stop the privateers. They captured all of their buildings and effectively terminated privateering on the Louisiana coast (The Louisiana Gazette-New Orleans, 1814b).

GRAND TERRE SUGAR PLANTATION

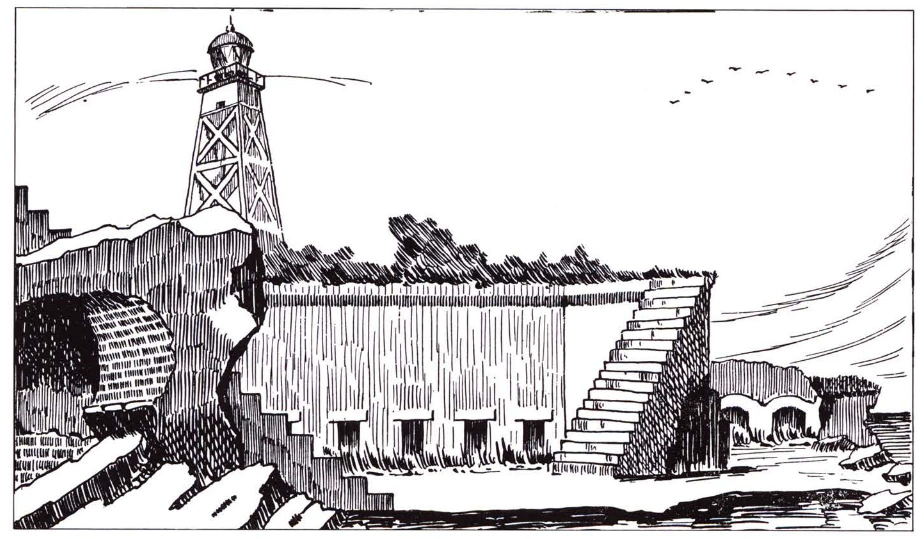
In 1795, Francois Mayronne purchased the Grand Terre sugar plantation from Joseph Andoeza, who claimed ownership of the island from a Spanish land grant. By 1823 Jean-Baptiste Moussier owned Grand Terre. Sixty-nine slaves worked this sugar plantation, which was valued at $38,000 and included a sugarhouse, draining house, steam engine, dwelling house, slave cabins, and other outbuildings (Chamberlain, 1942). In 1831 a hurricane completely inundated the island with water six meters deep. Two sugarhouses and the sugar cane in the field were blown down, the corn crop was destroyed, and the island's residents were forced to seek shelter in "their boats and canoes" (The Daily Picayune [New Orleans] 1863, p. 3).

The Moussier family sold the island but retained most of the western tip—the future site of Fort Livingston. By the mid-nineteenth century, the eastern two-thirds of the island were under the control of F. G. and L. E. Forstall. In 1845 this property produced 300,000 lbs of sugar, but after the Civil War the plantation was abandoned because cheap field hands were no longer available.

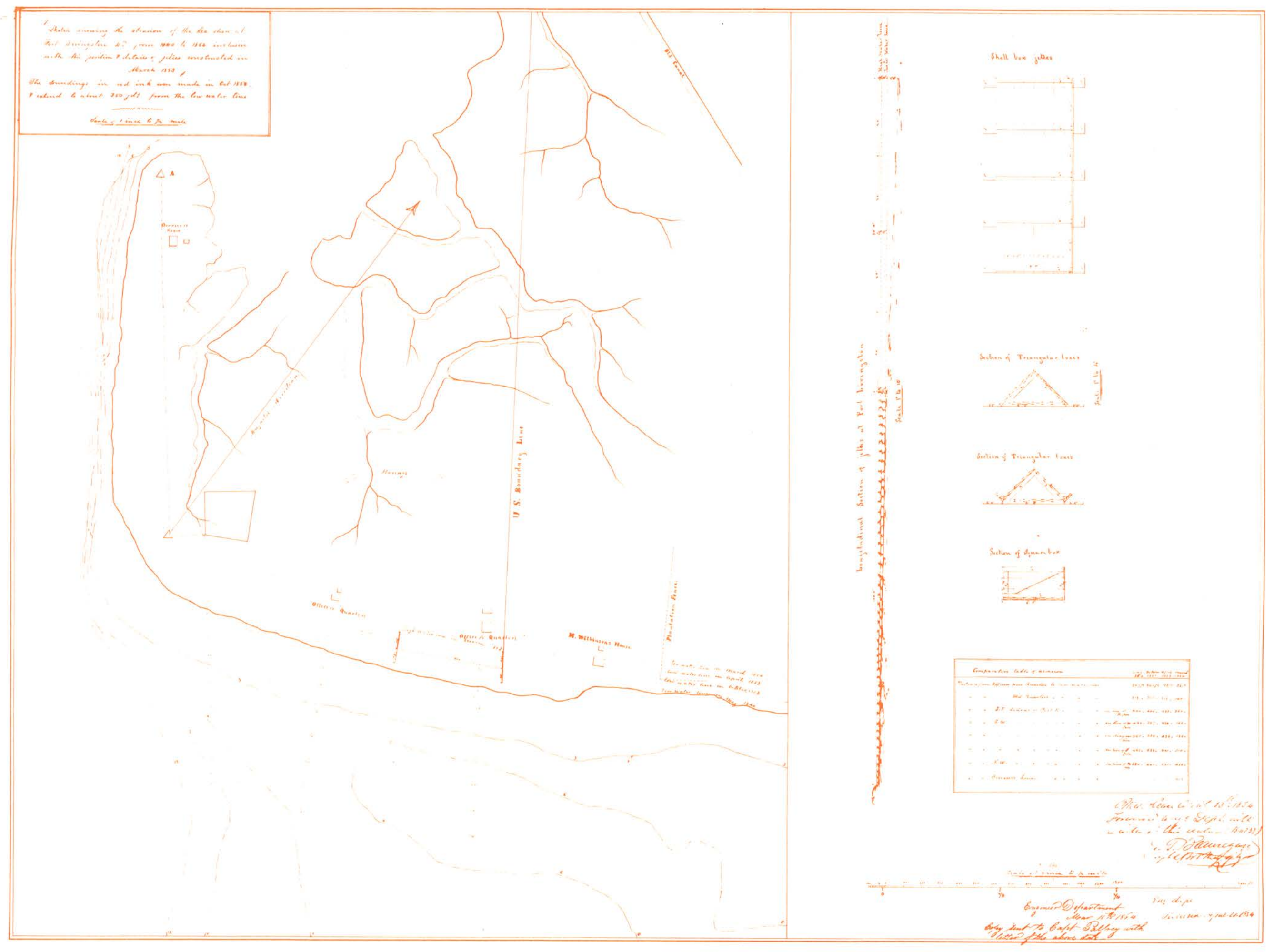
Jose Llulla bought most of the island, and until his death in 1888, he lived a quiet life raising cattle on Grand Terre. With the success of Grand Isle's hotels, several businessmen were convinced they could covert the former home of Jean Lafitte into a tourist attraction. They bought the Llulla estate for $2,500 intending "to divide it up into building sites for themselves and hold the remainder" (New Orleans Times-Democrat, 1893, p. 9). These investors believed that "if the railroad extends seven miles [11 kilometers] toward the bay ... they will have a small bonanza" (New Orleans Times-Democrat, 1893, p. 9). However, the railroad was never built, no hotel was constructed, and the island reverted to its original form.



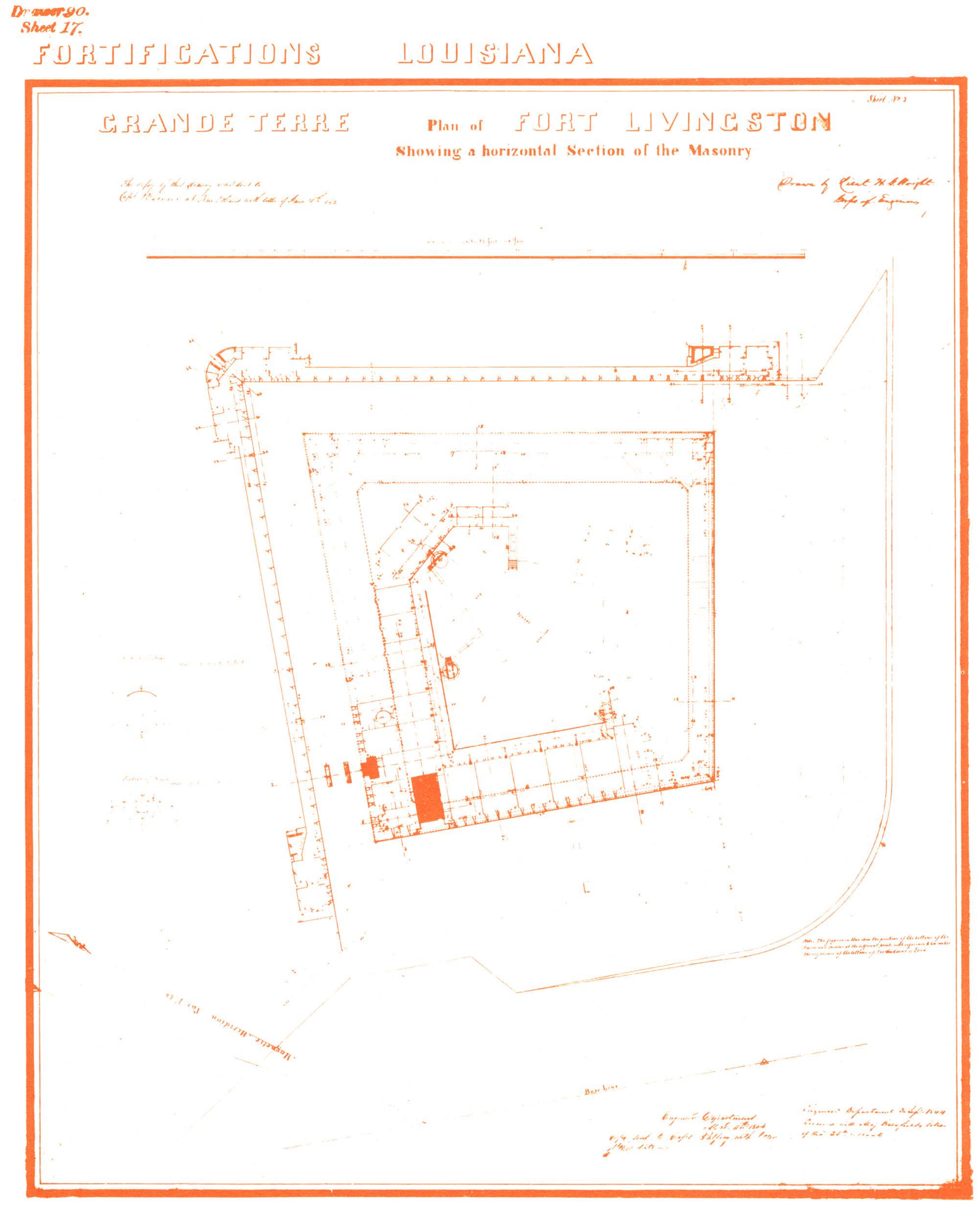
By the mid-1930's the western end of Grand Terre was eroded to the point where the surf was pounding on Fort Livingston's outside walls, no date: (Fonville Winans, Louisiana State Library, Louisiana Photographic Archives).

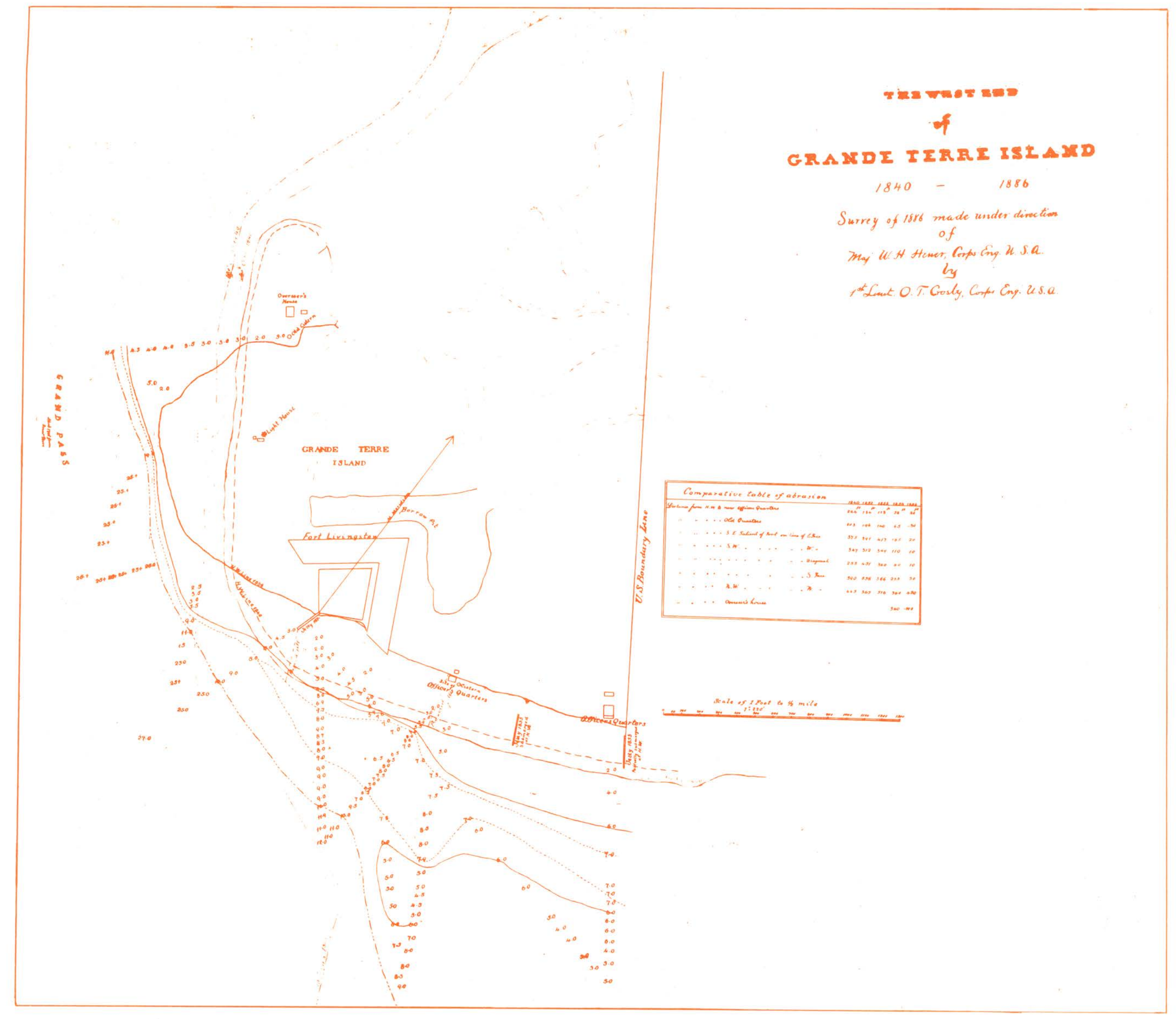


To build Fort Livingston, brick was shipped to the site from the Mississippi Gulf coast. Shells removed from Indian middens were also utilized. With time and the elements the structure became a derelict relic of the past, ca. 1933: (Pen and ink postcard drawing by George Izvolsky).



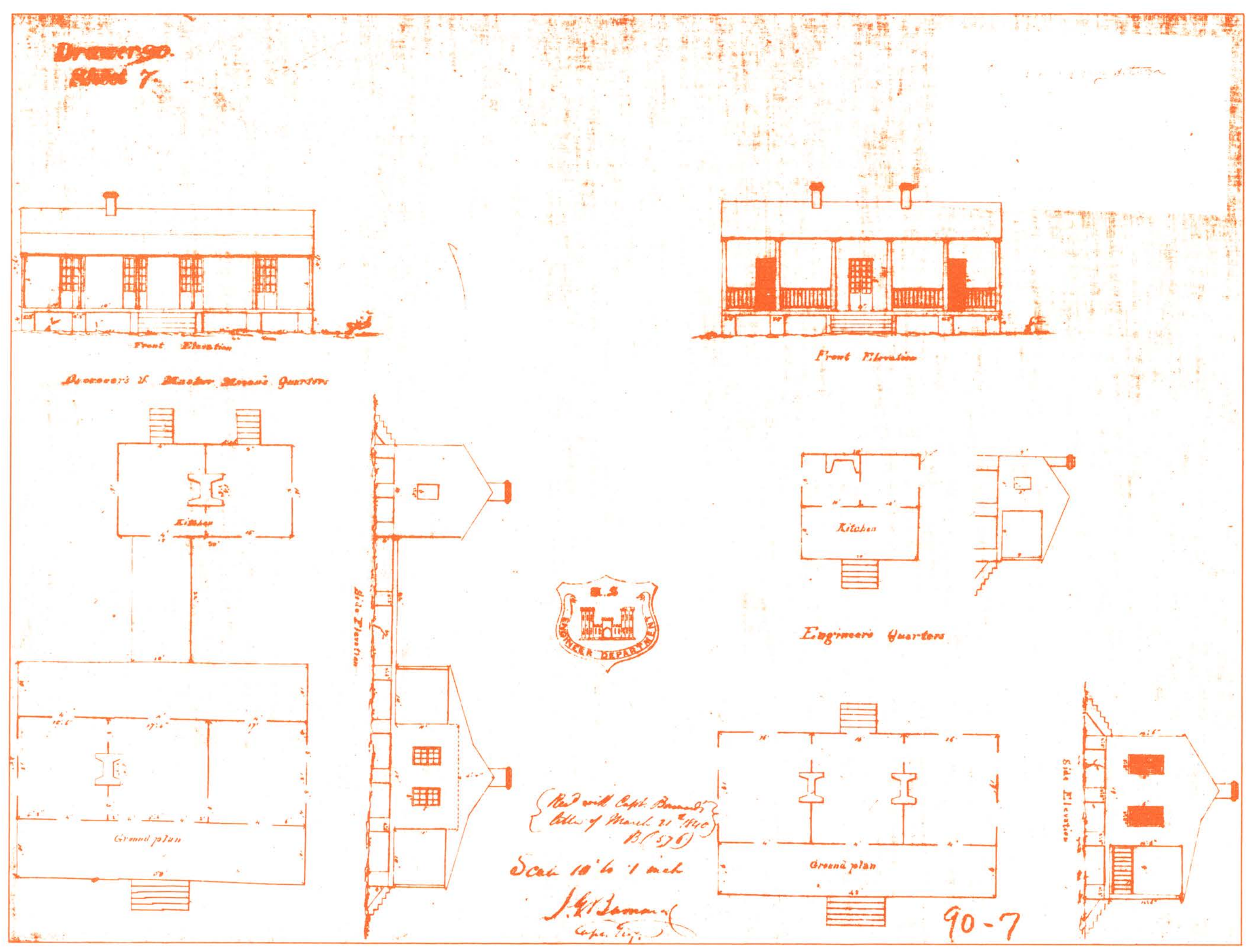
Erosion at the eastern end of Grande Terre Island, 1840-1854: (National Archives, Record Group 77, Drawer 90, Sheet 34).

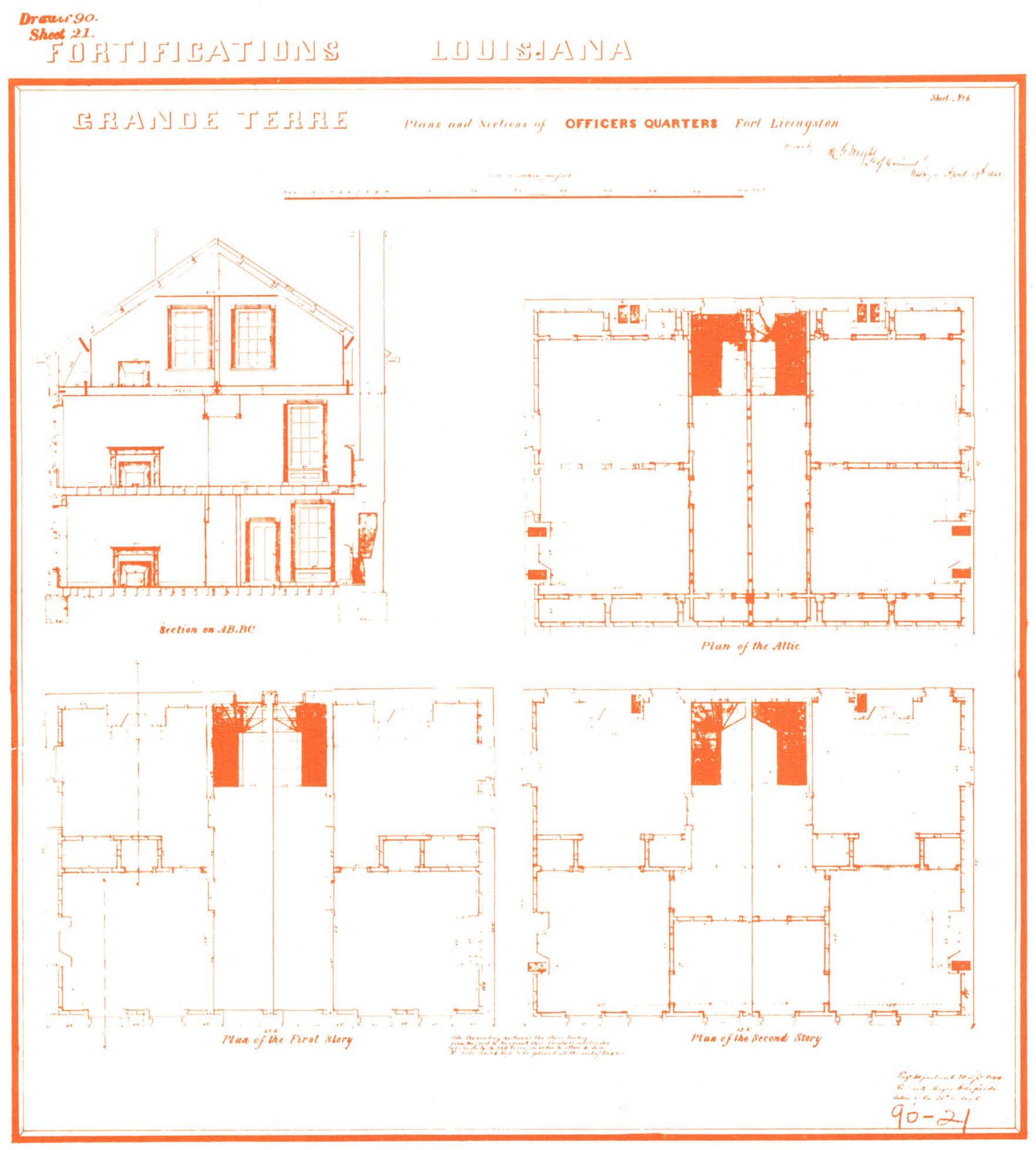


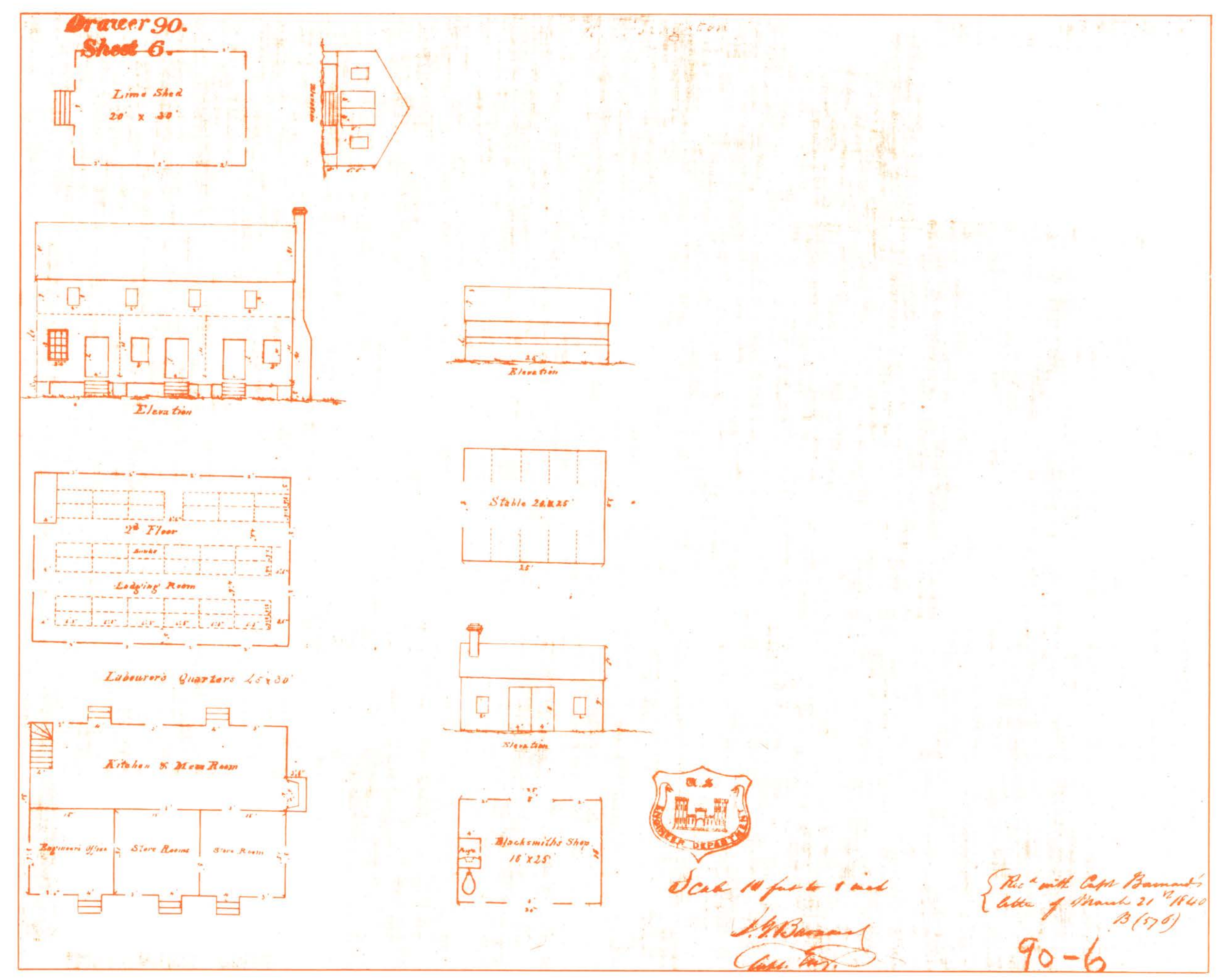


Erosion at the western end of Grande Terre Island, 1840-1886: (National Archives, Record Group 77, Drawer 90, Sheet 44).

Floor Plan of Fort Livingston



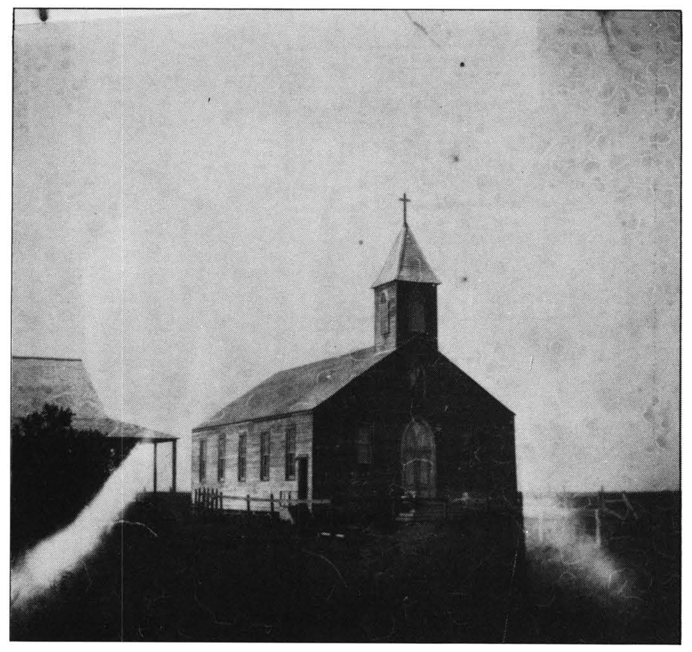




Cheniere Caminada: The Disappearance Of A Community

In 1893 a hurricane swept Cheniere Caminada almost clean—four homes survived, no date: (*Frank Leslie's Illustrated Weekly*, October 26, 1893, p. 269, Biloxi Public Library Archives).

Father Grima, the Breton priest responsible for building the Catholic Church on Cheniere Caminada, no date: (*Harper's Weekly*, October 21, 1893, p. 1,000, Biloxi Public Library Archives).



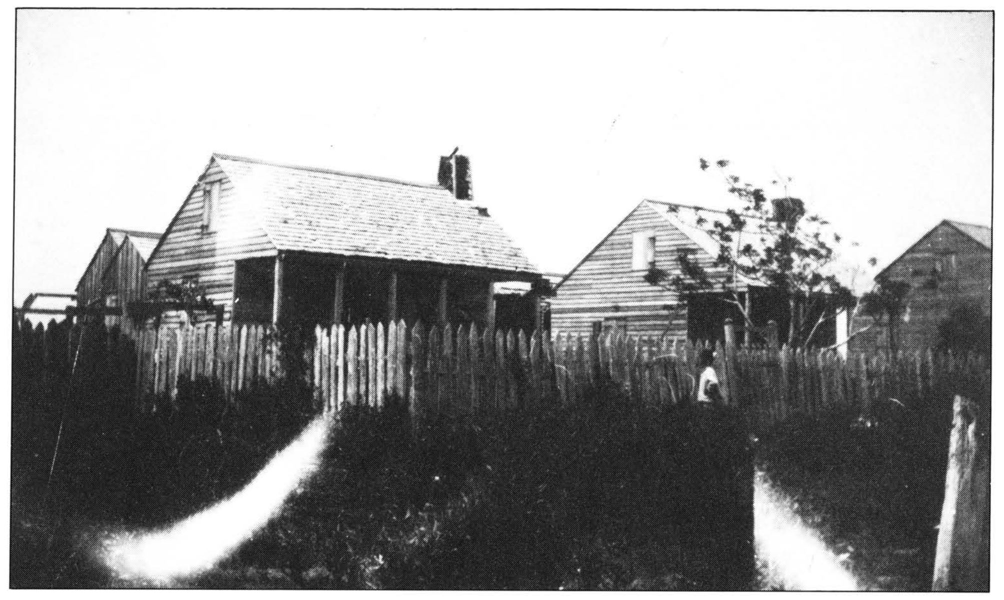
Cheniere Caminada's Our Lady of Lourdes church, 1891: (National Archives, Negative No. 22-FCD-39).

Fisherman's wife next to a typical south Louisiana outdoor (*bousillage*) oven, which could hold up to 15 loaves of bread at a time, 1891: (National Archives, Negative No. 22-FCD-37).

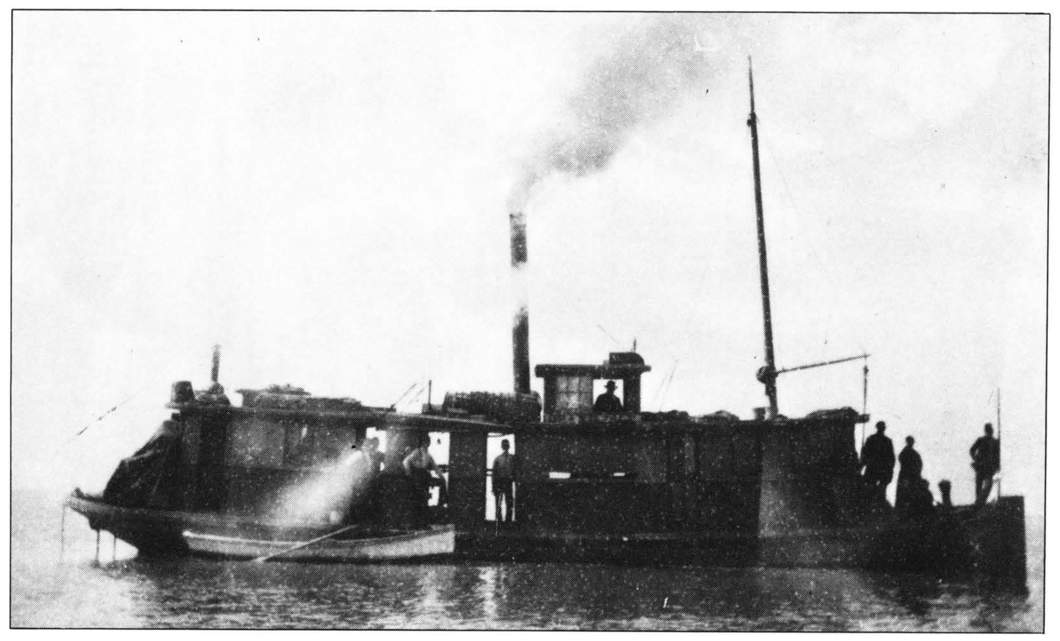
Leon Theriot's sail-powered lugger *Neptune* flying the French flag, near Cheniere Caminada, 1891: (National Archives, Negative No. 22-FCD-32).

After the 1893 hurricane, the dead were buried in shallow graves, no date: (*Frank Leslie's Illustrated Weekly*, October 26, 1893, p. 269, the Biloxi Public Library Archives).

The palmetto-covered Chinese camp at Bayou Andre, where 63 people were lost during the 1893 hurricane, 1893: (*Harper's Weekly*, October 21, 1893, p. 1,000, Biloxi Public Library Archives).



Typical Cheniere Caminada Creole houses, surrounded by a cypress *pieux* fence, 1891: (National Archives, Negative No. 22-FCD-33).



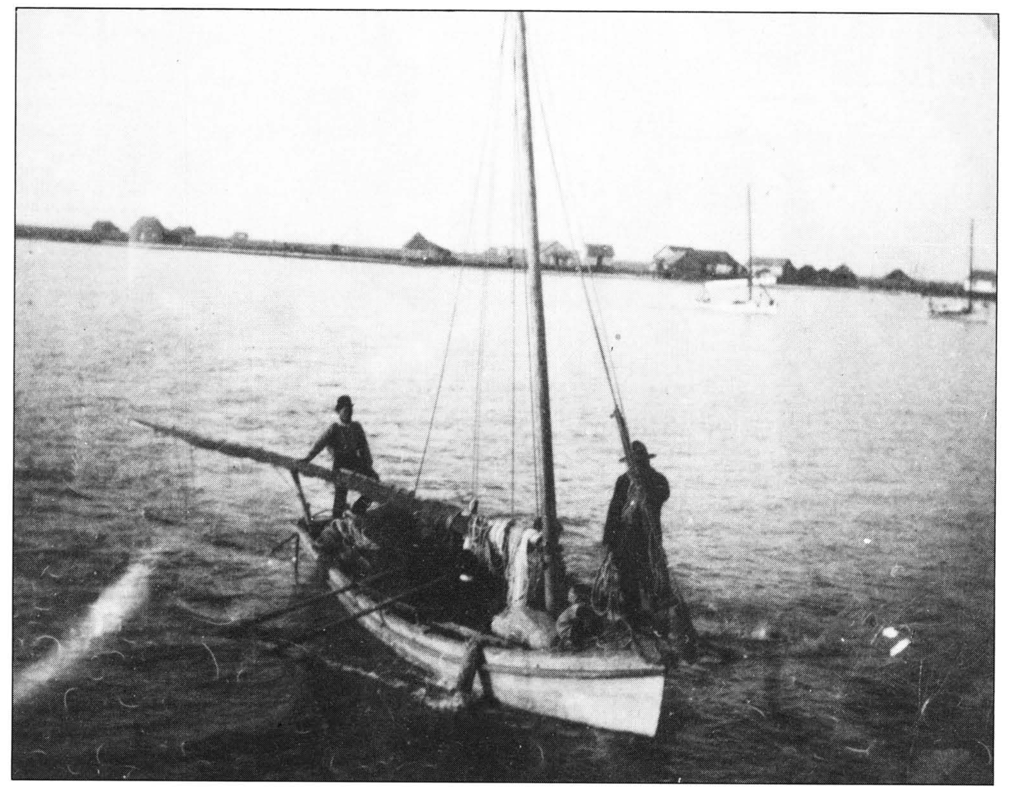
Steamboats were used to bring supplies to Louisiana's coastal fishermen, 1891: (National Archives, Negative No. 22-FCD-246).

John Meralina, a Barataria Bay Malay fisherman, rescued eight persons after the 1893 storm, no date: (*Harper's Weekly*, October 21, 1893, p. 1,000, Biloxi Public Library Archives).

Grand Isle's Kranz Hotel was depicted as a total loss in this line drawing, no date: (*Frank Leslie's Illustrated Weekly*, October 26, 1893, p. 269, Biloxi Public Library Archives).

Cheniere Caminada fishermen, 1891: (National Archives, Negative No. 22-FCD-42).

The folk architecture of Cheniere Caminada included palmetto-covered structures built with techniques learned from the indigenous Indian population. Cast nets were hung on the fence to dry, 1891: (National Archives, Negative No. 22-FCD-41).



Of Louisiana's folk boats, the *esquif*, or skiff, is the most easily distinguished. This sail- and oar-powered boat from Cheniere Caminada would have been identified locally as a *peniche, chaloupe,* or *galere*, 1891: (National Archives, Negative No. 22-FCD-47).

CHENIERE CAMINADA

> Cheniere Caminada lifts its comb of roof and gray gable and soft-colored adobe chimneys from out the clumps and clouds of the chinaberry tree. Along the shores in the water shallows the fishermen have hung their long seines to dry. (Cole, 1892a, p. 12)

At the west end of Grand Isle, less than a mile across the Caminada Bay, was the "Isle of Cheniere," or "Island of Chetimachas" (Public Lands, 1836). The island, valued at nearly $20,000 and worked by about 50 slaves, was an operating plantation in 1836 (Swanson, 1975). By 1890 Cheniere Caminada (from the French, meaning *a roadway through oaks*) was an important fishing settlement and the most densely populated community on Louisiana's barrier islands with its ownership roots dating back to 1763 (Public Lands, 1836). It had a cosmopolitan ambience, made up of Yugoslavians, Italians, Chinese, Malays, and a few blacks (Sampsell, 1893).

The island was a thriving hamlet with a population of 1,471. About 250-450 small, gray, pleasant homes were stretched side by side in two long lines—one faced Caminada Pass parallel to the Gulf shore and a short distance from the beach, the other fronted Caminada Bay. Space was precious, so the homes were set close together—as dense as urban row housing (Cole, 1892b).

The palmetto-covered, bousillage homes were spartan but neat, with brick dust floors and huge fireplaces. The smell of coffee was always in the air—"black as sin, hot as the hinges of hell, and strong as revival religion" (Frost, 1939, p. 76). Fences were made of driftwood stuck into the ground (Cole, 1892b). Homemade outdoor ovens, located behind the homes and often in a grove of orange trees, were used to bake water-bucket-sized loaves of bread (*pain chaud*)—12 to 15 at a time; it was some of the "best bread you ever ate" (Lenski, 1943). A Breton priest, Father Grima, built a high, narrow, brown and yellow Gothic church on the island and dedicated it Our Lady of Lourdes (Cole, 1892b). There were also nine grocery stores; each sold seines, castnets, sails, and oil coats, items the native fishermen considered essential (Cole, 1892b). All of Cheniere Caminada's outside needs were met by either these grocery stores or by supply boats that came through the Barataria water system from New Orleans (Van Pelt, 1943).

The chief form of entertainment on Cheniere Caminada was a ball held on Saturday nights. Admission was free to the locals, and soft drinks, gumbo, and coffee were sold, along with a regional specialty, boiled mullet or *meuil bouille.* Guests could attend these functions for 25 cents, which guaranteed a supper with red wine (Cole, 1892b).

Docked in front of each home were the long, shallow boats that under sail were well adapted to both the legal and illegal activities of the fishermen. Jake Kilrain, John L. Sullivan, Buffalo Bill, Il Destino, and Nativita di Caminada were stenciled on the bows of these boats. Boats were the net fishermen's transportation. It is quite possible that many of these net fishermen were descendants of the crews of the privateer Jean Lafitte.

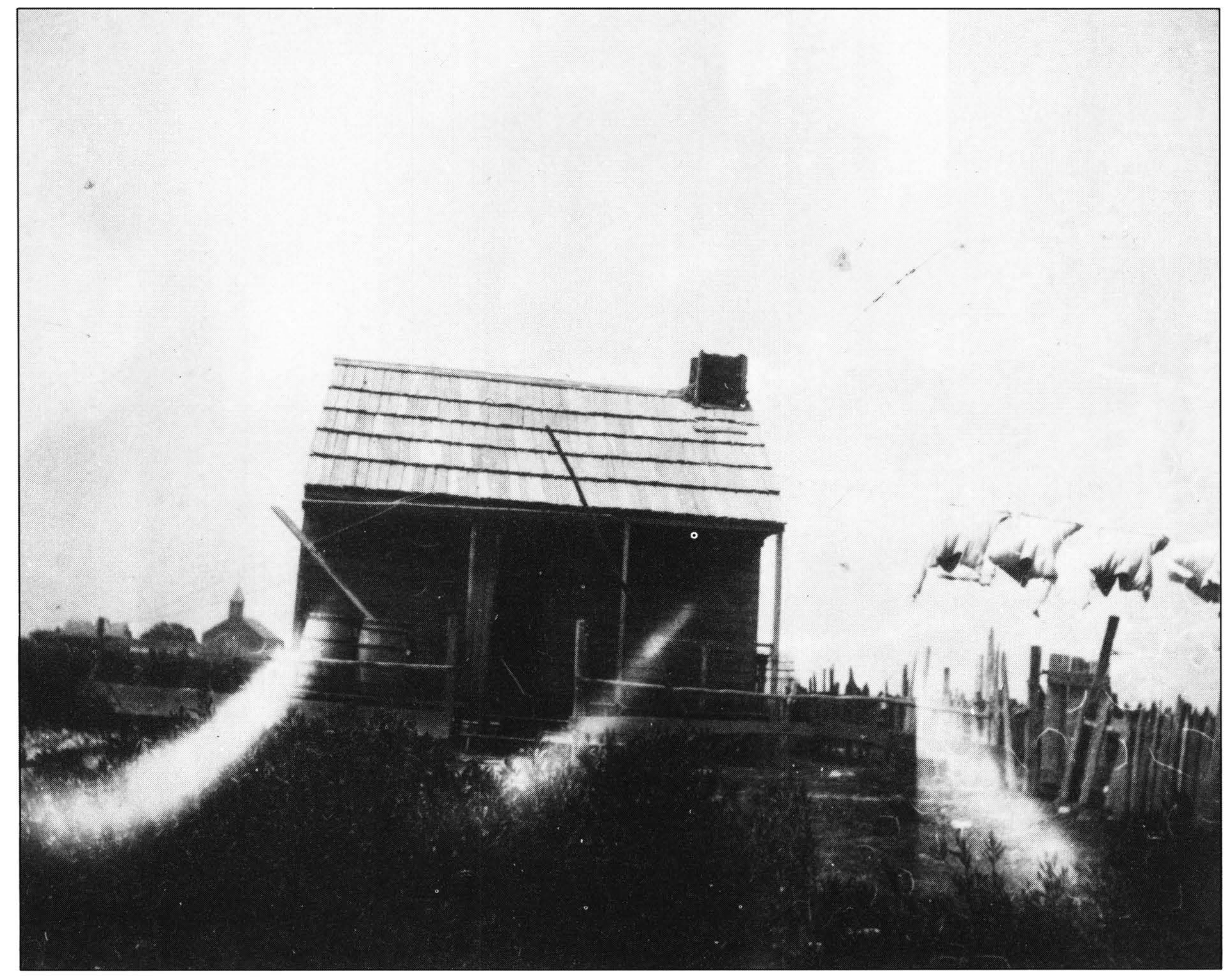
Cheniere Caminada was a thriving community. Its population primarily harvested the region's renewable resources: shrimp, oysters, crabs, and fin fish. They practiced their seasonal occupations in virtual isolation. These net fishermen would leave their homes, often for months, to sail to their winter camps where they harvested various aquatic species. Shrimp, oysters, and crabs were shipped to New Orleans and consumed by the city's hotels, restaurants, and steamboats or exported to other markets.

LOUISIANA'S WORST HURRICANE DISASTER

The 1893 storm destroyed Cheniere Caminada. Four homes remained, and these were filled with crowds of survivors (The Weekly Thibodaux Sentinel, 1893b). The land was swept clean, and the death toll varied from 779 to 822, with only 696 people surviving (The Weekly Thibodaux Sentinel, 1893b). Some survivors drifted nearly 100 kilometers across the Gulf to Southwest Pass. There were 78 people in one home; the house collapsed, killing 74 (The Weekly Thibodaux Sentinel, 1893a). Dead were everywhere; the odor endured. Often coffins and separate graves were unavailable, so bodies were buried where they were found. There were so many dead, the graves of those who were recognizable were aligned like the rows in a plowed field (Sampsell, 1893; The Weekly Thibodaux Sentinel, 1893a). Those who survived saved themselves by using timber, roofs, and doors—anything that floated—for rafts. Of the island's fishing schooners and red-sail luggers, only the *Good Mother* and *Counter* survived (The Daily Picayune [New Orleans], 1893). The storm also took its toll on Grand Isle and many shrimp platforms in Barataria Bay, such as at Bayou Andre, Bird Island, and Bayou Dufond. Relief boats from New Orleans brought supplies and ice to be melted for drinking water; crew members were appalled by the destruction (Van Pelt, 1943).

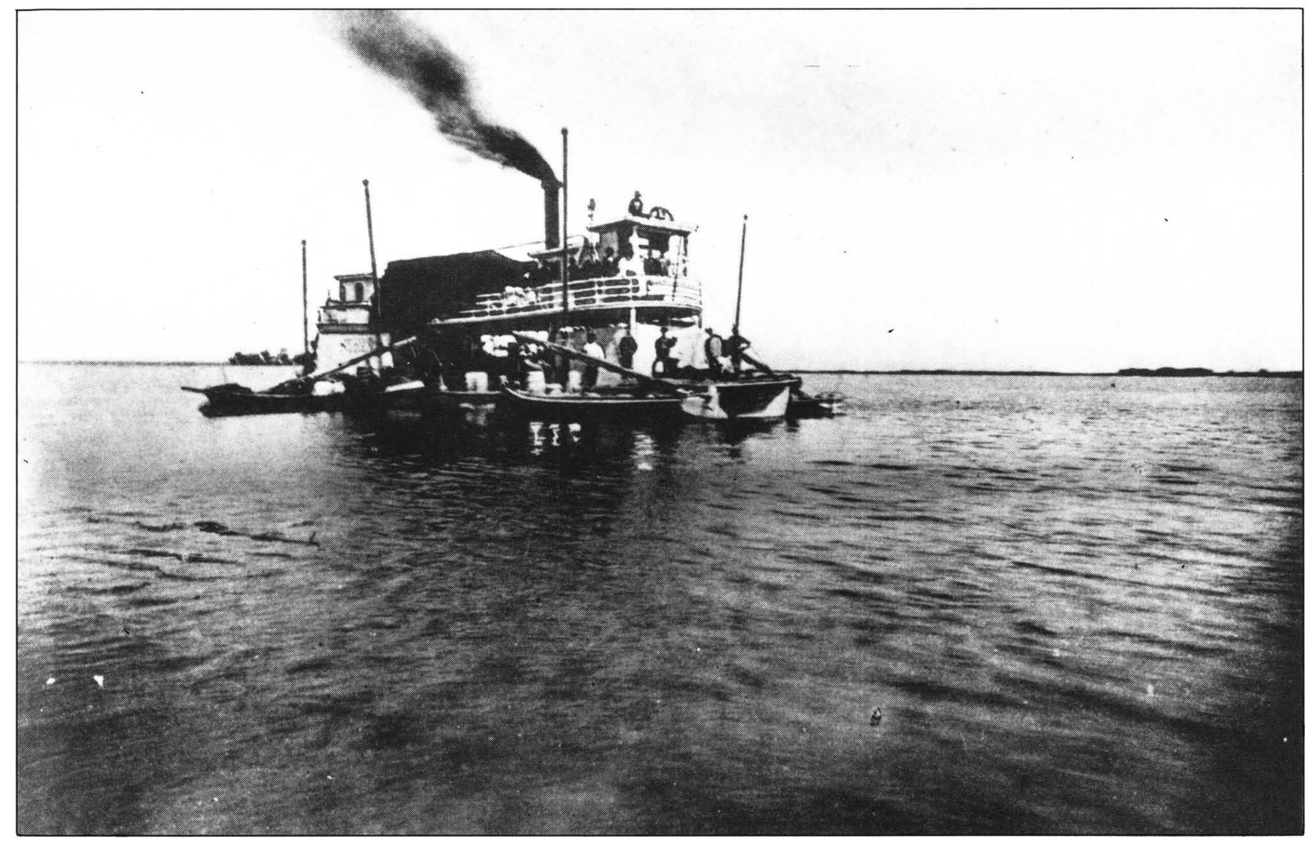
After the hurricane, Cheniere Caminada was abandoned. Some people eventually returned, but their new community was destroyed by a 1915 hurricane (Baker, 1946).

One of the few houses that partially survived the 1893 storm, no date: (in Mark Forrest, *Wasted by Wind and Water: a Historical and Pictorial Sketch of the Gulf Disaster,* Milwaukee, Art Gravure and Etching Company, Louisiana and Lower Mississippi Valley Collections, Hill Memorial Library, Louisiana State University Libraries).



Wash day at a shrimp fisherman's home at Cheniere Caminada, with the Catholic church and other structures in the background, 1892: (National Archives, Negative No. 22-FCD-34).

Sixty-two people survived the Cheniere Caminada disaster under the roof of this collapsed shed, no date: (in Mark Forrest, *Wasted by Wind and Water: a Historical and Pictorial Sketch of the Gulf Disaster,* Milwaukee, Art Gravure and Etching Company, Louisiana and Lower Mississippi Valley Collections, Hill Memorial Library, Louisiana State University Libraries).

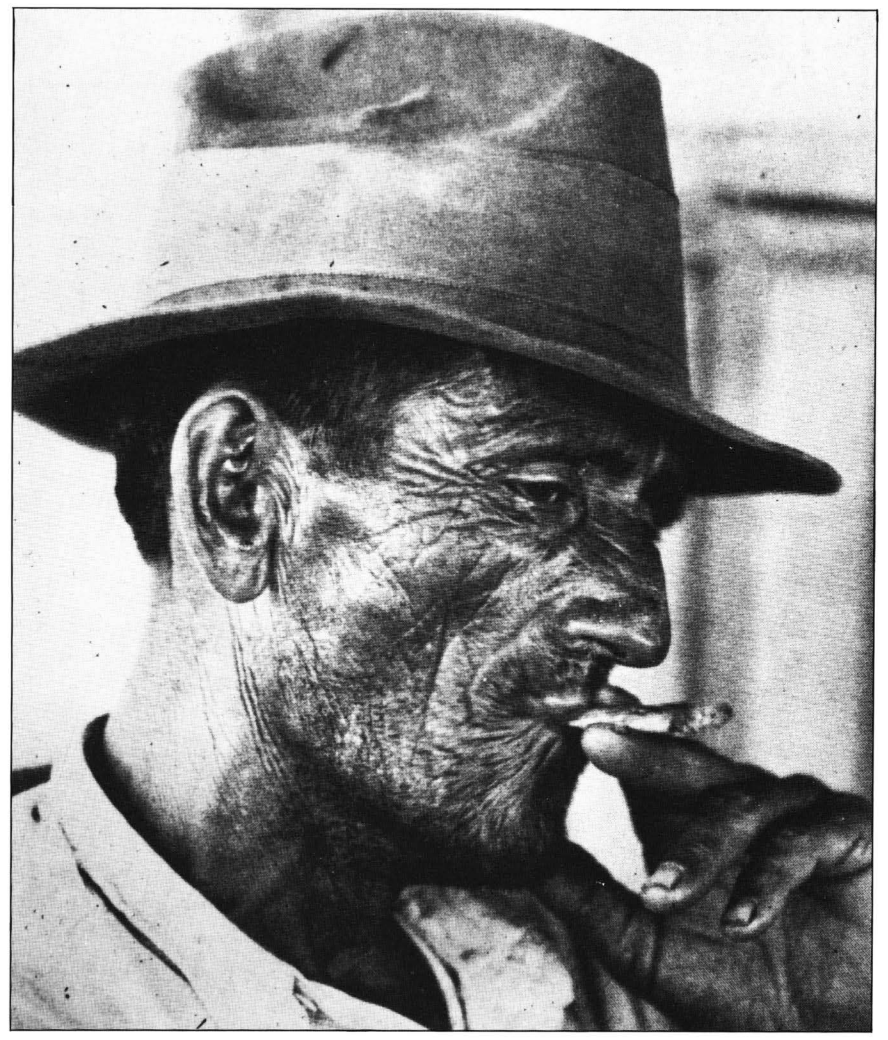


Relief steamer, surrounded by luggers, taking supplies to the survivors of the 1893 hurricane, no date: (in Mark Forrest, *Wasted by Wind and Water: a Historical and Pictorial Sketch of the Gulf Disaster,* Milwaukee, Art Gravure and Etching Company, Louisiana and Lower Mississippi Valley Collections Hill Memorial Library, Louisiana State University Libraries).

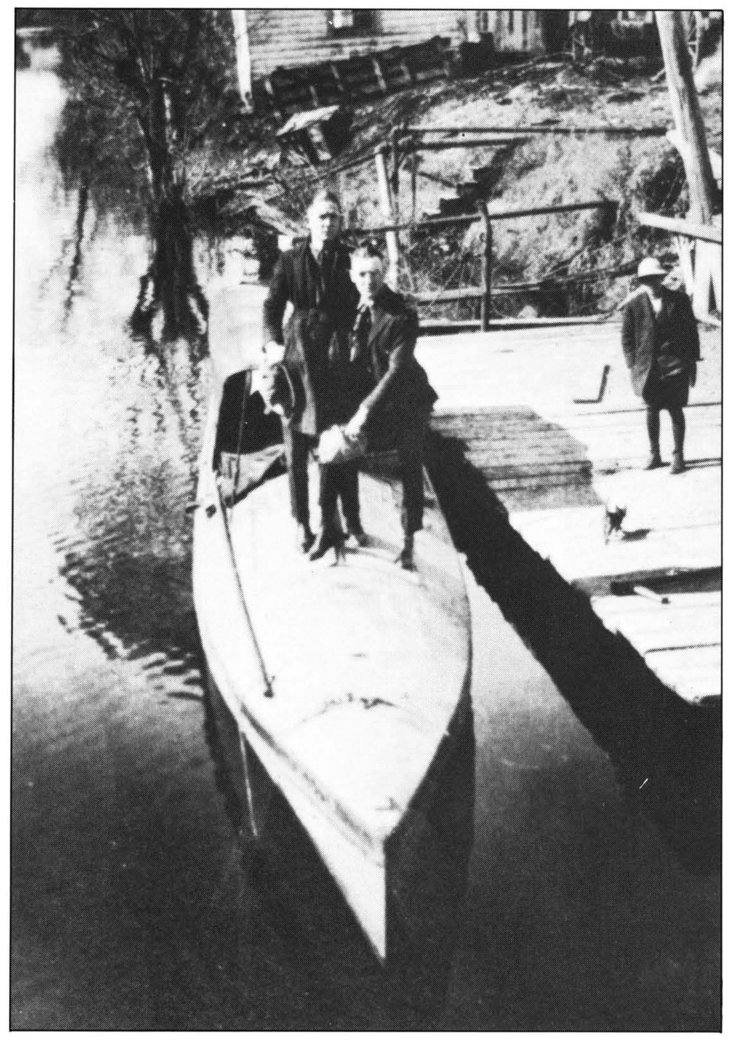
Out of a population of about 1,500 people, more than half did not survive; dead were everywhere, no date: (in Mark Forrest, *Wasted by Wind and Water: a Historical and Pictorial Sketch of the Gulf Disaster,* Milwaukee, Art Gravure and Etching Company, Louisiana and Lower Mississippi Valley Collections, Hill Memorial Library, Louisiana State University Libraries).

Part of the aftermath of the Cheniere Caminada hurricane, no date: (in Mark Forrest, *Wasted by Wind and Water: a Historical and Pictorial Sketch of the Gulf Disaster,* Milwaukee, Art Gravure and Etching Company, Louisiana and Lower Mississippi Valley Collections, Hill Memorial Library, Louisiana State University Libraries).

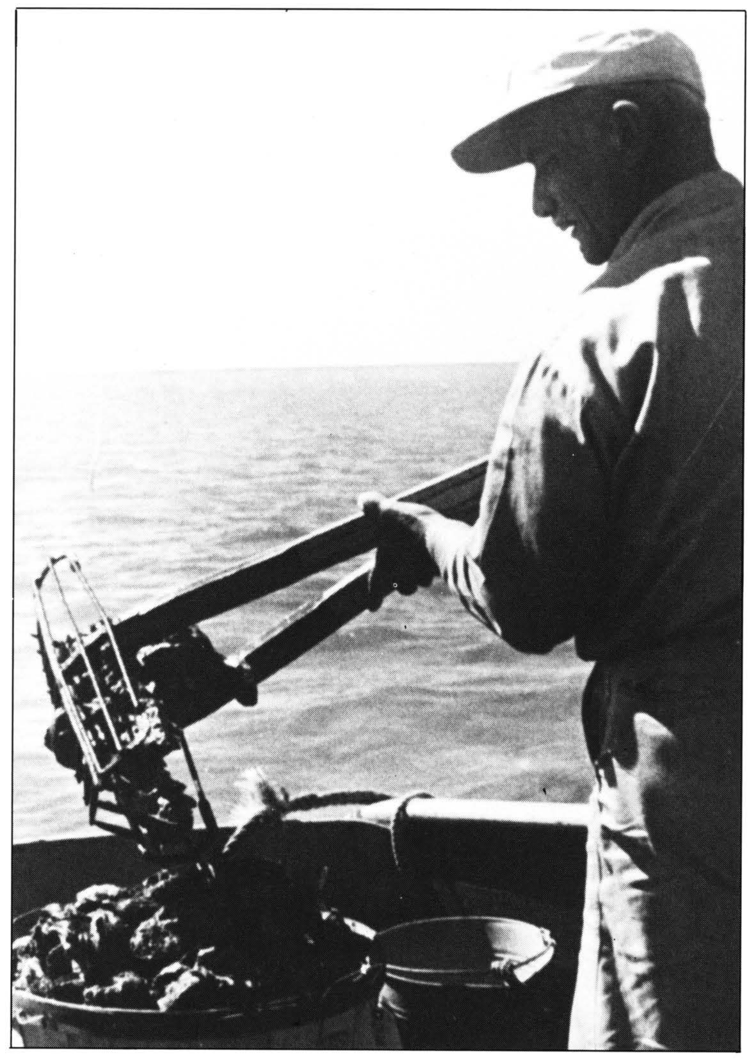
Wetlands Harvest



Grand Isle fishermen, burned by thousands of days of exposure to the sun, vividly describe the history of the area's hardy inhabitants, ca. 1940: (*in* Justin F. Bordenave, ed., *Jefferson Parish Yearly Review*, Special Collections Division, Hill Memorial Library, Louisiana State University Libraries, p. 50).

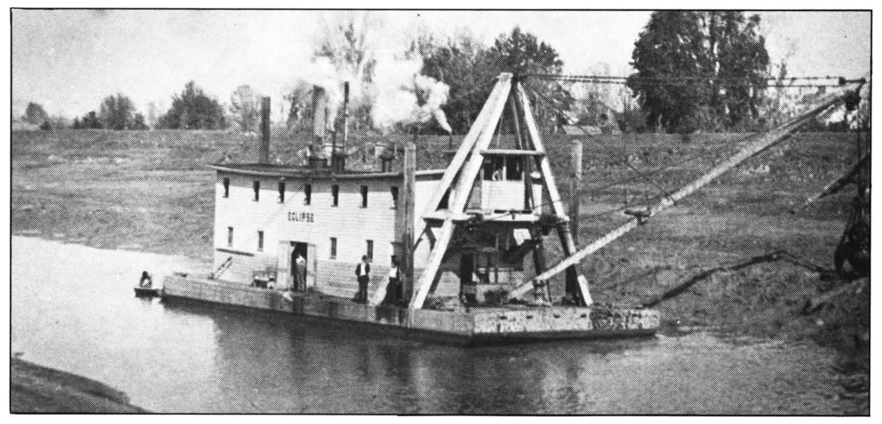


A racing hull designed and built in Houma. Annual races were held at Sea Breeze—a community that has been eroded away, ca. 1930: (Randolph Bazet Collection, Houma, Louisiana).

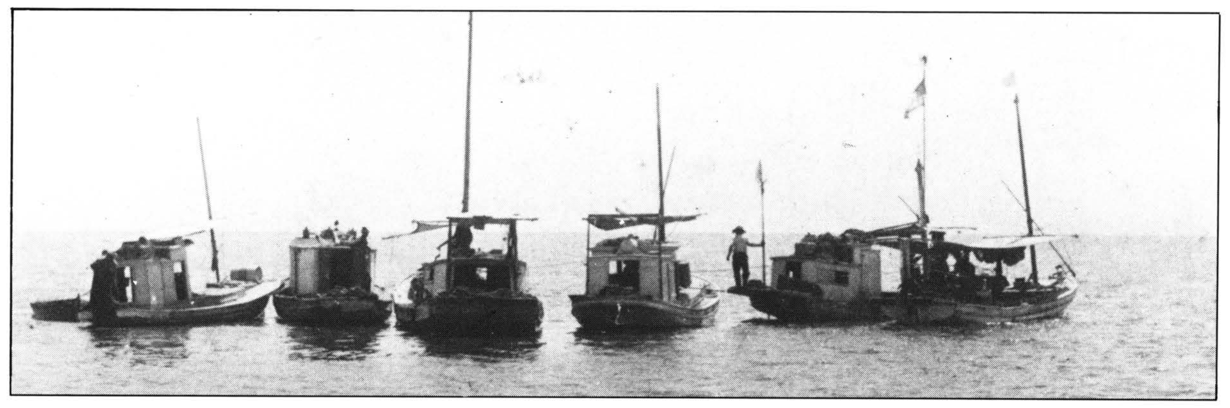


Successfully tonging oysters from Louisiana's prolific oyster beds, no date: (Louisiana Department of Wildlife and Fisheries, Photographic Archives).

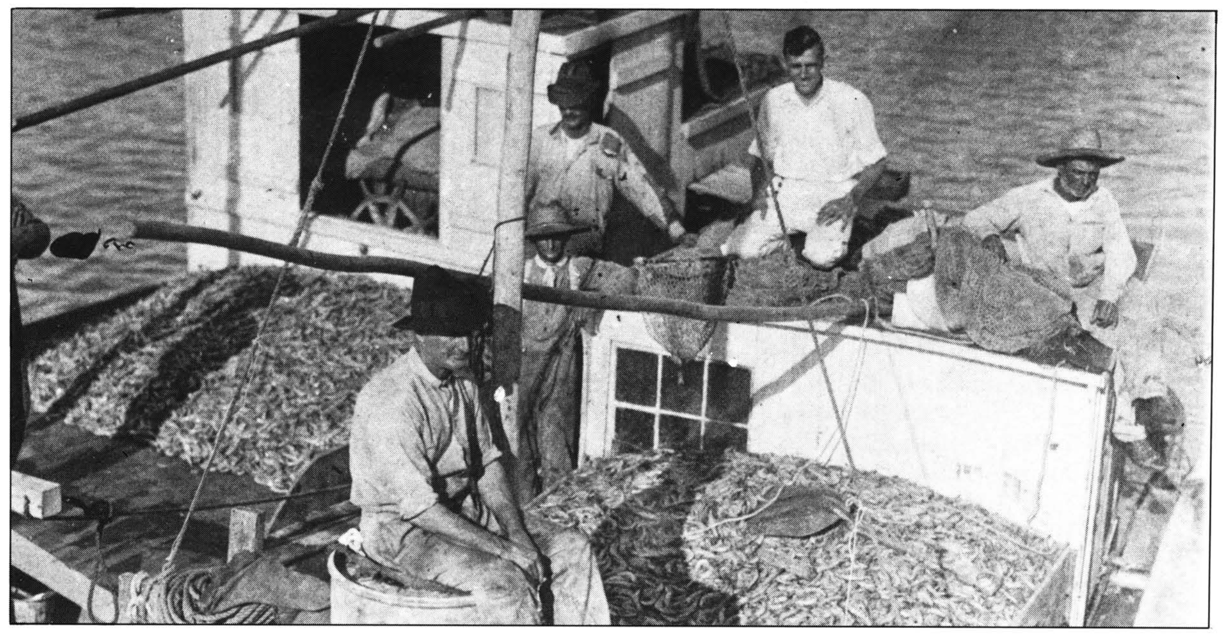
Scooping up blue crabs in Barataria Bay, ca. 1930: (Fonville Winans, Louisiana State Library, Louisiana Photographic Archives).



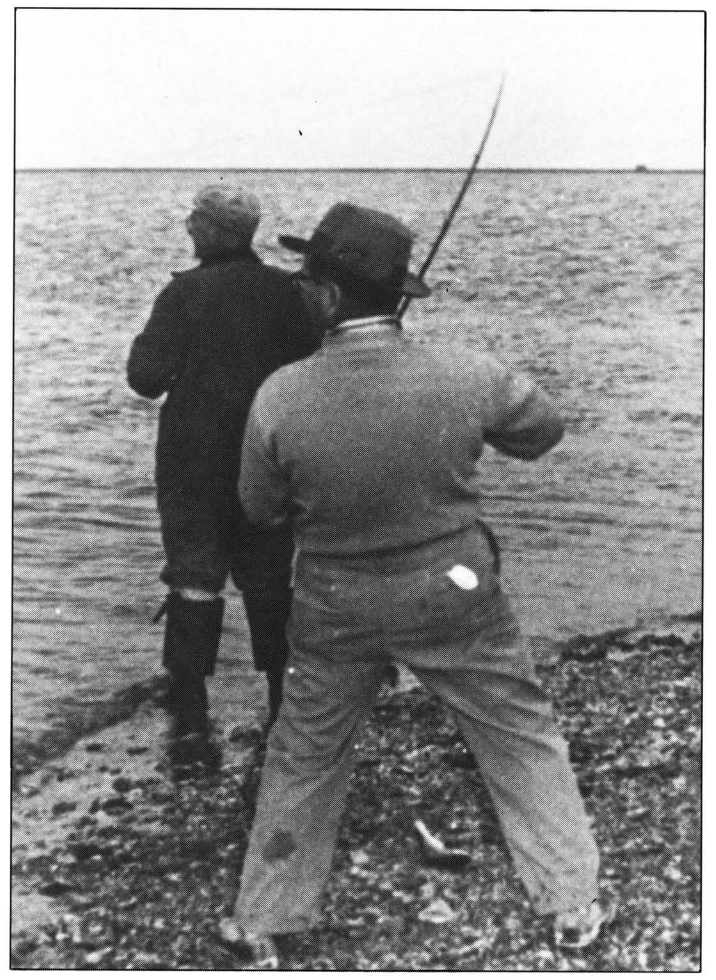
To maintain navigability many bayous were dredged, or canals were cut to connect existing waterways. The dredge *Eclipse* was active in Lafourche and Terrebonne parishes, no date: (Historic Lafourche Collection, Allen Ellender Memorial Library Archives, Nicholls State University, Thibodaux, Louisiana).



A fishing boat rendezvous, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).



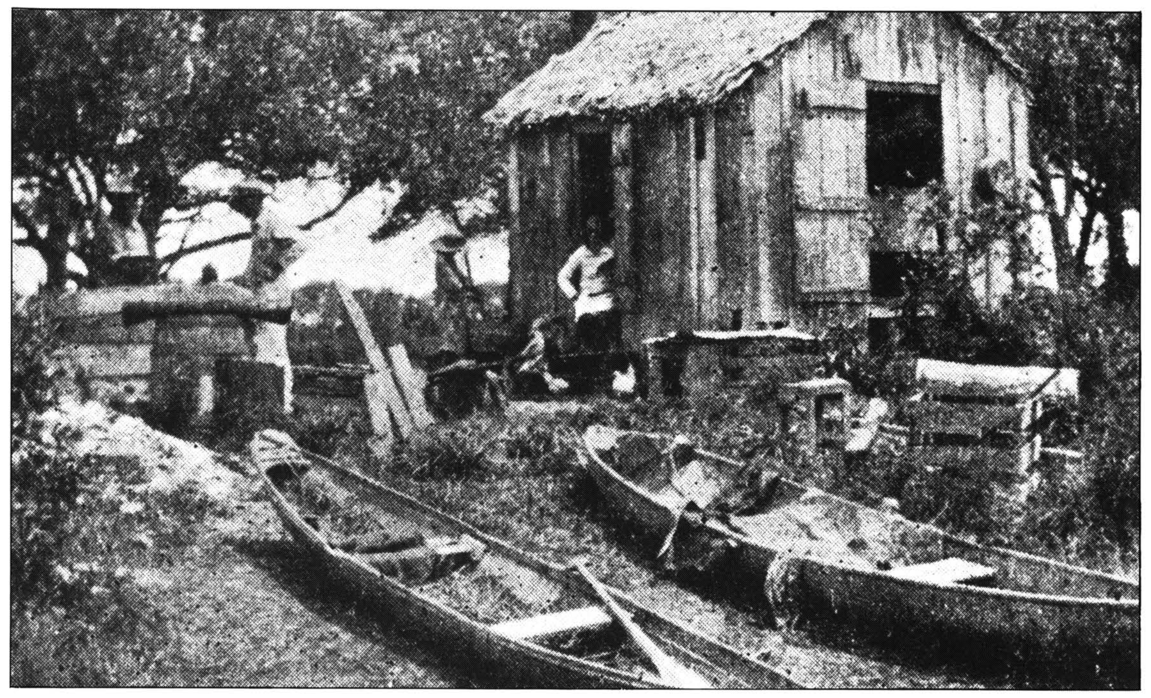
A successful shrimp harvest, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).



Fishing has always been a popular recreational activity along Louisiana's coast, no date: (Louisiana Department of Wildlife and Fisheries, Photographic Archives).

December, January, and February were the traditional trapping months. The animal's pelt was fleshed, washed, stretched, and dried, no date: (Louisiana Department of Wild Life and Fisheries, Photographic Archives).

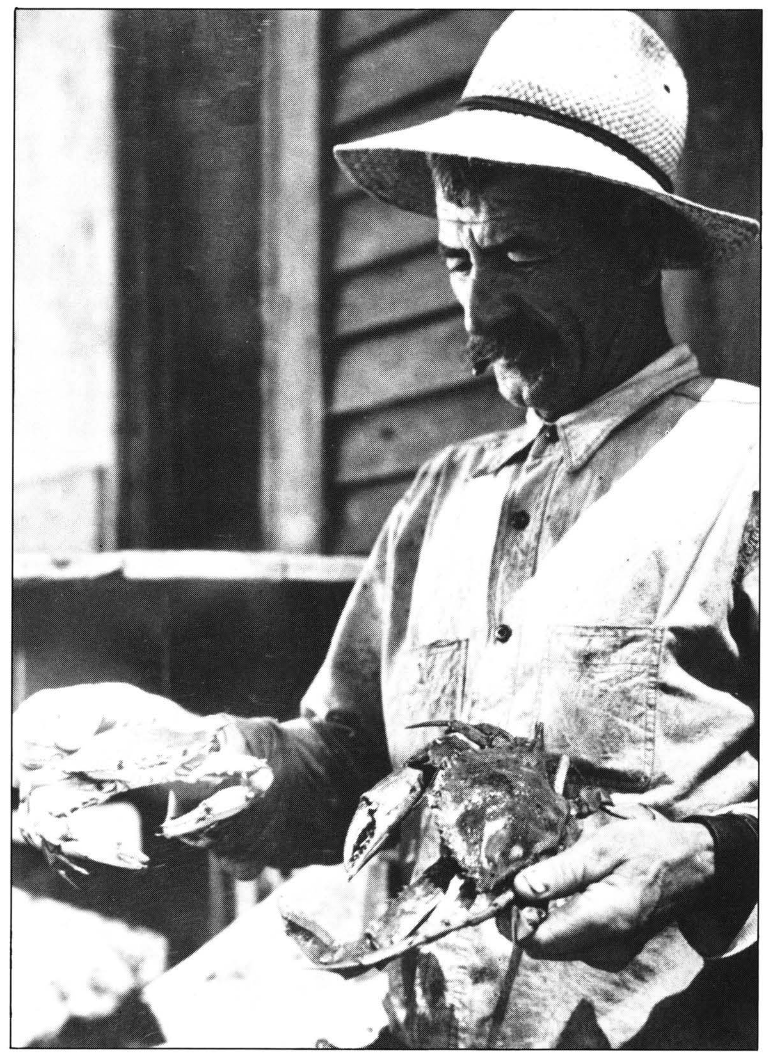
Trappers built rough-hewn camps in the marsh to efficiently harvest their leases during the winter season. Entire families moved into these settlements. Schools closed because most of the students were working their families' trapping lines, ca. 1930: (Louisiana Department of Wild Life and Fisheries, Photographic Archives).



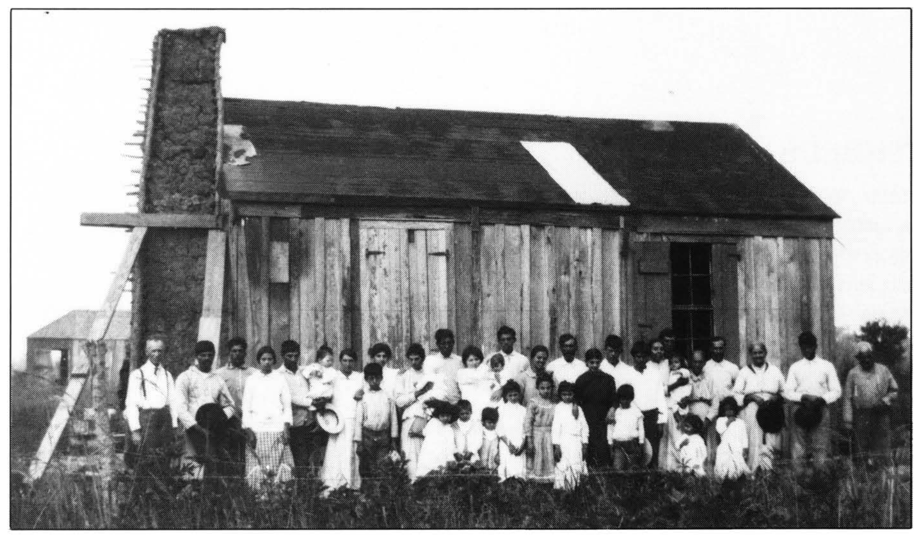
The Louisiana pirogue (*pettyaugre*) draws so little water it is said to "float on a heavy dew." This shallow-draft folk boat became an indispensable tool to the coastal dweller, ca. 1935: (*in* Channing Stowell, ed., *Jefferson Parish Yearly Review*, Special Collections Division, Hill Memorial Library, Louisiana State University Libraries, p. 54).

In the late 1800's and early 1900's market hunters and sportsmen harvested thousands of birds and millions of eggs for restaurants, glue manufacturers, photographic films, and the millinery trade, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).

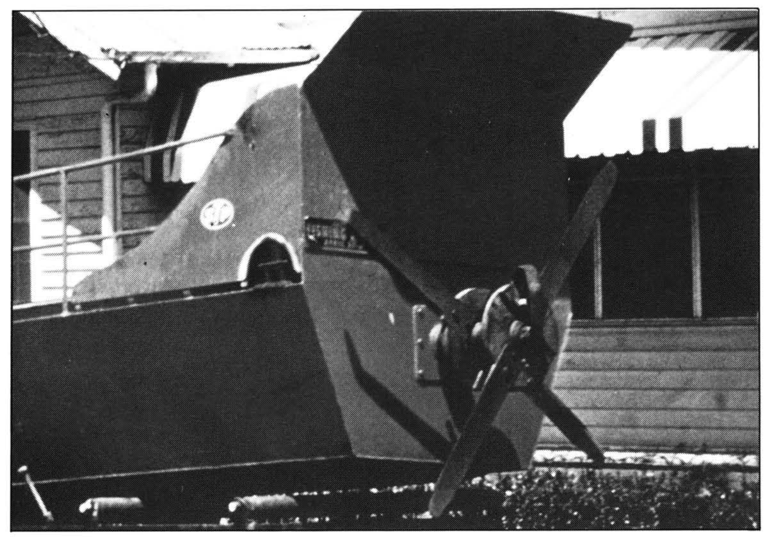
In the late 1800's, one hunter could market more than 1,000 alligator hides annually, ca. 1905: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).



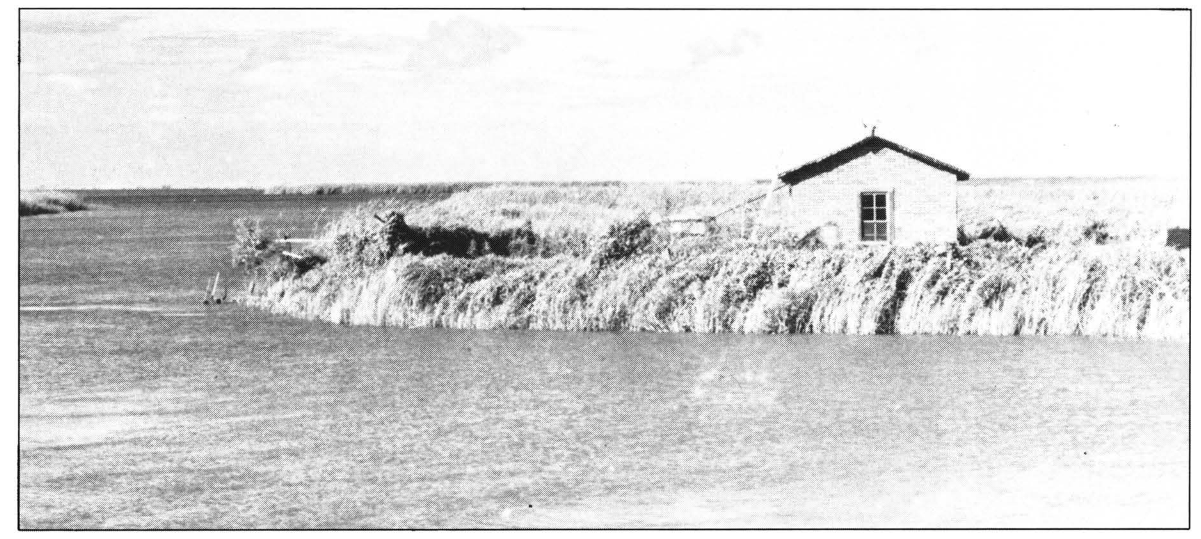
Crab fisherman, ca. 1930: (Fonville Winans, Louisiana State Library, Louisiana Photographic Archives).



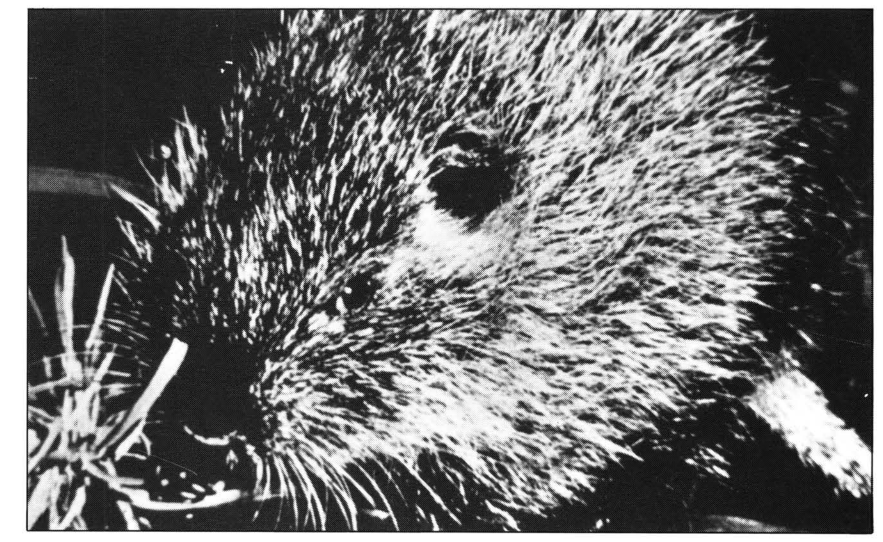
Mixed Houmas at Little Bayou Barataria, 1907: (Swanton Collection, Smithsonian Institution, Photo No. 142D).



A *trainasse* machine cut the narrow pirogue trails that allowed trappers access to their trapping areas, 1969: (Donald Davis Collection, Baton Rouge, Louisiana).



To effectively harvest the marsh, trappers built isolated camps near the areas they trapped, 1947: (Todd Webb, Louisiana State Library, Louisiana Photographic Archives).



The Louisiana muskrat, ca. 1940: (Louisiana Department of Wild Life and Fisheries, Photographic Archives).

A trapper "fleshing" the day's catch, no date: (from the U.S. Army Corps of Engineers, New Orleans District, Photographic Archives).

At one time, Louisiana produced more fur than the remainder of the United States and Canada combined, 1984: (Donald Davis Collection, Baton Rouge, Louisiana).

WETLANDS TRAPPING IN FRENCH LOUISIANA

Trapping, one of the oldest means for obtaining food and clothing, originally was a profession confined primarily to the taiga and tundra regions of northern Alaska and Canada. Once alligator (*Alligator mississippiensis*), mink (*Mustela vison*), otter (*Lutra canadensis*), and raccoon (*Procyon lotor*) were recognized as valuable hide- and fur-bearing animals, the belief that quality furs came only from cold climates was dispelled. Within 150 years Louisiana marshes became North America's preeminent fur-producing region. By the early twentieth century, Louisiana's annual harvest was greater than that of Alaska and Canada combined. Louisiana's wetlands were considered an important and easily exploited wildlife habitat (Ashbrook, 1953; O'Neil, 1965).

Before the 1914-22 increase in fur prices from 8 to 50 cents a pelt (Chatterton, 1944), hunting was more profitable than trapping; a brace of ducks sold for 25 cents. Locals changed their winter subsistence activity from hunting to trapping because of the 500 percent increase in fur prices.

Ten years later approximately 20,000 people were involved in Louisiana's essentially uncontrolled trapping industry. A trapper set lines on any land that suited him because he was concerned with productivity, not property ownership. To work this land a trapper went into the marsh with his entire family. Children lived on the trapping lines and returned to school after the three-month season to "catch back" their studies (Frost, 1939).

Marsh dwellers used cane poles to mark their trapping areas and brought order to what could have been chaos. Once staked out, individual plots were respected. Ditches were cut to gain access to the marsh. A *trainasse* or ditch, could be used to cross someone else's claim, but traps were never set on another person's land (Davis, 1976). It was folk law that trapping grounds were honored and divided according to families; often husband and wife trapped different parcels. When fur prices increased, people from outside the area became involved in the industry (Davis, 1973). These outsiders competed for the choice trapping areas. This disregard for individual rights culminated in a trapper's war in St. Bernard and Plaquemines parishes (Washburn, 1951).

To remedy the situation, the State intervened and established a controlled harvest; pelts were, for the first time, graded to determine their value. In addition, landowners assigned individual trappers parcels of land, and licensed trappers, free-lancers, and bootleggers were unable to work the land easily. Competition and poaching by outlaws and outsiders were eliminated (Washburn, 1951). Arrangements with landowners varied; generally, a trapper worked on a 50-50 basis. When furs were scarce, a 65-35 share was negotiated, with the trapper receiving 65 percent (Frost, 1939).

With the increased value of furs, trappers spent more time in the marsh, so they lived on their trapping leases in small, one- or two-room, palmetto-thatched huts called camps, crude by today's standards but adequate and always clean. The huts were copies of the houses built on the natural ridges by many native Americans. There was no need for a larger structure because trapping families spent most of their time outdoors.

The camps evolved into more permanent structures with wood-burning or butane stoves to supply heat, white-gas or kerosene lantern lights, and cistern water (Gary and Davis, 1979). These camps were rough-hewn buildings but actively used only in December, January, and February, so they were quite adequate. Everything required at the camp was hauled in by boat (Daspit, 1948). Large boats provided access, but motorized pirogues and mudboats allowed the trapper to increase his trapping from 150 to 400 traps by increasing the territory covered (O'Neil and Linscombe, 1975).

At the camp the pelts were fleshed, washed, stretched, and dried. They were then sold to a local buyer who sold to one of the Louisiana fur dealers. Trapping was and is a labor-intensive industry. In fact, the method employed in trapping and handling the fur has changed little since the invention of the steel trap by Sewell Newhouse in the mid-1800's (O'Neil, 1969).

MUSKRAT AND NUTRIA

Beaver, otter, and mink did not account for Louisiana's trapping growth; it was a result rather of the willingness of the local population to exploit the region's unique resources: muskrat (*Ondatra zibethicus rivalicius*) and nutria (*Myocastor coypus*).

Before the late 1800's the muskrat ranged as far south as southeastern Arkansas, but by 1900, it had become a permanent resident of Louisiana's marshes (O'Neil, 1949). Although it inhabited the wetlands, Arthur (1931) and O'Neil (1949) found no documentation linking muskrats to the early French fur trade. Fur buyers were interested in buffalo (*Bison bison*) and the American beaver (*Castor canadensis*). Muskrat pelts were offered to northern markets in 1870, but wholesalers considered them useless. By 1914, however, pelt prices increased. The animal was on the fur market and became the State's number one fur product, a title it eventually lost to the nutria (Chatterton, 1944).

To increase their marketability, muskrat pelts were often specially treated, and sold under the label French Seal or Hudson Seal (Chatterton, 1944). With time, the muskrat gained prestige under its own name. Because each pelt has three distinct colors: black (stripe down the back), light golden brown (sides), and silver (body), they could be used for three different garments (Murchison, 1978).

A muskrat builds its house, made of woven marsh grass and plastered with mud, 1.2 to 1.5 meters above the marsh surface, from which it can forage into the surrounding terrain. These houses are the keys to production because they identify the muskrat's brackish water habitat.

The Argentinian *coypu*, or nutria, was inadvertently introduced into the Louisiana wetlands in 1938 and is now well established throughout the State. The rodent first was considered a nuisance because it was heavy to carry out of the marsh, difficult to skin, and confined to a single area, but with increased prices, attitudes changed (Dozier and Ashbrook, 1950). By the early 1950's, trappers were harvesting nearly 80,000 pelts annually. Six years later, over 500,000 pelts were processed, a significant increase in less than 20 years (Davis, 1978). During that time, nutria pelts generated over $7 million a year and represented about half of the State's fur income—all from a dozen *coypu* that escaped captivity (Daspit, 1950).

In the 1961-62 season, nutria surpassed muskrat in number of pelts sold. Although the nutria's habitat is shrinking, the population is expanding swiftly. Because fur prices are declining, it is no longer worth the time, money, and effort for trappers to harvest this rodent. Nutria, therefore, have begun to overpopulate their habitat and cause considerable environmental concern.

Muskrats and nutrias thrive in the marshes. There is ample range to graze, and they have co-existed quite well. Nutrias prefer freshwater marshes but with increased population densities will move into the muskrat's brackish water habitat.

THE AMERICAN ALLIGATOR

There are at least 500,000 alligators (*Alligator mississippiensis*) living in the Louisiana coastal zone's fresh-to-slightly-brackish habitats. Muskrats, nutrias, rabbits (*Sylvilangus aquaticus*), rails (*Rallus longirostris saturatus*), and waterfowl feed in these marsh zones and naturally attract the omnivorous predator.

The alligator, first described in 1718, has survived two centuries of hunting. Even after they were extensively harvested to meet the Civil War demand for shoe leather, the marshes supported an immense population (Johnson, 1969). In the late 1800's, 4.5- to 6-meter alligators were so commonplace they did not attract considerable attention and were considered a nuisance. Le Page Du Pratz (1774) relates, in his *History of Louisiana*, the killing of a 5.8-meter alligator, whose head was 1 meter long and at least 76 centimeters wide.

Alligator hunters realized their quarry's skin and meat were valuable, so they often shot swimming gators, and although the dead reptile sinks almost immediately, it could be retrieved easily. Hunters also used baited hooks attached to about 15 meters of line suspended 15 centimeters above the water; when the bait was taken, the hook became embedded in the reptile's stomach. The alligator was then caught, hand lined to the surface and shot.

In the late 1800's one hunter could market over 1,000 alligator hides annually. Between 1880 and 1904, the population was reduced an estimated 80%, but as late as 1890, some 280,000 alligator skins still were being processed in this country annually (Waldo, 1957).

During the next 60 years, hunters were encouraged by escalating prices. In 1916, a 1.5-m hide brought only 40 cents. By 1928, it brought $1.25, and by the early 1960's hide prices had increased to over $30 a meter. Consequently, the reptile's population was nearly exhausted. To try to reestablish the reptile within its native habitat, in 1966 the alligator was placed on the Federal list of rare and endangered species. This protective action, along with habitat preservation, has allowed the reptile to make a dramatic recovery. Since then, the reptile has been removed from the federal endangered and threatened species list. Louisiana now considers the animal a renewable resource and has sanctioned a strictly regulated September hunting season.

Palmetto homes were a visible part of the wetlands landscape, ca. 1910: (Swanton Collection, Smithsonian Institution. Photo No. 244).

Once dried, pelts were graded and sold to local buyers, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).

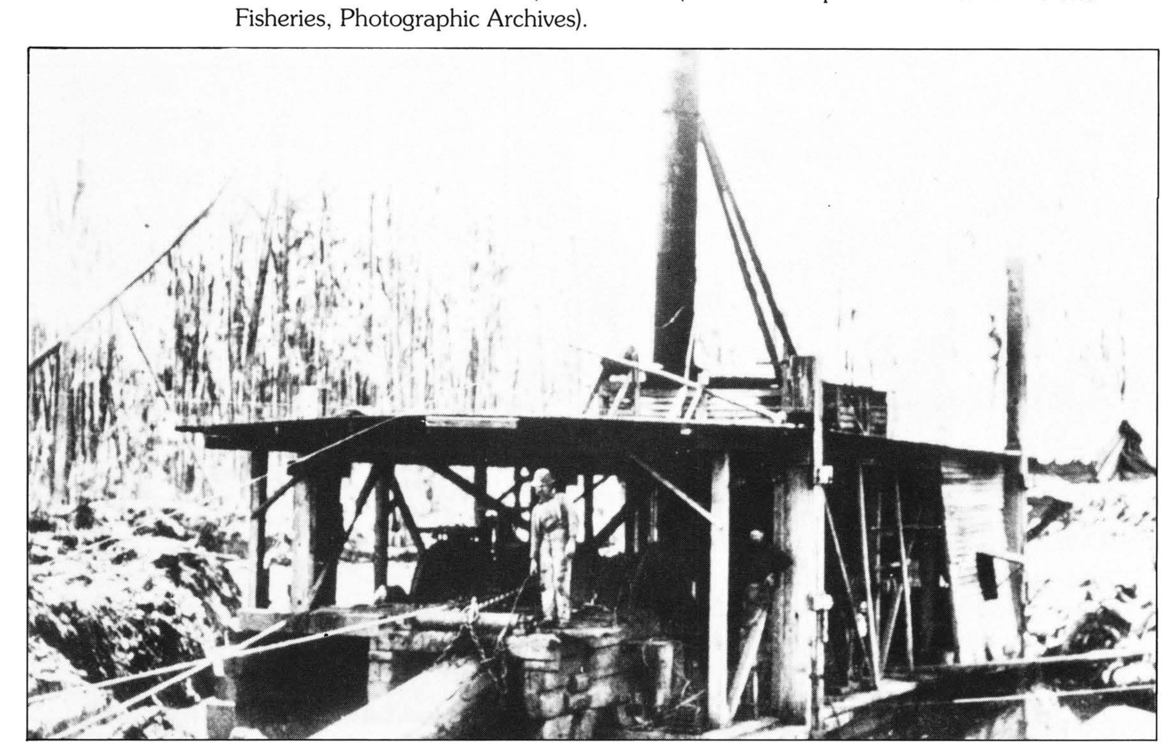
In some places, an isolated trapping village was constructed to meet the needs of several families, ca. 1930: (Louisiana Department of Wild Life and Fisheries, Photographic Archives).

In a good year, a trapper would harvest from 50 to 200 animals a day. When brought back to camp, muskrat and nutria had to be cleaned immediately, ca. 1930: (Louisiana Department of Wild Life and Fisheries, Photographic Archives).

The Argentinean *coypu*, or nutria, was accidentally introduced into Louisiana's coastal lowlands, where it has proliferated, 1986: (Donald Davis Collection, Baton Rouge, Louisiana).

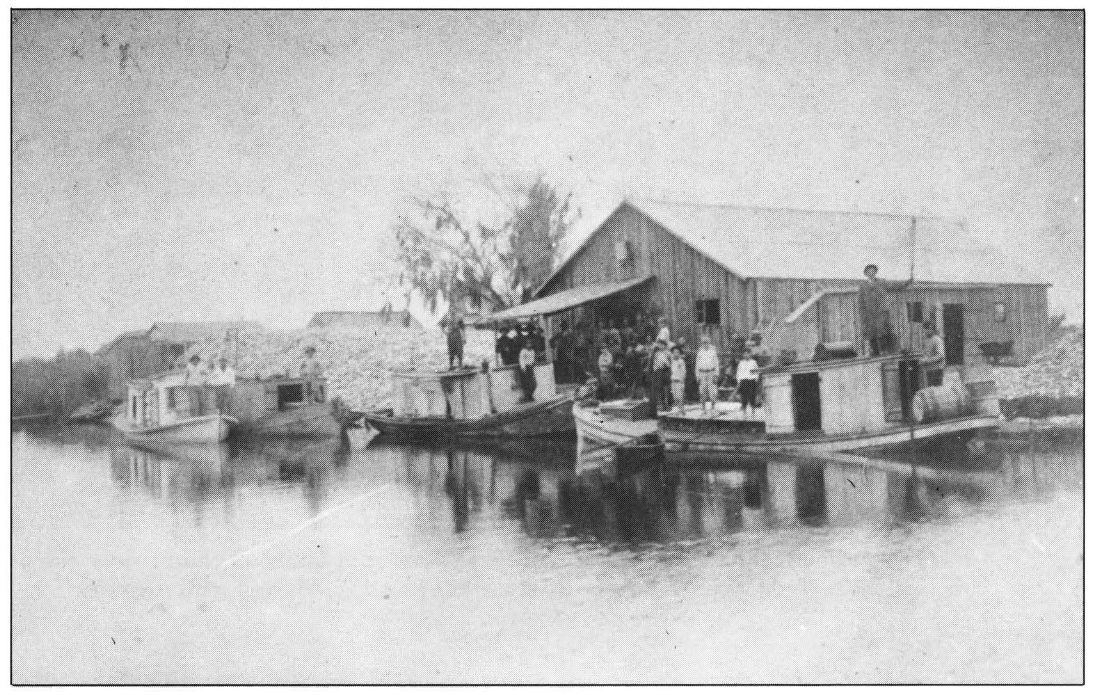
Mule carts were used to transport pirogues to access points, ca. 1930: (Randolph Bazet Collection, Houma, Louisiana).

Once an endangered species, the alligator has been reestablished in the wetlands. Each September, Louisiana has a controlled alligator hunt, 1988: (Donald Davis Collection, Baton Rouge, Louisiana).



At the turn of the century, pullboats were used to harvest the swamps, ca. 1900: (courtesy of Milton Newton, Louisiana State University, Department of Geography and Anthropology, Bowie Lumber Company Collection).

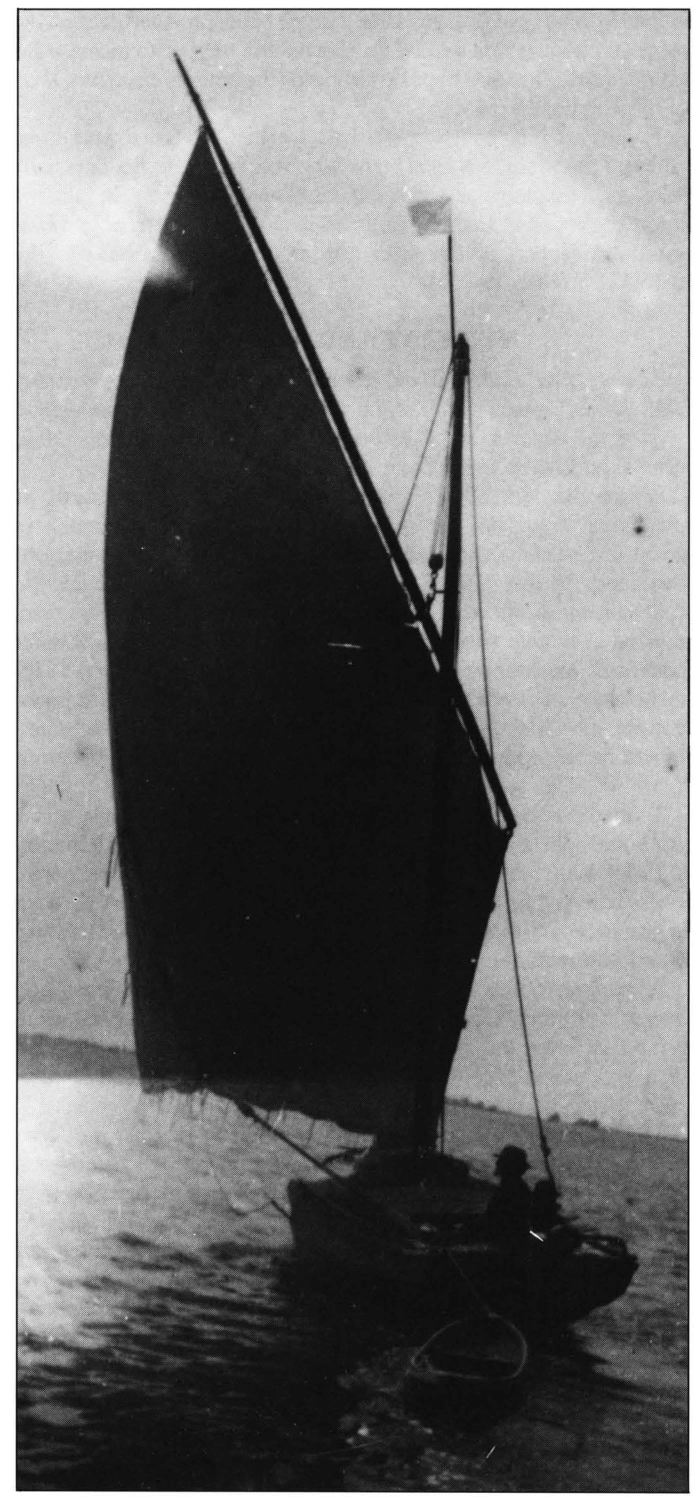
For over 100 years Louisiana's waterpeople have harvested oysters from the State's estuarine habitats, ca. 1940: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).



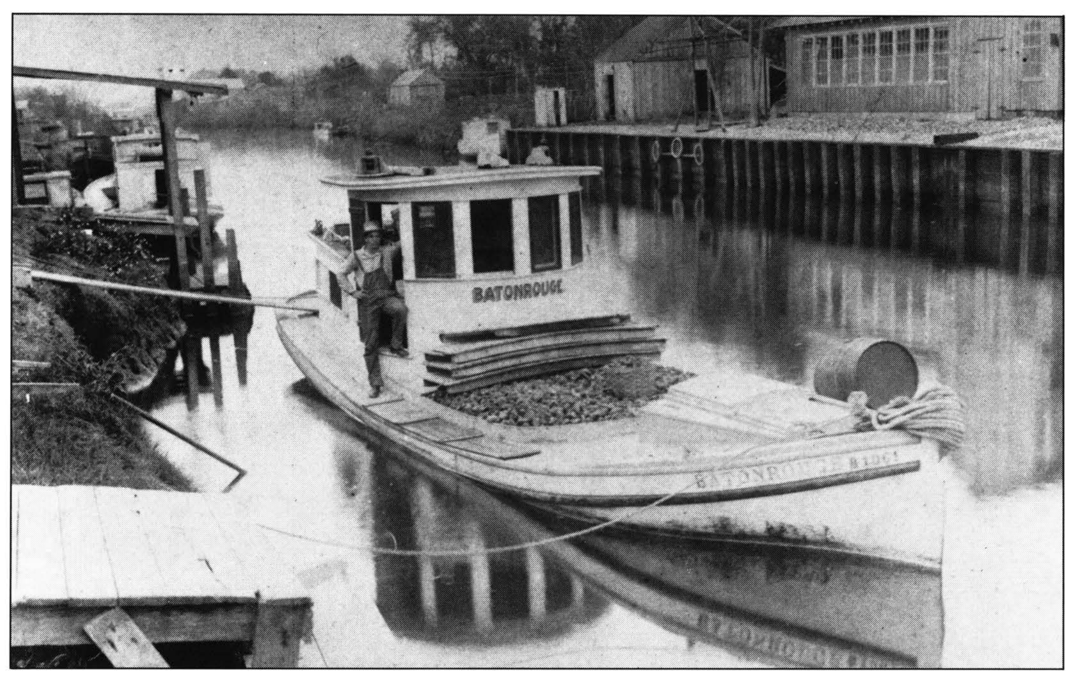
To facilitate processing, oyster shops often were built on isolated sites near the oyster beds. This shop was located in the Terrebonne-Timbalier complex, south of Houma, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).

Fishermen often sold their oysters, crabs, or shrimp to larger boats, so they could remain at work, rather than losing time travelling to market, 1891: (National Archives, Negative No. 22-FCD-247).

In Terrebonne Parish, at Boudreaux Canal on Bayou Petit Caillou, Andrew St. Martin built an oyster-shucking plant to quickly process the region's harvest, 1911: (Randolph Bazet Collection, Houma, Louisiana).



Historically, movement through the coastal wetlands presented people with a special challenge and resulted in development of unique folk boats. The shallow-draft, sail-driven Louisiana lugger became the preferred working vessel of the region's fishermen, 1891: (National Archives, Negative Number 22-FCD-32).



Although New Orleans was recognized as Louisiana's principal oyster market, oyster-shucking houses were built in many delta-plain communities. Houma developed into one of these regional centers, no date: (Randolph Bazet Collection, Houma, Louisiana).

LOUISIANA'S PROLIFIC OYSTERBEDS

Estuarine-dependent oystermen rely almost totally on one species, the American oyster (*Crassostrea virginica*). At the turn of the century, Louisiana and Mississippi were leaders in the production of this important bivalve. To harvest their oysters, Louisiana's watermen leased the right to harvest the state's water bottoms. Isolated settlements were established to watch the leases to ensure that poachers would not disturb the tonging grounds.

To exploit the beds, oystermen used a pair of tongs, which resembled two long-handled rakes tied so the teeth were facing each other. Leaning out over their luggers, oystermen spread and lowered their tongs into the water. The opened tongs were shoved into the reef and forced closed, grabbing several bivalve clusters. The oystermen then dumped their catches into their boats. One man would tong and another would cull the undersized product. This process was repeated until the boat was full, the catch too small, or darkness or bad weather set in and forced the men to return to camp. Using this technique, oystermen could harvest 20 barrels a day.

Tongs were eventually replaced by the oyster dredge—a large basket-like framework with curved teeth that was dragged through the beds to snag the oysters. With this new technology, the harvest increased. Luggers were customized with a false deck and temporary sides to accommodate the expanded catch. The dredge's deck became an extension of the vessel's hold and could carry from 50 to 80 barrels of oysters (Zacharie, 1898; Prindiville, 1955). The watermen who lived near their beds used small boats to work their leases, but sold to owners of larger boats. In this way, they could remain at work, rather than lose time traveling to the market.

Eight boats from the Barataria communities of Bayou Cook, Bayou Chalous, and Four Bayous unloaded their catches in New Orleans every week. Thirty luggers delivered the harvest from Southwest Pass and Salina. From the Timbalier region another 15 luggers transported their harvest to the city from "considerable villages composed of ... rude camps of the oystermen built upon piles on the sea marsh" (Moore, 1899, p. 71). In all, an estimated 4,000 people were involved, directly or indirectly, in the oyster trade (Sterns, 1887).

By 1887 approximately 200 luggers, employing over 600 men, supplied New Orleans' Lugger Bay with oysters (Sterns, 1887). These sailing vessels delivered from 50,000 to 125,000 barrels annually; a barrel held approximately 200 pounds of oysters and sold for $2.00 to $3.50. Wholesalers paid 40 cents for a sack of oysters and transported them to New Orleans where city vendors sold them for about 70 cents a sack—a profit of almost 75 percent (Ross, 1889b).

Each boat was unloaded by stevedores, who controlled the discharge of New Orleans' cargo. A quasi-organization of Sicilians and Italians was solely responsible for unloading the oyster vessels (Sterns, 1887) and overseeing the crews that worked the docks.

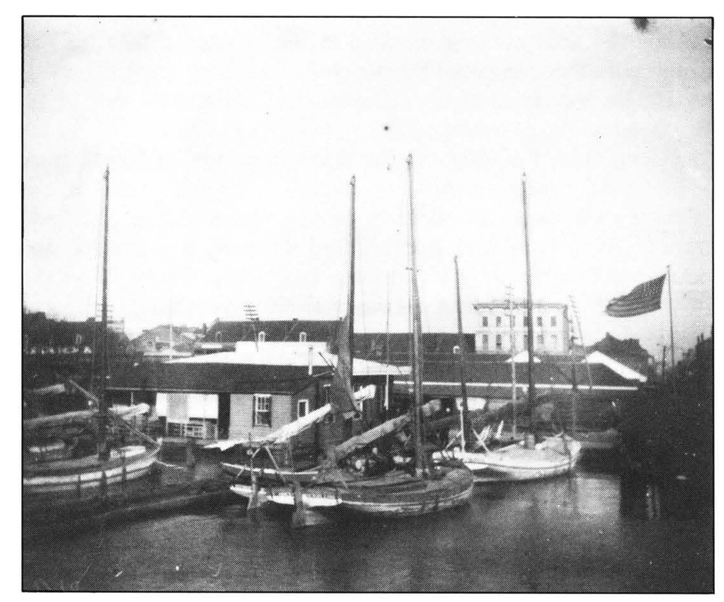
Competition between Louisiana and Mississippi over the oyster beds east of the Mississippi River became so keen, men were accused of being "oyster pirates." Using a fleet of lumber schooners capable of carrying from 1,000 to 2,000 barrels a trip, Mississippi-based watermen reportedly harvested hundreds of schooner loads of St. Bernard Parish oysters (Zacharie, 1898). The issue became a heated one, and in 1905, armed boats began patrolling the State boundary to ensure that only licensed fishermen were exploiting Louisiana's oyster beds (Fountain, 1985). Bohemians manned Biloxi schooners that operated for weeks in the marshes of the Mississippi River delta country—often illegally in Louisiana waters (Fountain, 1966).

Predators were also a problem. To protect the beds from schools of drum or sheepshead, which could devour hundreds of barrels of oysters in a single night, pens were constructed of old seine supported on pickets or hardware cloth (Zacharie, 1898). At times lines with rags attached to them were used to frighten the fish away.

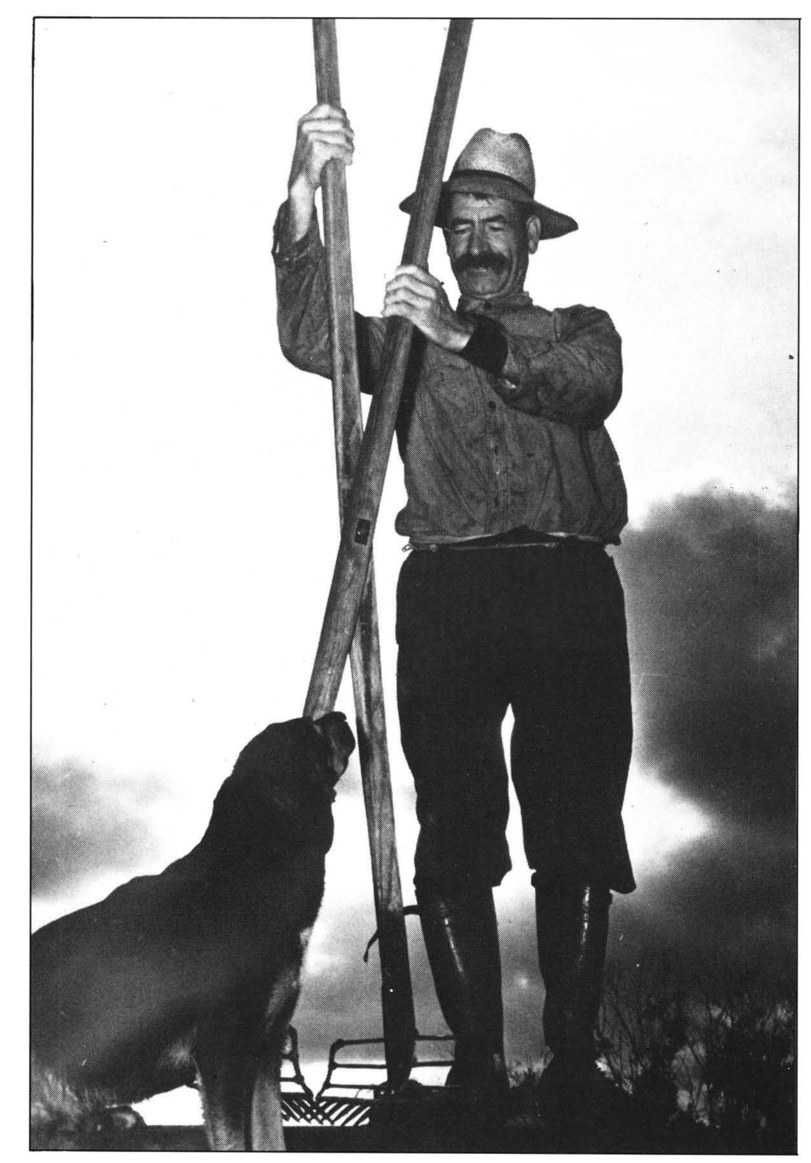
OYSTERING IN BAYOU COUNTRY

Jack's Camp, Camp Malnomme, and Bayou Landry were important harvesting sites in the barrier-island-protected leases of south central Louisiana. Small fishing villages were near these sites. Oysters harvested in one area sometimes were used to restock other beds. In this way, oystermen accumulated catches that would warrant a trip to the New Orleans' market. Fishermen worked beds at the Chandeleur Islands, Bayou Cook, Grand Bayou, Bayou Lachuto, Timbalier Bay, Isles Dernieres, Barataria Bay, Wine Island Lake, Vermilion Bay, and Calcasieu Lake. Bayou Cook oysters were generally considered the State's best (Zacharie, 1898). Prized oysters were also being harvested in Lake Felicity, Lake Barre (especially at Mud, Hatchet, and Muddy Bayous), and Bay Jocko (Moore, 1899).

In the late 1800's there were at least 20 camps along Grand Bayou du Large between the Gulf of Mexico and Sister Lake. Oyster camps were also located on Pelican Lake, and the Timbalier region's oyster grounds were quite productive. Even with a relatively small number of people working the beds, Sister Lake alone yielded from 4 to 8 barrels of oysters per day (Moore, 1899). It is a region that continues to serve the oyster industry well.



Oyster luggers at the New Orleans' French Market, 1891: (National Archives, Negative No. 22-FCD-18).

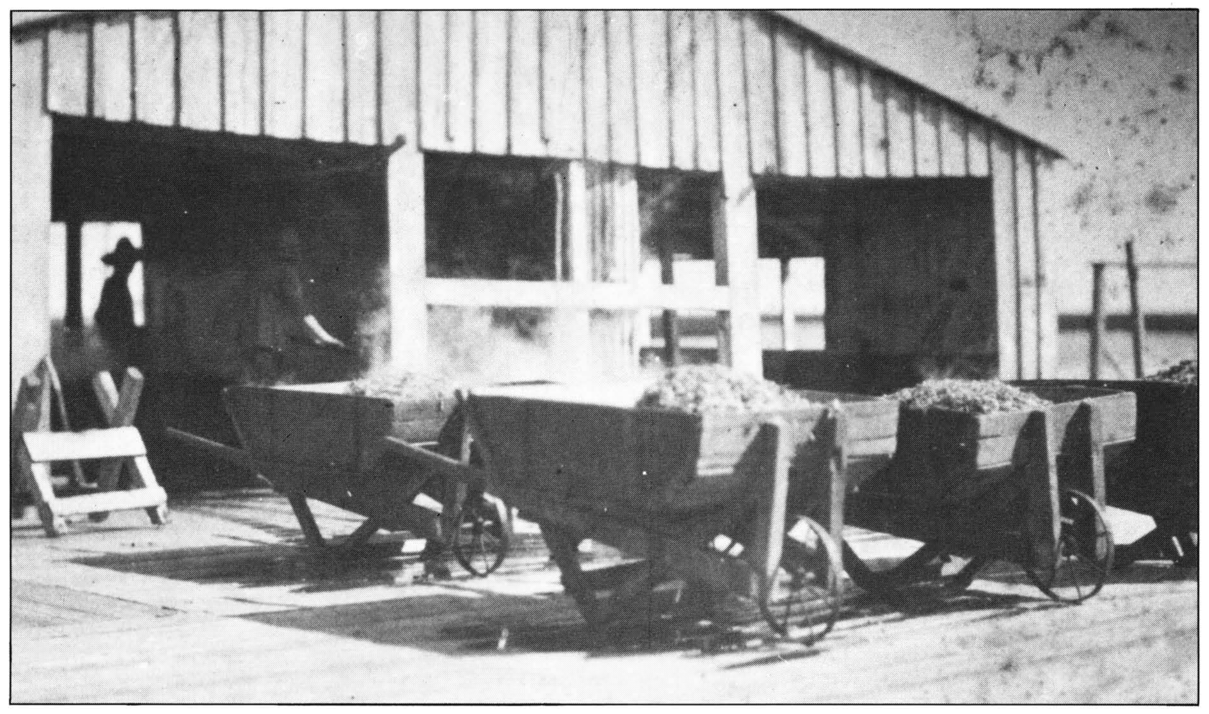


A pair of tongs resembling two long-handled rakes tied so their teeth were facing each other was used to harvest Louisiana's oyster beds, ca. 1930: (Fonville Winans, Louisiana State Library, Louisiana Photographic Archives).

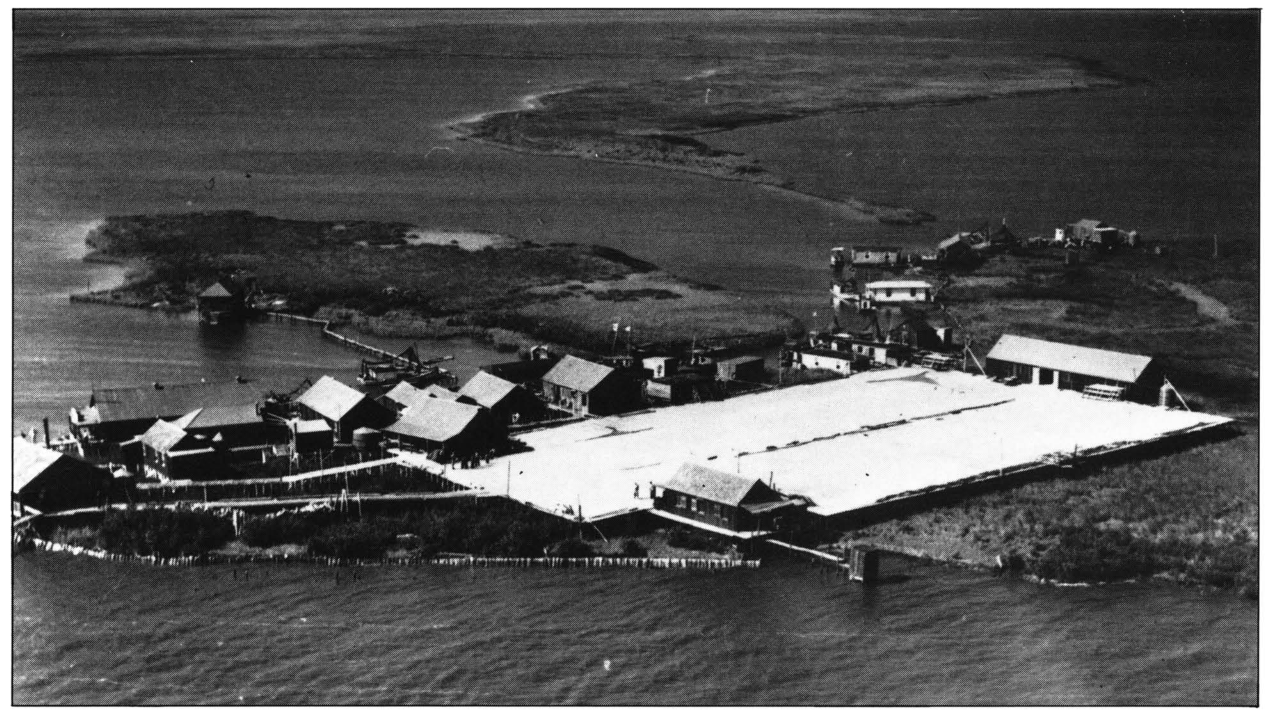
Eight members of the *Descaricadores*, a quasi-organization of Sicilians and Italians that controlled the unloading of New Orleans' oyster vessels, 1891: (National Archives, Negative No. 22-FCD-265).

In 1887, the oyster industry was well established in coastal Louisiana. Approximately 200 luggers, employing more than 600 men, supplied New Orleans' Lugger Bay with oysters, 1891: (National Archives, Negative No. 22-FCD-17).

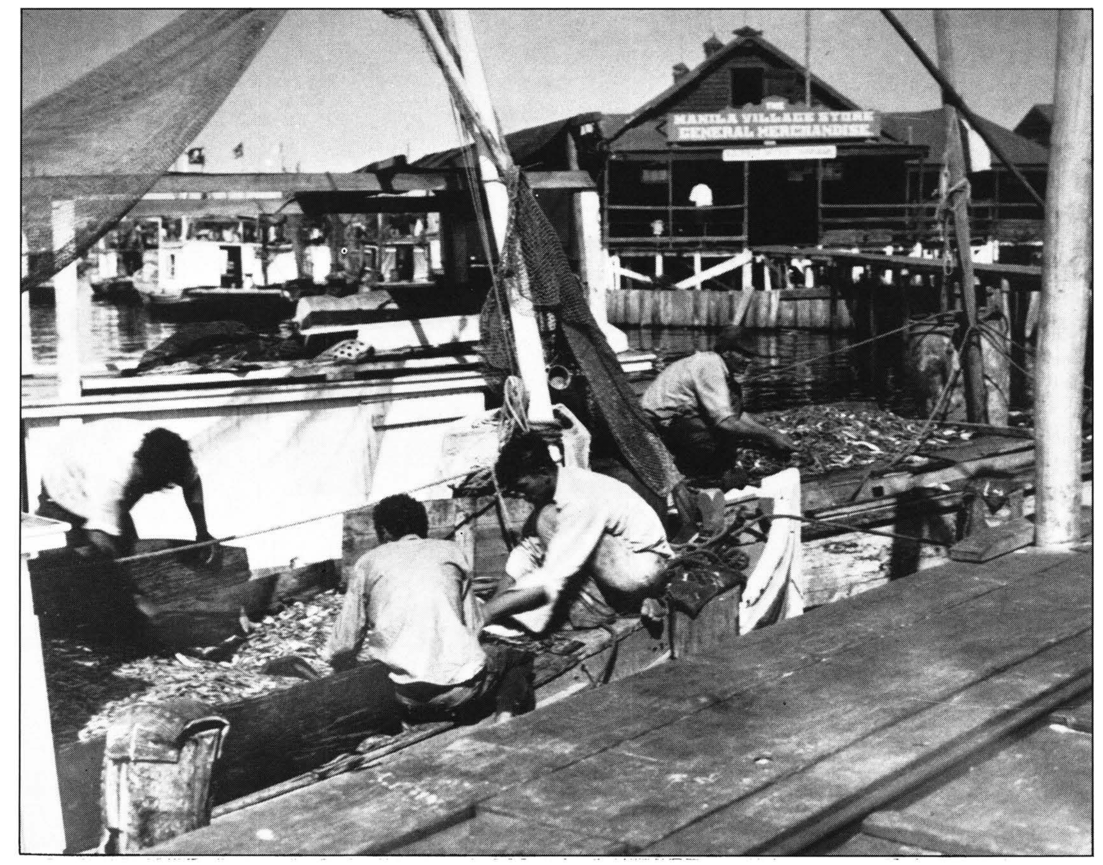
Locks at Empire allowed oyster luggers to move easily between the Mississippi River and the estuarine complex west of the river, ca. 1938: (Fonville Winans, Louisiana State Library, Louisiana Photographic Archives).



Shrimp used in the shrimp-drying business were boiled in a hypersaline solution. When removed from the vats, the shrimp were taken by wooden wheel barrows to the platform's drying area, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).



At the southern limit of Dupre Cut-Off canal in Barataria Bay was the shrimp-drying settlement of Manila Village. Dominated by a large platform, this was the largest shrimp-drying community in Louisiana's alluvial wetlands, 1938: (Fonville Winans, Louisiana State Library, Louisiana Photographic Archives).



Manila Village's buildings and wharf, built over the shallow water on hand-driven pilings, were used to unload the newly arrived unprocessed shrimp, no date: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).

Hand-woven china baskets, along with wheelbarrows, were used to move shrimp around the platform, no date: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).

SHRIMP DRYING: AN ANCIENT CHINESE ART

The shrimp-drying procedure used in Louisiana originated in the Orient and diffused to Louisiana from the United States' west coast. In 1871, Chinese immigrants began to harvest San Francisco Bay shrimp (Jordan, 1887; Bonnot, 1932). These fishermen were quite successful and found it profitable to supply the markets with shrimp at three cents a kilogram. "From the very start they dried the bulk of their catch for the Oriental export trade. The shrimp industry quickly grew to large proportions and fishing was carried on at many places in San Francisco Bay" (Scofield, 1919, p. 2). By 1873, Chinese migrants from California had introduced the lucrative sun-dried-shrimp process to Louisiana, hoping to duplicate the profits generated from the San Francisco Bay enterprises (Padgett, 1960).

Shrimp-drying villages were well-organized hamlets established to overcome the early problems of food preservation in Louisiana. The sites were dominated by large, undulating, wooden platforms—a term which locally had two meanings; one referred to the drying area only, the other included the associated support structures as well.

Shrimp in Louisiana had been a source of income and a basic food item since the colonial period. As early as 1718, the Dutch historian A. S. Le Page Du Pratz, stated

> The Shrimps are diminutive crayfish ... usually about three inches long, and of the size of the little finger ... in other countries they are generally found in the sea ... in Louisiana you will meet with great numbers of them more, than a hundred leagues up the rivers. (Le Page Du Pratz, 1774, p. 277)

Le Page Du Pratz also noted that shrimp were not limited to the sea. Indeed, the majority of shrimp used in the sun-drying process was caught in Louisiana's inland waters. As a result, Barataria, Timbalier, Terrebonne, Caillou, and Atchafalaya bays, and Breton and Chandeleur sounds are important to the production of marketable shrimp. These estuarine or estuarine-like areas also served as settlements because before ice and modern freezing techniques were available, shrimp caught in these fishing grounds were taken to one of the nearby platforms to be dried, packaged, and sold.

There are conflicting reports on the original practitioner of this art in Louisiana; it was either Lee Yeun, Chen Kee, or Lee Yim (Adkins, 1973). Although the person responsible for starting this occupation is apparently lost to history, it is fairly well agreed that the first crude drying platform was built on the

> south side of the mouth of Grand Bayou in Barataria Bay, at a site later to be Cabinash. This camp was originally used in an effort to sun dry oysters, but when this proved to be impractical the men began to dry shrimp. (Padgett, 1960, p. 142)

Louisiana Land Office records show that in the early 1880's Oriental immigrants purchased, for $1.25 a hectare, several small islands in Barataria Bay for platform sites (Adkins, 1973). These tracts were ideally suited for this purpose. By 1885, the industry was well established when

> Yee Foo was issued Patent Number 310-811 for a process to sun-dry shrimp. Actually, the Chinese have used this method for preserving shrimp and other animal foods for centuries, but the patent made the process and established method of food preservation. (Love, 1967, p. 58)

Originally, the primary market for dried shrimp was the large Oriental communities on the Pacific coast; nearly $100,000 in dried products a year were shipped there from each camp (Cole, 1892a). As production increased, distribution expanded to the Far East; the greatest volume was exported to China, the Philippine Islands, and Hawaii. Smaller quantities were shipped to the West Indies and South America (U.S. Department of Interior, 1950).

PLATFORM SETTLEMENTS

Settlements at Bassa Bassa, Manila Village, Camp Dewey, Chenier Dufon, Cabinash, Fifi Islands, and Bayou Brouilleau were established for shrimp preservation and shipment to the various markets. In Barataria Bay there were six or more of these camps, occupied by hundreds of people (House Document, 1917).

Most of the shrimp seining was done by the French, the Chinese, or the Malays. Although Oriental peoples dominated the platform population, other ethnic groups also were involved. Platform crews frequently were a melange of representatives from water-oriented cultures. As many as 15 seine crews and a year-round platform population of about 100 contributed to a maximum of 500 people living on one platform. Most did not leave these isolated settlements because they were in this country illegally. It is rumored that some were smuggled into Louisiana by commercial fishermen who placed the aliens in barrels to bring them through coastal waters.

THE GEAR REQUIRED

In Louisiana's inland waters shrimp fishermen used the sail-driven Louisiana lugger. This vessel used lugsails—quadrilateral sails that bend upon a yard that crosses the mast obliquely. Effective in Louisiana, the boat never diffused from its area of origin, the State's inside waters. Prior to motor-powered vessels this was the major craft used to harvest platform shrimp.

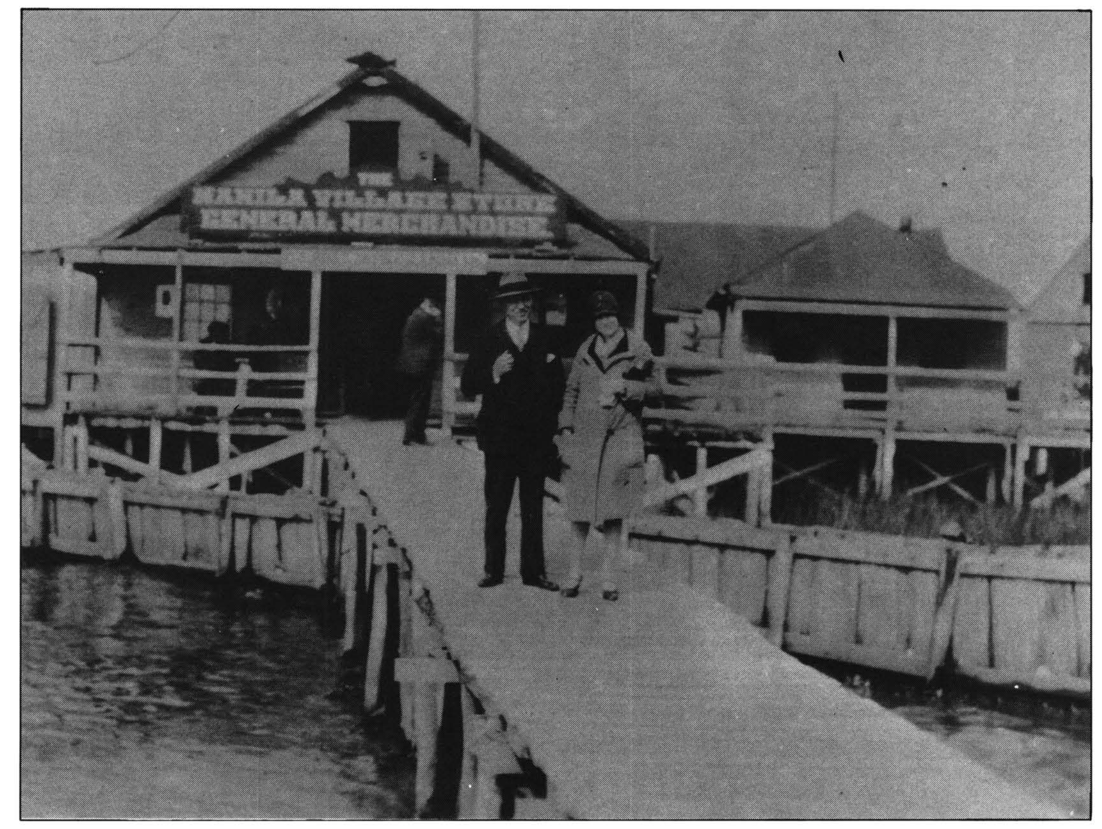
Before the introduction of the otter trawl, most of the catches were taken with haul seines operated by a single boat with a crew of from 8 to 20 men (Cole, 1892a; Johnson and Linder, 1934). Barataria seines were some of the largest in the world. Local informants claim that a good crew could harvest up to 900 kilograms a day. At times the catch was so great, a platform would work continuously to keep up with its seine crews.

Seines were efficient, but the otter trawl, introduced in 1917, revolutionized shrimping and increased production.

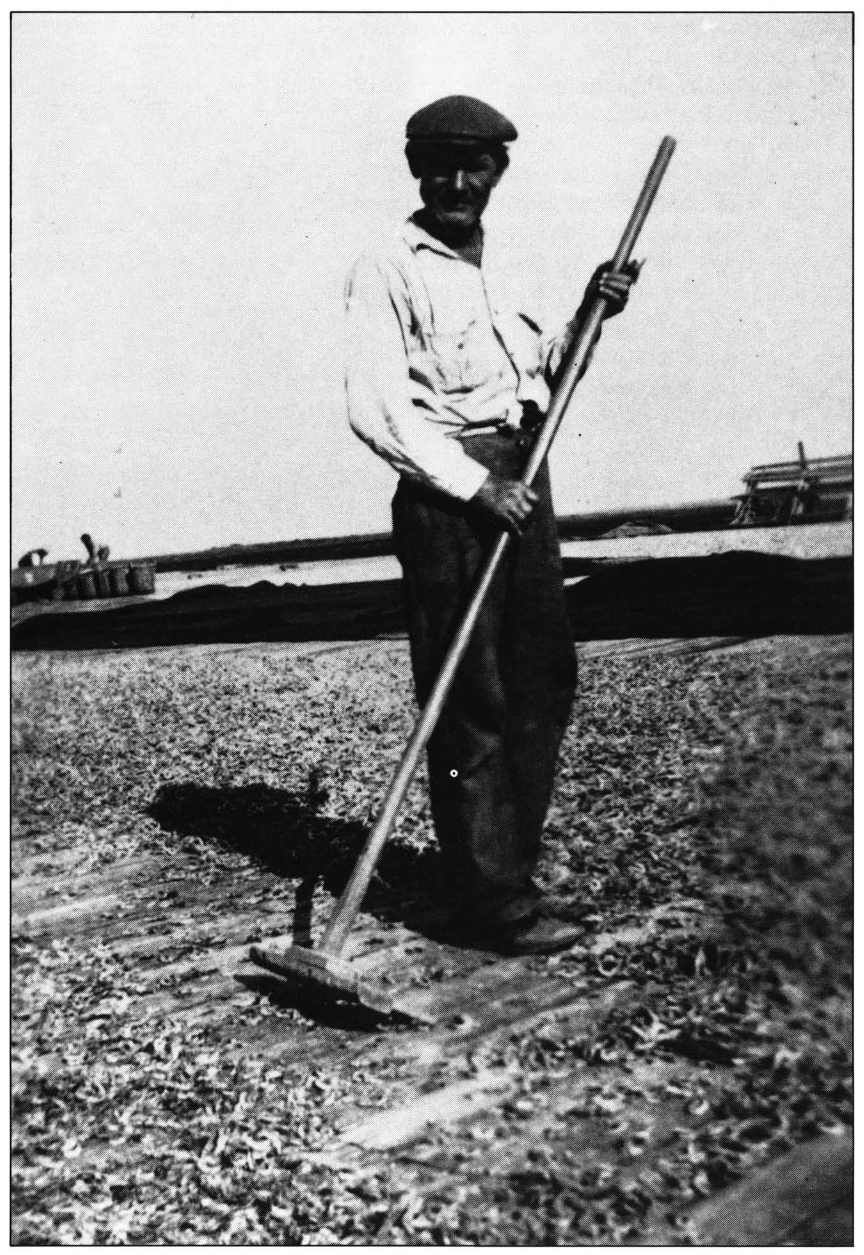
> The haul seine could be used only in shallow waters, requiring a large crew. It could be operated for only a limited time during the summer and fall months, the otter trawl was adaptable for use over a much greater range, could be operated with fewer men, yielded a greater production per man, and was a much more efficient type of gear. With its introduction, entirely new fishing grounds were opened up and a rapid expansion of the fishery followed. (Padgett, 1960, p. 147)

In 1930, the total shrimp harvest in Louisiana was over 13 million kilograms, nearly twice that of the preceding year (Padgett, 1960). Catch statistics normally fluctuate, but this increase in harvest was attributed directly to the acceptance and use of the otter trawl, the availability of ice, and improved boats.

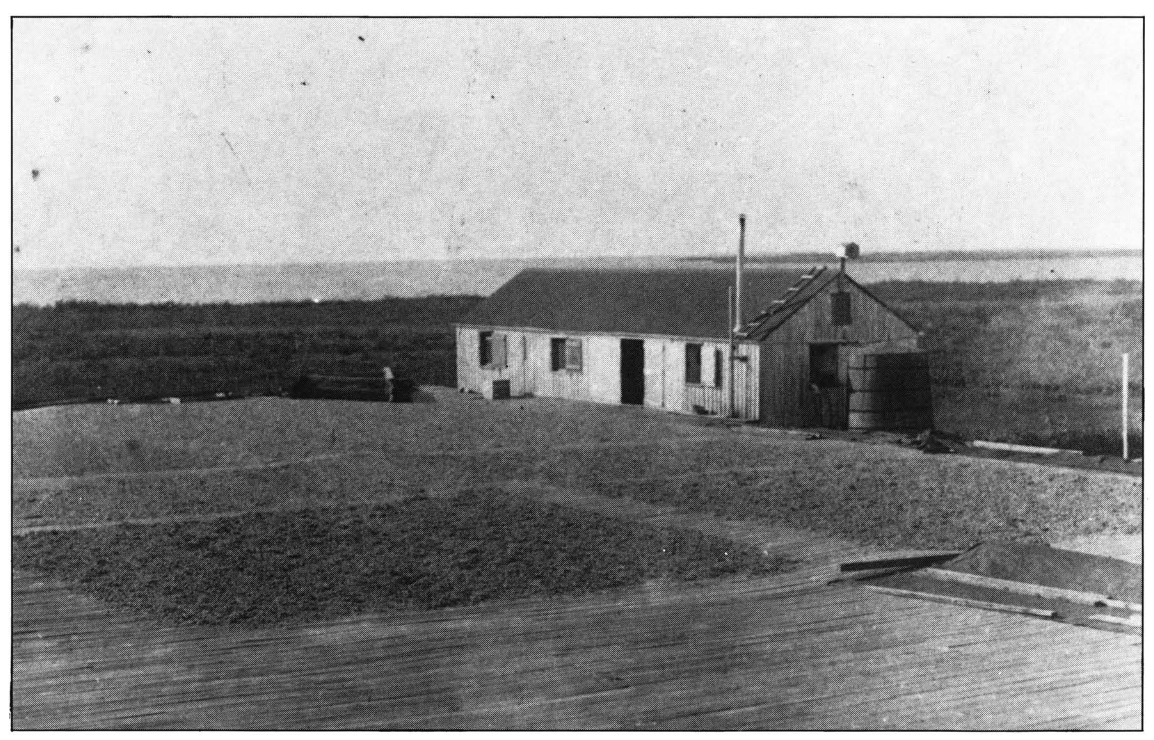
Coastal fishermen used a rig called a butterfly net (in French, *poupier*) with haul seines and otter trawls—invented to provide smaller and cheaper shrimp to the sun-drying industry (Love, 1967). These nets were mounted on boats and wharves, rigged on iron-pipe frames from 2.1 to 4 m^2, and equipped with small mesh bags about five meters long.



Manila Village was the largest of an estimated 75 drying platforms that served Louisiana's seine fishermen, no date: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).



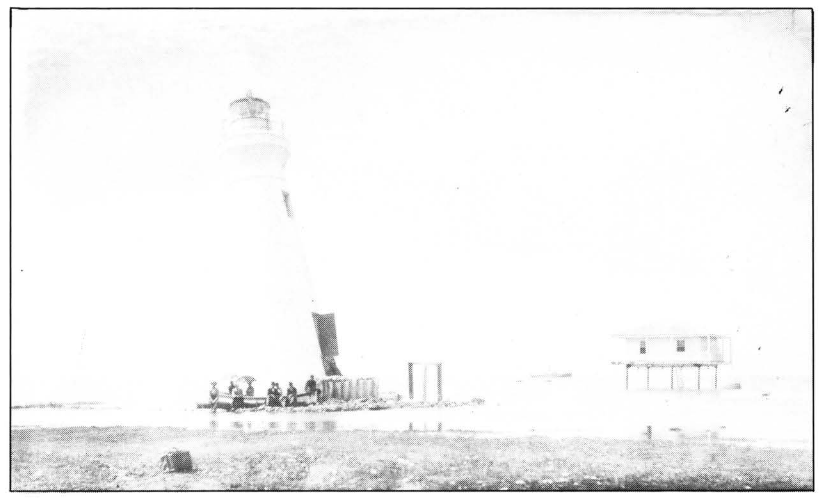
To insure uniform dehydration, the shrimp were spread evenly over the cypress platform's surface with wooden rakes, no date: (Louisiana State Library, Louisiana Collection, WPA Photographic Archives).



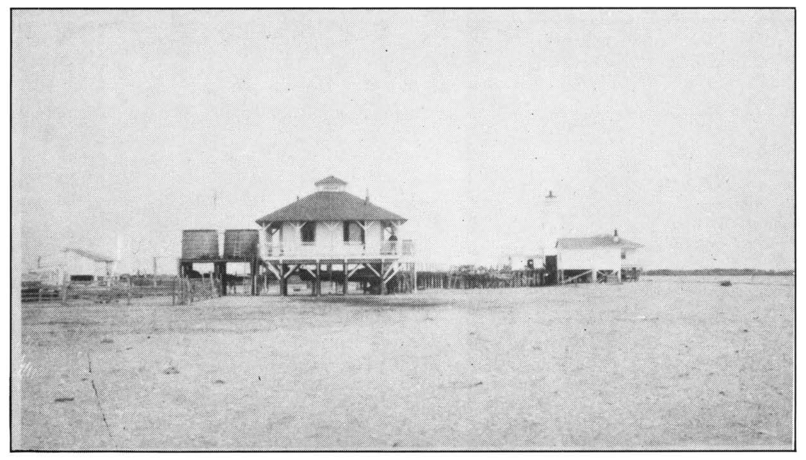
Most shrimp-drying platforms were constructed with cypress. The size of the drying surface varied with each site, but most had a capacity of 1,000 baskets of shrimp—about 50,000 kg, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).

When the shrimp were thoroughly dried, the heads and shells were removed by laborers who "danced the shrimp" in shoes wrapped with cloths or sacks, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).

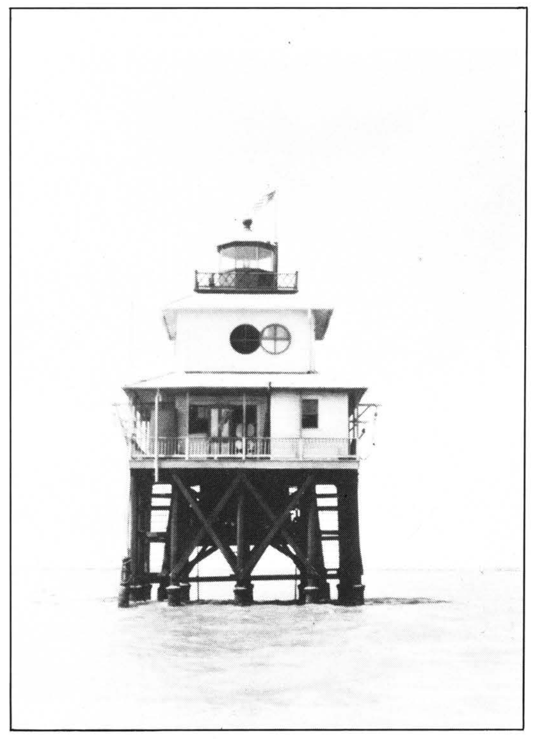
From isolated platform sites, waterpeople depended on their luggers to harvest the region's renewable resources, 1891: (National Archives, Negative No. 22-FCD-47).



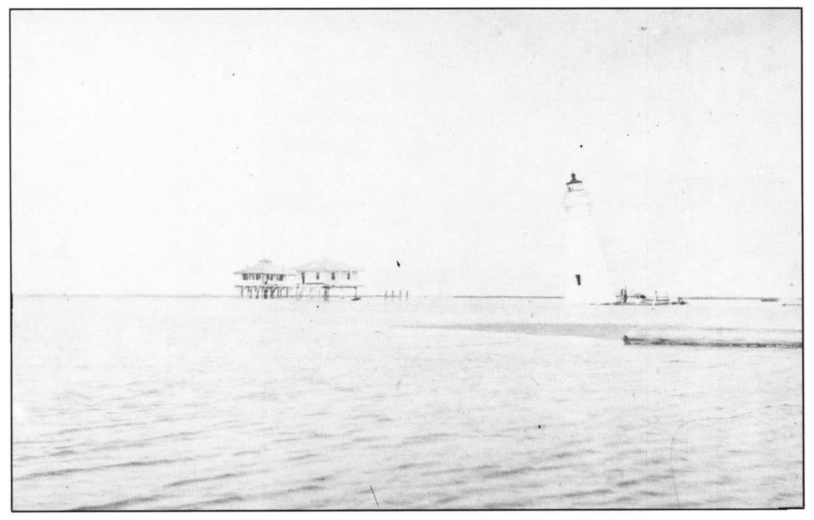
The Chandeleur lighthouse after the 1893 hurricane, October 1, 1893: (National Archives, Negative No. 26-LG-35-48).



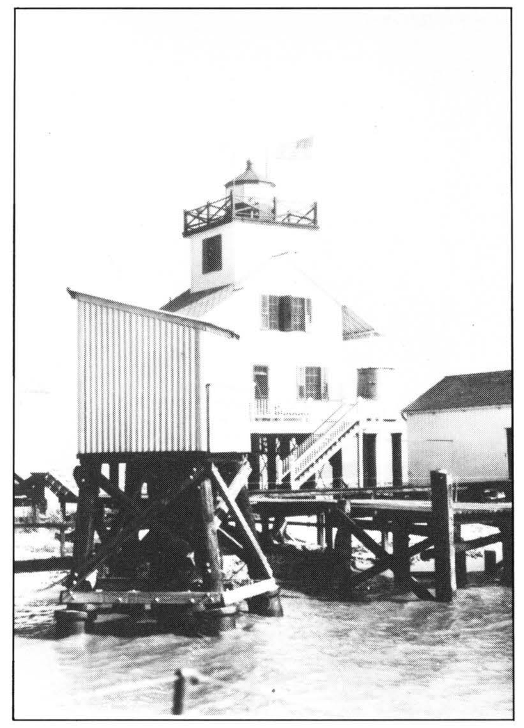
Chandeleur lighthouse and the outbuildings that survived the 1893 storm, 1893: (National Archives, Negative No. 26-LG-35-47G).



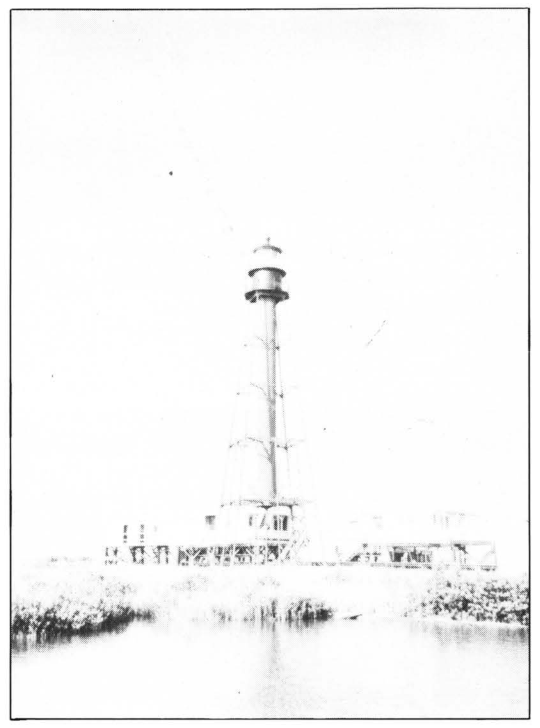
Point-Au-Fer lighthouse, ca. 1945: (National Archives, Negative No. 26-S-686).



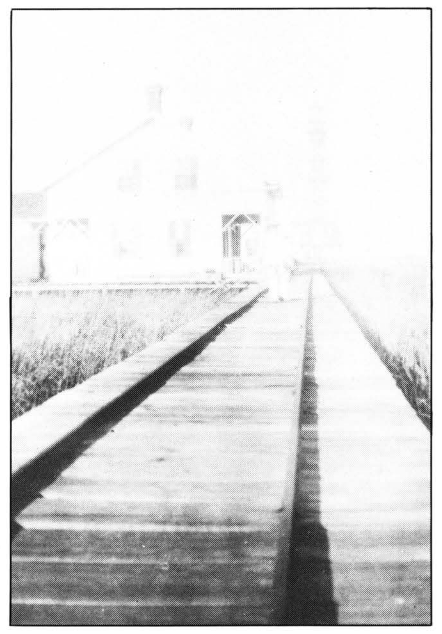
The "leaning" Chandeleur lighthouse after the 1893 storm leveled the island, ca. 1893: (National Archives, Negative No. 26-LG-35-47A).



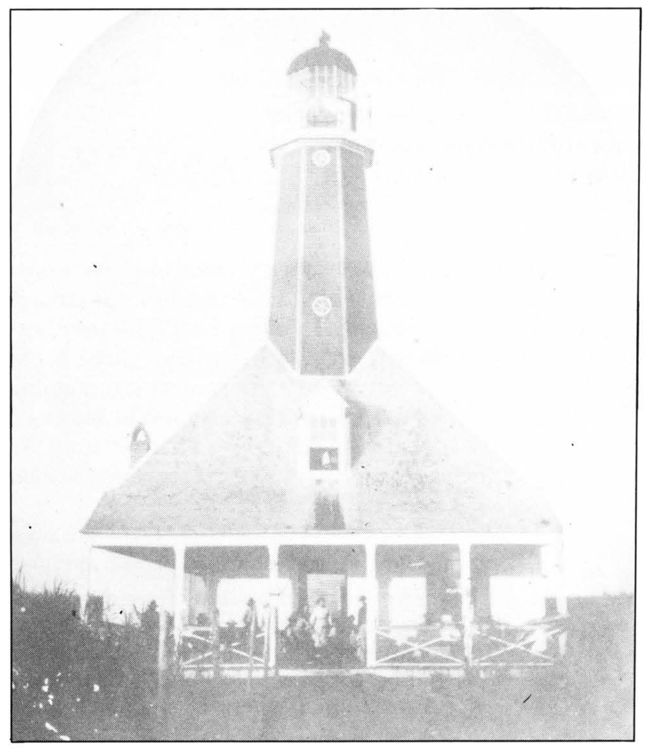
Oyster Bayou lighthouse, ca. 1945: (National Archives, Negative No. 26-S-756).



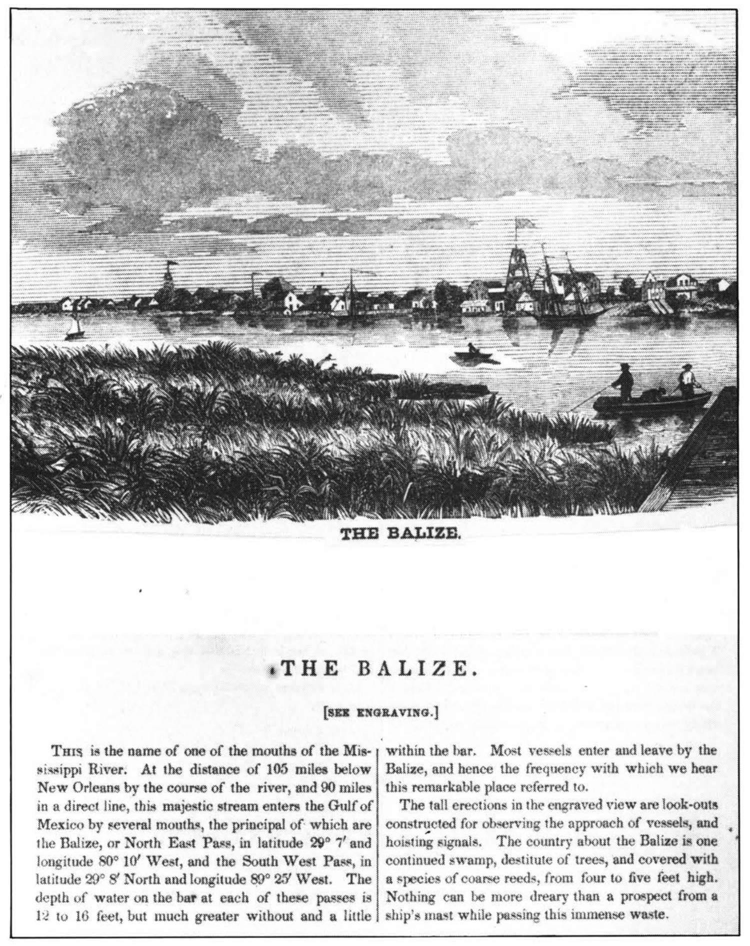
After the 1893 hurricane, the Chandeleur lighthouse was replaced by a steel tower, ca. 1945: (National Archives, Negative No. 26-S-153).



Travelling the Mississippi River has always required navigational aids. The Southwest Pass lighthouse, connected by a boardwalk, guided ships into the river's navigable channel, October 8, 1915: (National Archives, Negative No. 26-LG-39-32C).



The unique architecture of the wood-framed Southwest Pass lighthouse, ca. 1890: (National Archives, Negative No. 26-LG-39-14).



THE BALIZE.

THE BALIZE.

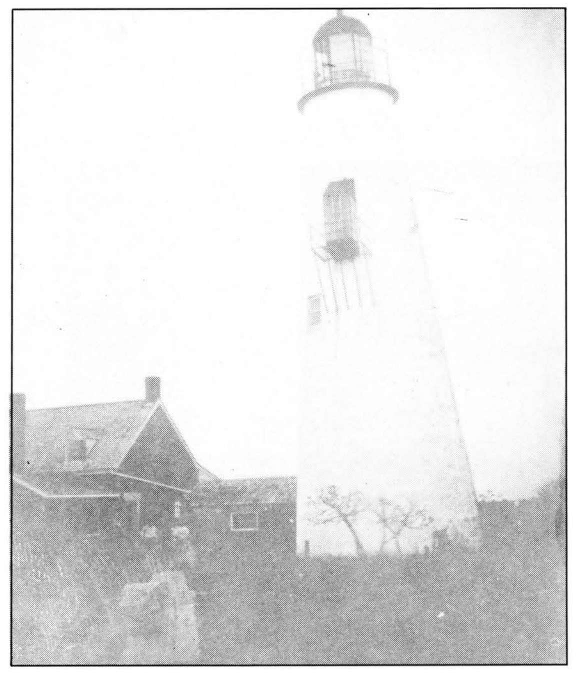
[SEE ENGRAVING.]

THIS is the name of one of the mouths of the Mississippi River. At the distance of 105 miles below New Orleans by the course of the river, and 90 miles in a direct line, this majestic stream enters the Gulf of Mexico by several mouths, the principal of which are the Balize, or North East Pass, in latitude 29° 7′ and longitude 80° 10′ West, and the South West Pass, in latitude 29° 8′ North and longitude 89° 25′ West. The depth of water on the bar at each of these passes is 12 to 16 feet, but much greater without and a little within the bar. Most vessels enter and leave by the Balize, and hence the frequency with which we hear this remarkable place referred to.

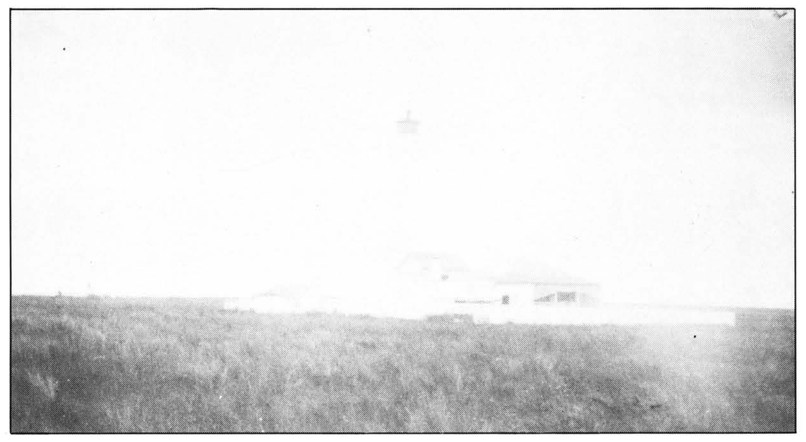
The tall erections in the engraved view are look-outs constructed for observing the approach of vessels, and hoisting signals. The country about the Balize is one continued swamp, destitute of trees, and covered with a species of coarse reeds, from four to five feet high. Nothing can be more dreary than a prospect from a ship's mast while passing this immense waste.

In order to safely navigate the Mississippi River, a lighthouse was built near the mouth of the river's northeast pass, at the community of Balize (from the French word *balise*, meaning beacon), no date: (Louisiana State Library, Louisiana Collection, Photographic Archives).

The Mississippi River's Pass-a-Loutre lighthouse before the 1893 storm, 1893: (National Archives, Negative No. 26-LG-37-17C).



The substantial lighthouse that served traffic navigating Southwest Pass, 1890: (National Archives, Negative No. 26-LG-39-34).



Barataria Bay lighthouse on the western end of Grand Terre, before the October 1893 hurricane, 1893: (National Archives, Negative No. 26-LG-34-10B).

THE COMMUNITY OF BALIZE

To safely navigate the Mississippi River, a lighthouse and community, Balize (from the French word *balise,* meaning beacon), were established near the mouth of the river's northeast pass. When the French first occupied Balize in 1722, it was a little flat island the locals called *Toulouse* (Roland, 1740); boats used a five-meter channel there to gain access to the Mississippi River.

In 1803, Balize was composed of "a small block-house and some huts of the pilots, who reside only here" (American State Papers, 1803, p. 347). The structures were erected on piles; the community was so narrow there was no room to cultivate a garden. Goods had to be imported at three to four times their normal retail cost.

By 1815 traffic on the Mississippi had become so great, a lighthouse was needed at the access point to the river (Louisiana Gazette, 1815). Twenty-thousand dollars was appropriated in 1812, but with the end of the War of 1812, it was deemed an unnecessary expenditure. Local interests still favored its construction, however. New Orleans "in strict truth, is the emporium of Western America; and the [Mississippi] ... is not a mere local avenue of trade and navigation" (Magruder, 1815, p. 2). The city's Gulf of Mexico trade depended on safe passage into the Mississippi River. This argument prevailed, but justifying the Federal expenditure was a difficult task. The lighthouse was built eventually at Southwest Pass.

In 1851, the community was large enough to put on a ball for a number of ladies from New Orleans and all of the "belles of the Pass and Balize" (Daily Delta [New Orleans], 1851, p. 2). One account notes

> the village ... had three large grocery stores and a dry goods store, a large church where services were held every Sunday and a good-sized town hall ...
>
> There were houses on both sides of the bayou, some of them two stories in height, and the town was full of children. We had two schools for them. There were fine shell roads around the Balize and levees to protect it from the Mississippi River ...
>
> It was a large settlement and there were possibly a thousand people there when it was abandoned. Fifty ... bar pilots made their headquarters in the village, and nearly everybody trapped, fished or had oyster beds. (New Orleans Times-Picayune, 1921, p. 12)

This community, like all of those along the coast, had to endure the hardships of hurricanes. In 1741 the French government was informed

> that the battery at the Balize was so much damaged that, if attacked, it could be carried by four gunboats. There was such a scarcity of everything that a cask of common wine was sold for five hundred livres of Spanish money, and eight hundred livres in the currency of the colony, and the rest in proportion. As to flour, it could be commanded by no price, as there was not to be had. (The Daily Picayune-New Orleans, 1863, p. 3)

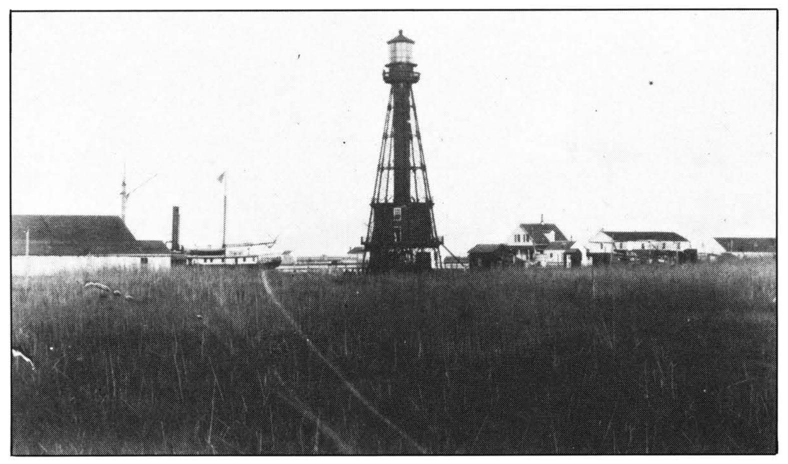
In addition, there were

> many families reduced to such a state of destitution that fathers, when they rise in the morning, do not know where they will get the food required by their children. (The Daily Picayune-New Orleans, 1863, p. 3)

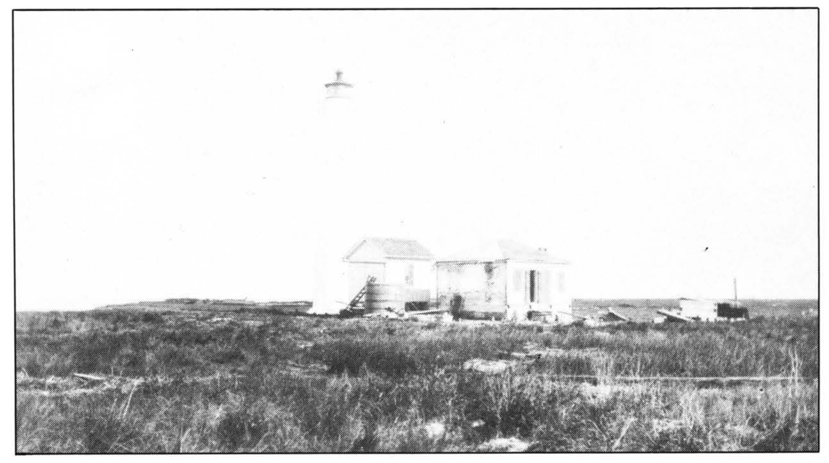
In 1831, a storm destroyed the "pretty little village" (Daily Delta [New Orleans], 1846, p. 2). Logs as long as 15 meters battered the community's homes, wharves, and fences. The storm surge was knee-deep in many homes. Gardens were covered with salt water and destroyed (Daily Delta [New Orleans], 1846).

In the hurricane of 1860, the water rose nearly two meters and washed away nine homes, three look-out houses and assorted boats and sheds. The telegraph house survived, but a number of flatboats used as homes were destroyed. Several "large house, more than half finished" floated away, and two buildings "belonging to and occupied by fishermen were destroyed" (New Orleans Daily Crescent, 1860, p. 1).

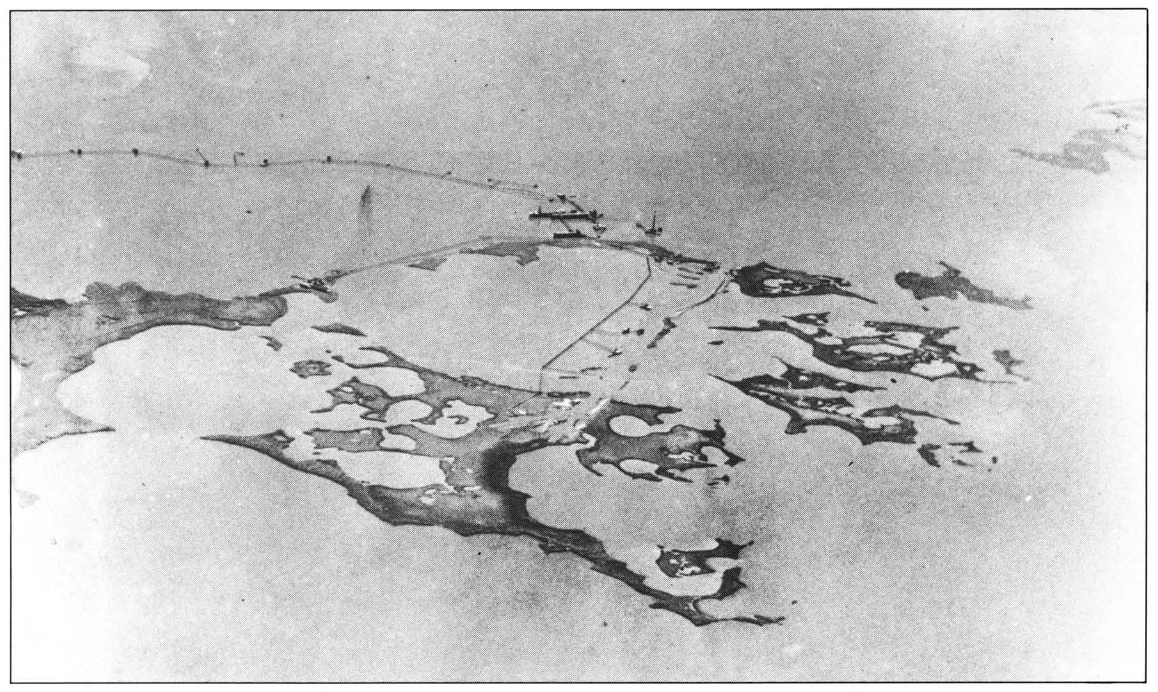
Balize was utilized for 150 years; during that time, the Spanish spent over 20,000 pounds sterling to fortify the position (New Orleans Times-Picayune, 1921). About 1865, a crevasse diverted the flow of the Mississippi River away from Balize (New Orleans Times-Picayune, 1921). Bar pilots were forced to move to Pilottown Bayou because Southwest Pass was used to gain access to the Mississippi. In a short time Balize was completely deserted. Eventually, the land subsided, so that the town hall, church, shell road, homes, and tombs were below sea level—captured by the Gulf of Mexico.



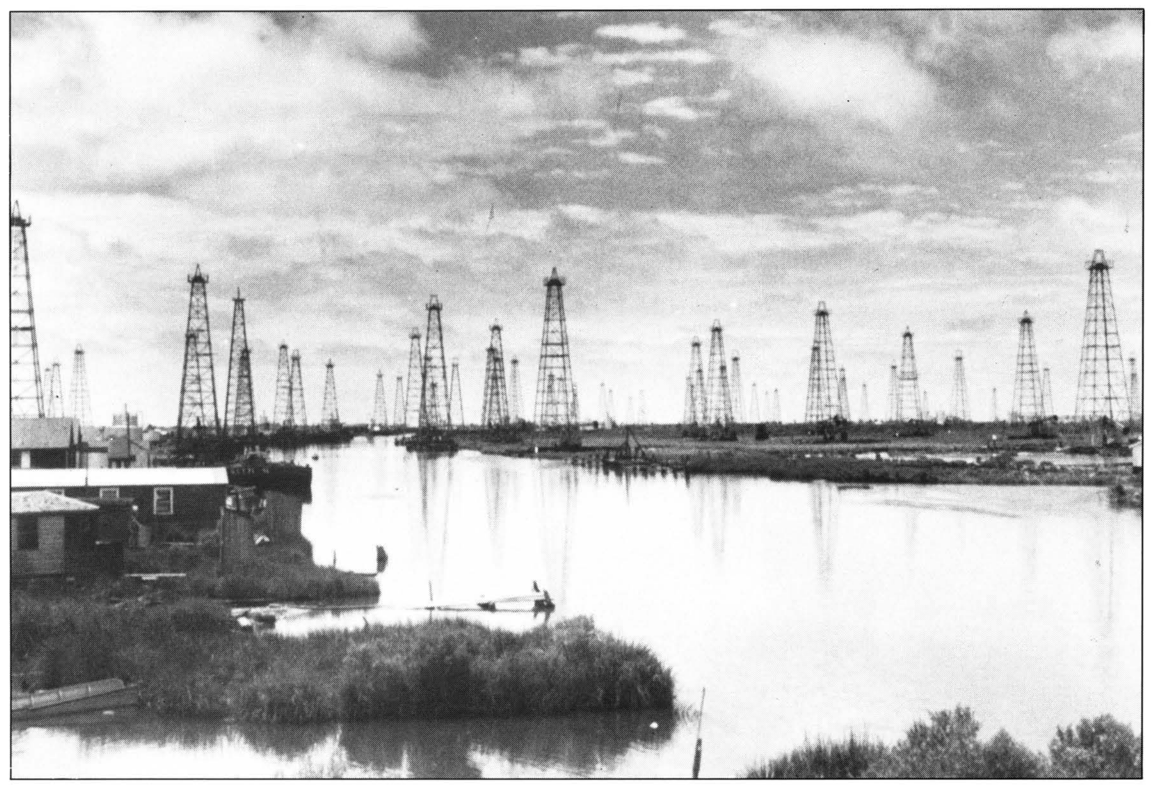
The community associated with the South Pass lighthouse, with ships anchored in the channel, ca. 1893: (National Archives, Negative No. 26-LG-39-28A).



Barataria Bay lighthouse after the 1893 storm. The picket fence and big house were destroyed. The light sustained only minor damage, December 18, 1893: (National Archives, Negative No. 26-LG-34-10A).

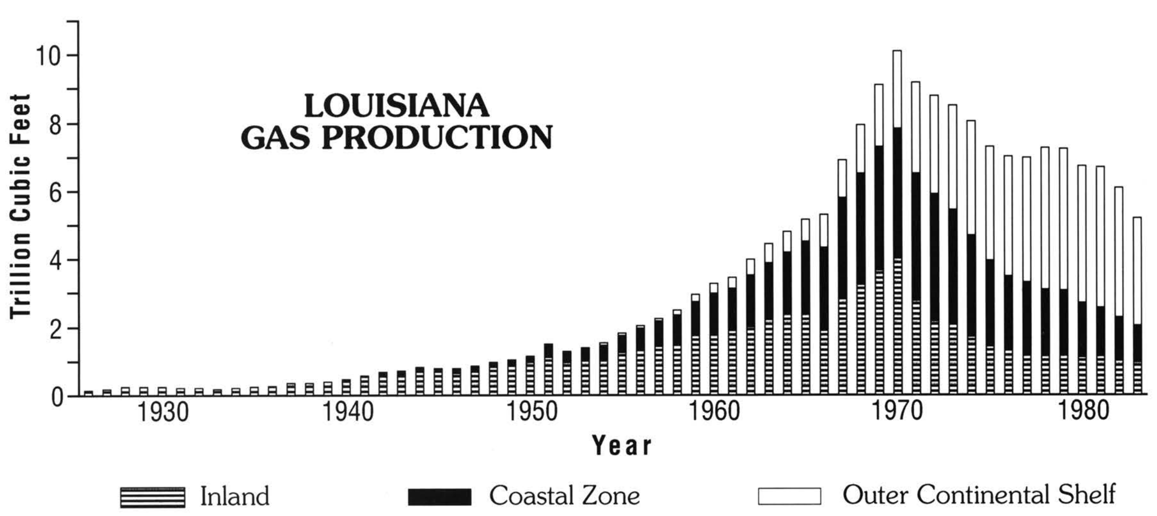


Drilling in coastal Louisiana has had a significant impact on the wetlands, no date: (Bernard Davis Collection, Houma, Louisiana).

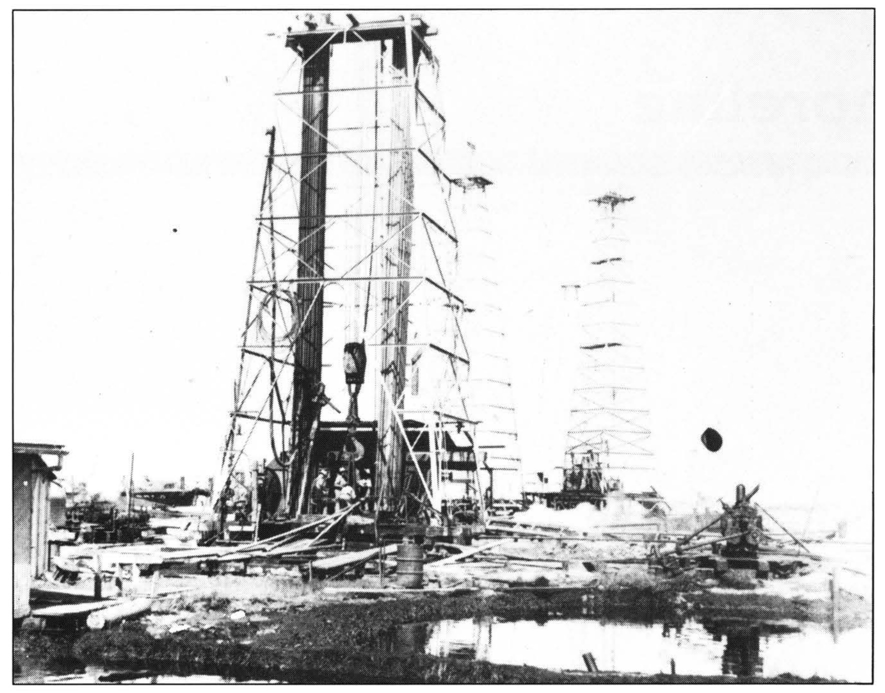


At Leeville, along Bayou Lafourche, the marsh was blanketed with oil wells, ca. 1938: (Fonville Winans, Louisiana State Library, Louisiana Photographic Archives).

Seismic crews used marsh buggies to run their profiles, ca. 1950: (Louisiana Department of Wild Life and Fisheries, Photographic Archives).



From Lindstedt, D.M. and others, 1991, History of oil and gas development in coastal Louisiana: Resource Information Series No. 7, Baton Rouge, Louisiana, Louisiana Geological Survey.



Petroleum exploration was relatively easy in the peats and mucks of the coastal marshes, 1935: (Randolph Bazet Collection, Houma, Louisiana).

THE WETLANDS' MINERAL FLUIDS

Since World War II, Louisiana's coastal lowlands have seen rapid economic growth, much of which can be attributed directly to development of its hydrocarbon resources. In the 1600's, sailors exploring the Texas and Louisiana coasts reported oil floating on the Gulf's surface. This seepage was an early clue to the enormous reserves locked in a geosyncline, or fold in the bedrock below the land and sea surfaces from Mississippi to Texas.

Commercial oil production began in Titusville, Pennsylvania, in 1856; 50 years later, wildcatters were drilling in South Louisiana. In 1901, W. Scott Heywood completed south Louisiana's first producing oil well in Jennings. Even with this discovery, oilmen ignored the wetlands for over 20 years; they favored north Louisiana's more easily exploited fields.

Between 1901 and 1923, only eight fields were discovered in south Louisiana because accessibility was a problem. Wetland exploration and development required a fleet of amphibious vessels. Everything had to float or fly, so conventional methods were impractical.

As geophysics and its new technologies emerged, promising fields were investigated. Also, required floating equipment was refined and further developed. In the 1930's, petroleum engineers moved aggressively into Louisiana's swamps and marshes. Systematic exploration required a well-developed infrastructure of support facilities on high ground. These logistic support sites were essential in providing the supplies drilling crews required, and evolved with the industry, gradually changing the area's demographic character.

To gain access to promising exploration sites, powerful suction and bucket dredges excavated navigable channels into well locations. The one-well, one-canal system evolved into an interlocking network of human-made channels, and often over 30,000 m^3 of material were removed per kilometer to open the wetlands to hydrocarbon exploration.

In less than a century, the complex canal system has become a dominant part of the State's coastal geography and has expanded into well-defined, but unplanned, patterns. The canal system met the industry's needs and evolved into the most visible structural modification of the coastal zone. As oil exploration and development moved across the coastal lowlands, virtually no section of the coast was spared canalization.

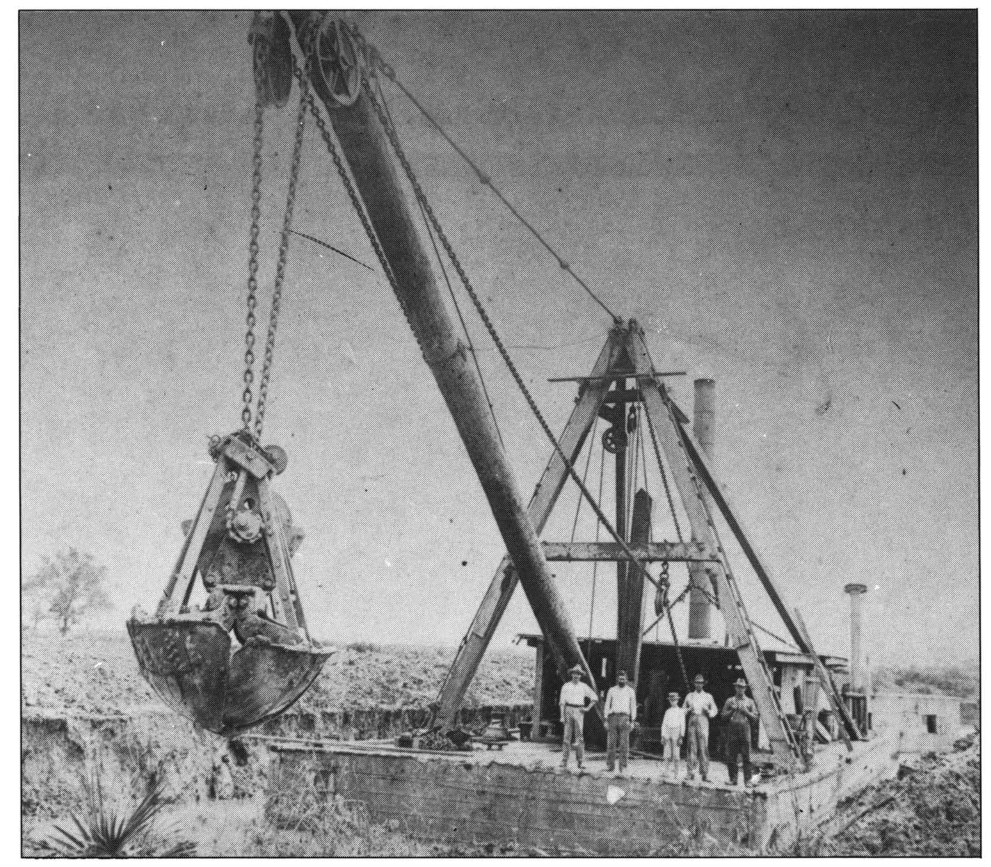
Gaining access to well sites was a relatively simple matter because the wetlands' waterlogged soils were easy to channelize. Dredging contractors encountered few problems. Drilling engineers, however, were frustrated by the hydric soil's low weight-bearing capabilities and were forced to rethink their drilling methods because the marsh lands would only support 1,200 kg/m^2. Wooden mats did work in some shallow water areas, but they were cumbersome. Pilings were used in open water, but drilling preparation was a labor- and time-intensive operation. Conventional equipment was too heavy to work in this environment. The industry needed a floating drilling platform.

In 1932, the Texas Company developed a patented submersible drilling barge. Equipped with a derrick, this vessel could drill easily on the extensive leases petroleum firms obtained in south Louisiana. Within 10 years, over 70 oil and gas fields were developed in Louisiana's delta country.

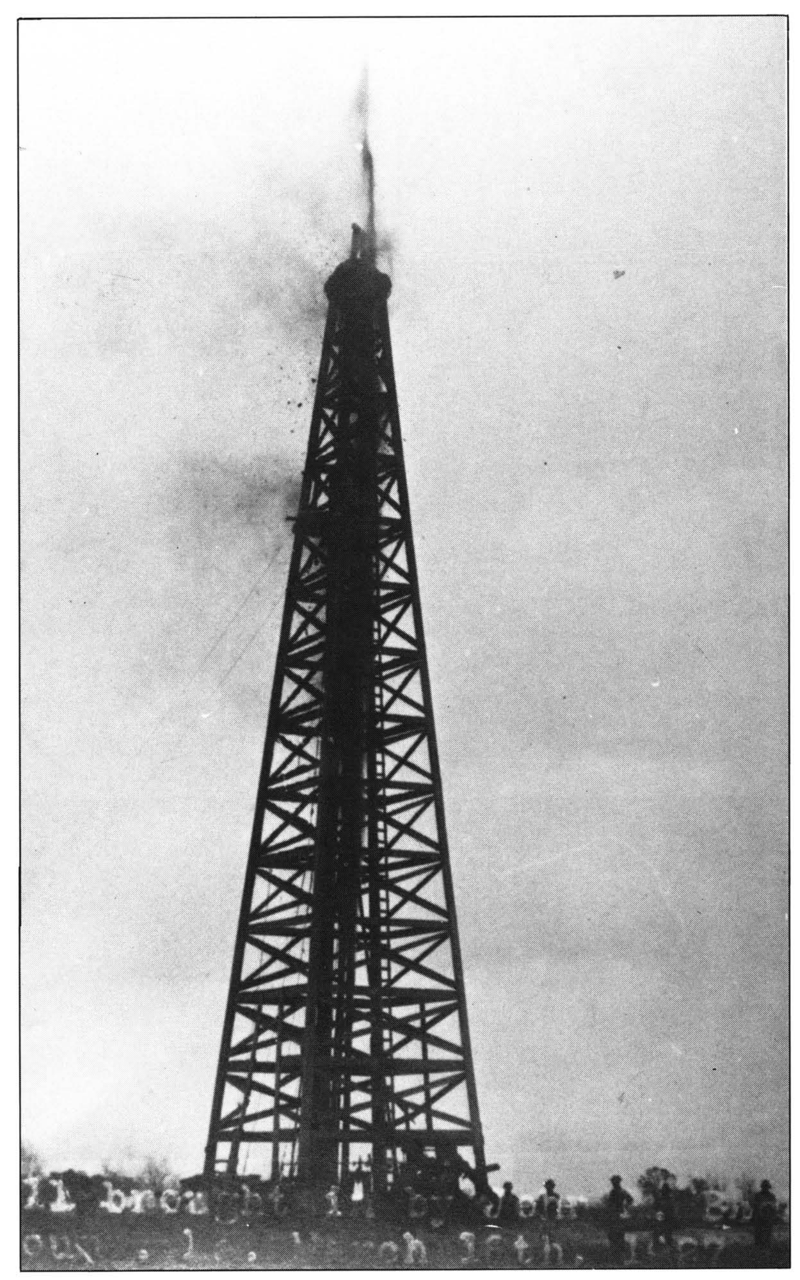
With the advent of World War II, the industry was well established; new fields were added constantly to the regional inventory. Wildcatters intensified their efforts in the tidal flatlands and backwater swamps. New wetland technology spurred some of this development, but the word was getting out about the impressive exploration results in south Louisiana. Nearly one out of every three wells drilled produced marketable hydrocarbons. Early pessimism turned to unbridled optimism.

By the mid-1940's it was apparent that operations on a "sea of mud" were no different from those on a sea of water. From a rather quiet beginning in 1947, when the first oil well out of sight of land was completed, the search for offshore hydrocarbons grew rapidly. Expectations were exceeded, particularly in the 1950's when the marine technological revolution began. Boat builders used diesel rather than gasoline; steel hulls rather than wooden-hulled boats were added to the support fleet. Shipyards fabricated vessels that operated in the Gulf of Mexico's hostile waters.

Onshore and offshore, the industry expanded rapidly. Early wildcatters and major firms who discovered the mineral fluids trapped below Louisiana's alluvial wetlands were right; the region was a significant hydrocarbon province. Over 25,000 wells onshore and at least 3,000 drilling and production platforms offshore made Louisiana's coastal lowlands one of the country's dominant forces within the oil and natural gas industry.



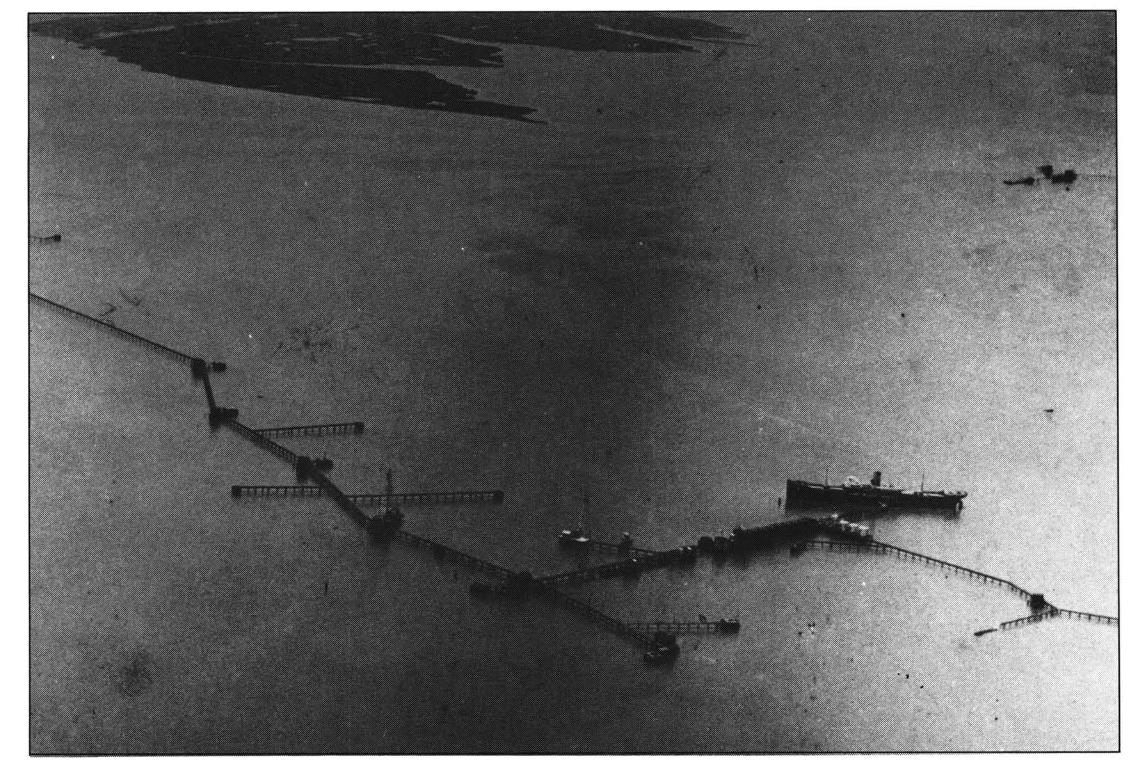
Canals were excavated for easy access to well sites. The marsh offered no resistance, so the process was relatively easy. At the turn of the century, the *Zoe B* was at work clearing navigable channels, ca. 1920: (Randolph Bazet Collection, Houma, Louisiana).



First oil well in Houma, Louisiana, March 18, 1927: (Bernard Davis Collection, Houma, Louisiana).

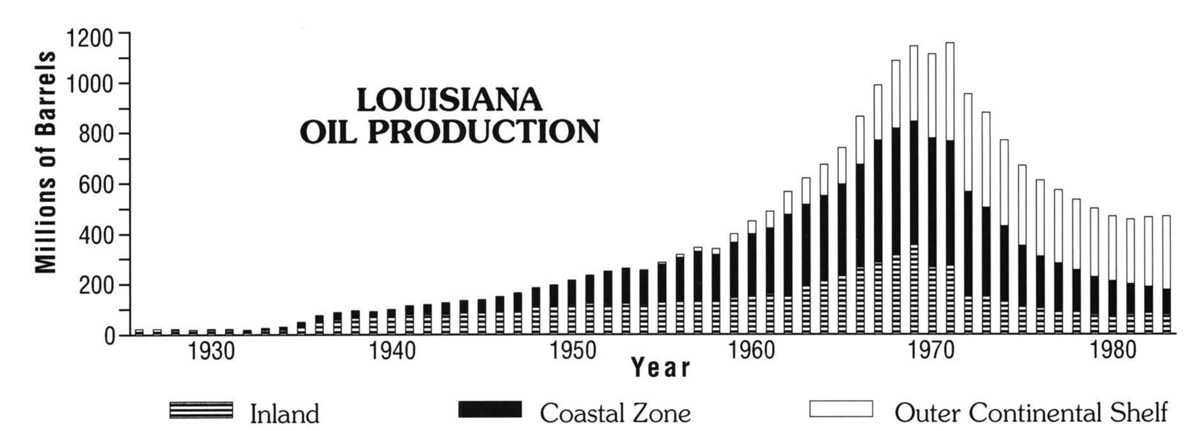
Recommended citation for this chapter:
Davis, D. W., 1992, A historical and pictorial review of Louisiana's barrier islands, *in* Williams, S. J., Penland, Shea, and Sallenger, A. H., Jr., eds., Louisiana barrier island erosion study—atlas of barrier shoreline changes in Louisiana from 1853 to 1989: U.S. Geological Survey Miscellaneous Investigations Series 1-2150-A, p. 8-23.

To maintain production schedules, supplies and work crews were shuttled to isolated camps by flying boats, later replaced by helicopters, 1947: (Bernard Davis Collection, Houma, Louisiana).



After the discovery of easily recoverable and marketable petroleum and natural gas, the marsh became a labyrinth of petroleum-oriented facilities, ca. 1940: (Bernard Davis Collection, Houma, Louisiana).

After purchasing a fleet of airplanes used to carry mail from ships anchored in the delta to New Orleans, Texaco became a pioneer in using aircraft to support their marsh operations, ca. 1930: (Bernard Davis Collection, Houma, Louisiana).



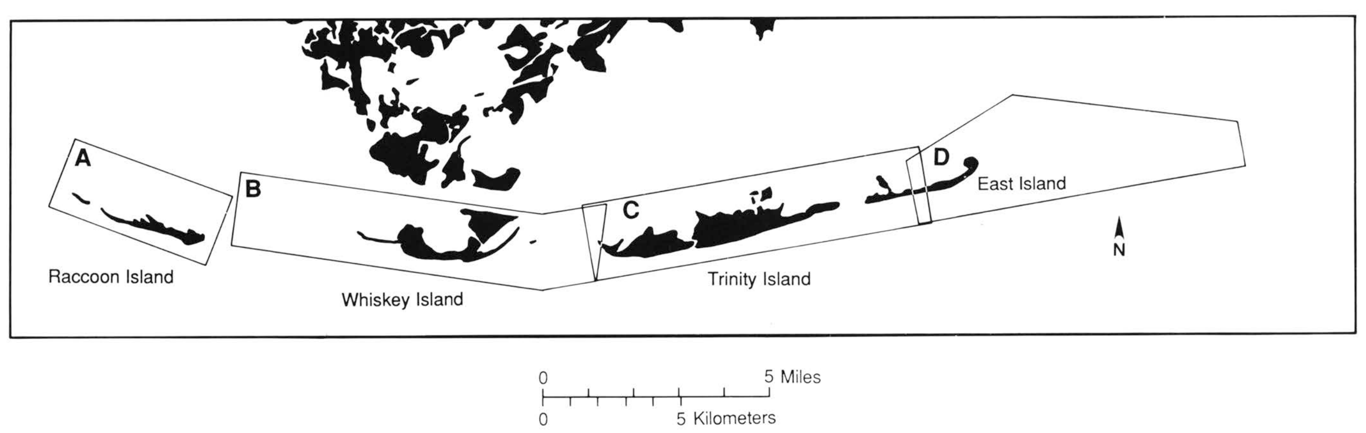
From Lindstedt, D.M. and others, 1991, History of oil and gas development in coastal Louisiana: Resource Information Series No. 7, Baton Rouge, Louisiana, Louisiana Geological Survey.

Chapter 3 Aerial Photographic Mosaics of Louisiana's Barrier Shoreline

by Karen A. Westphal and Shea Penland

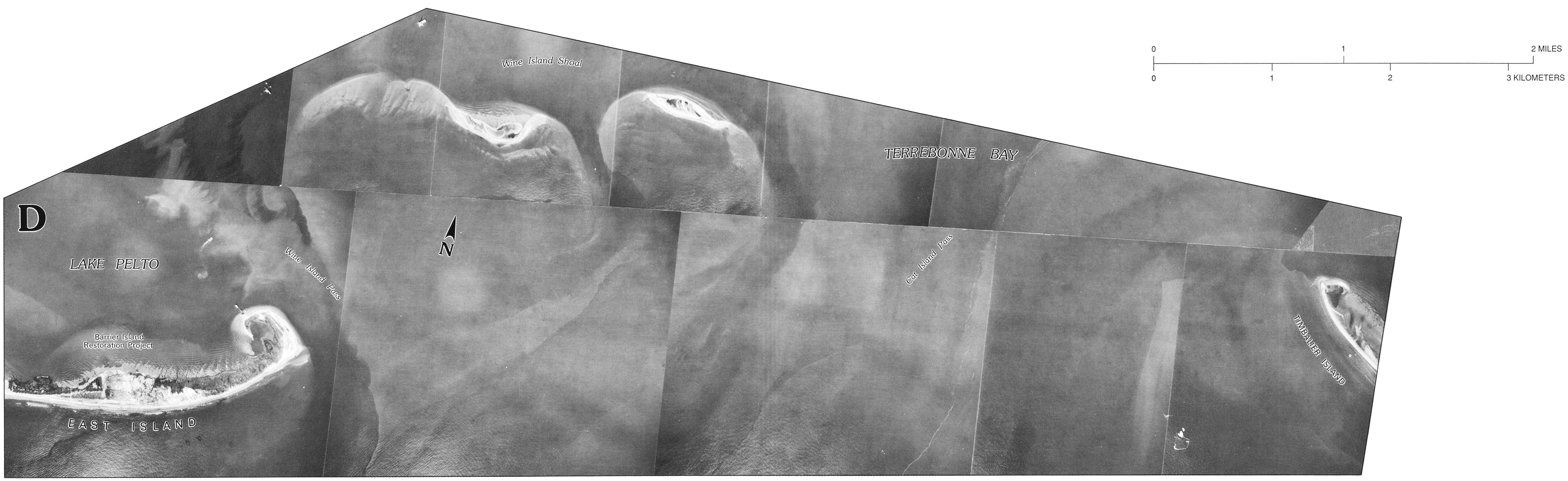
These mosaics introduce the viewer to the geomorphology of Louisiana's barrier shoreline. They are assembled from vertical aerial photography at a scale of 1:15,000 but reproduced here at 1:24,000. The shoreline is divided into four sections and presented sequentially from west to east (Isles Dernieres, Bayou Lafourche, and Plaquemines shorelines) and south to north (Chandeleur Islands shoreline). Some overlap has been provided for continuity of the image. Significant place names for islands, tidal inlets, bays, bayous, towns, and a variety of human-made structures and other human impacts are indicated.

The photographs for the barrier shoreline west of the Mississippi River mouth between Raccoon Point and Sandy Point, except for Grand Isle, were taken on January 21, 1988. Grand Isle was photographed on October 15, 1986. The viewer is encouraged to examine these mosaics carefully to better understand the character of the marshes, dunes, washover, and tidal inlet features, as well as the imprint of human activity on the landscape of Louisiana's barrier shoreline.

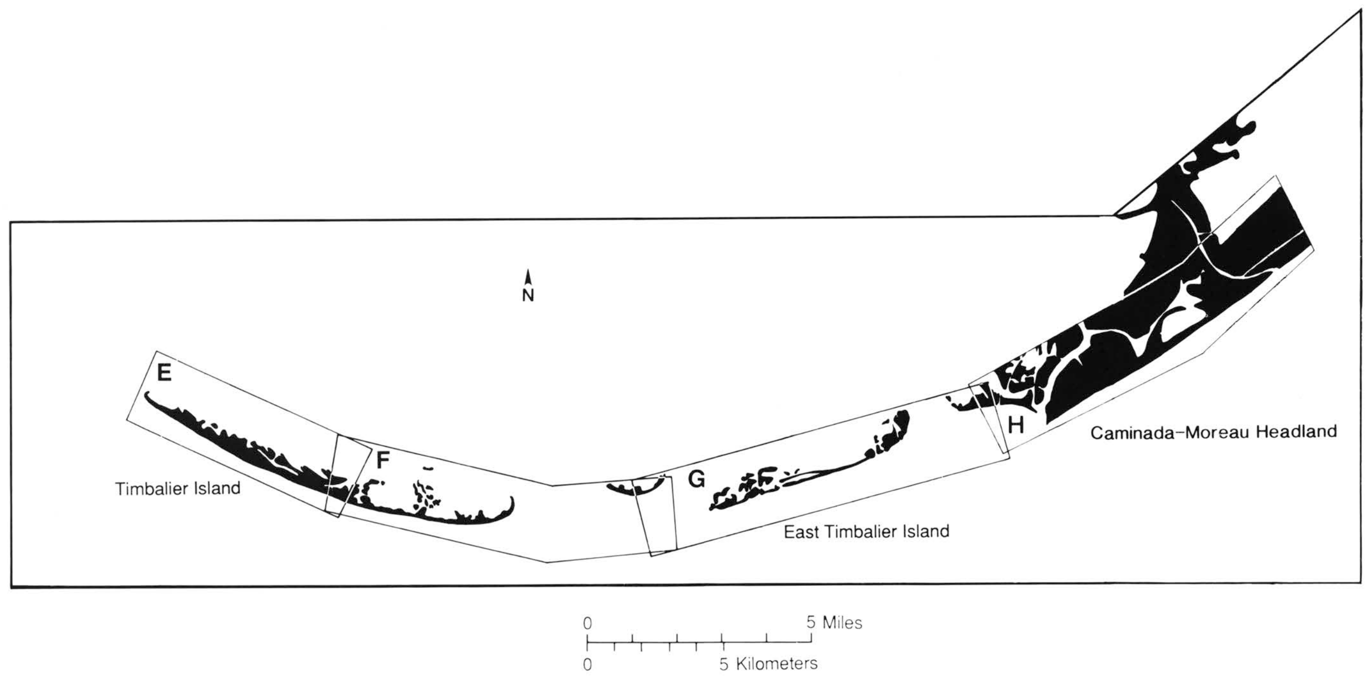


Isles Dernieres Barrier System

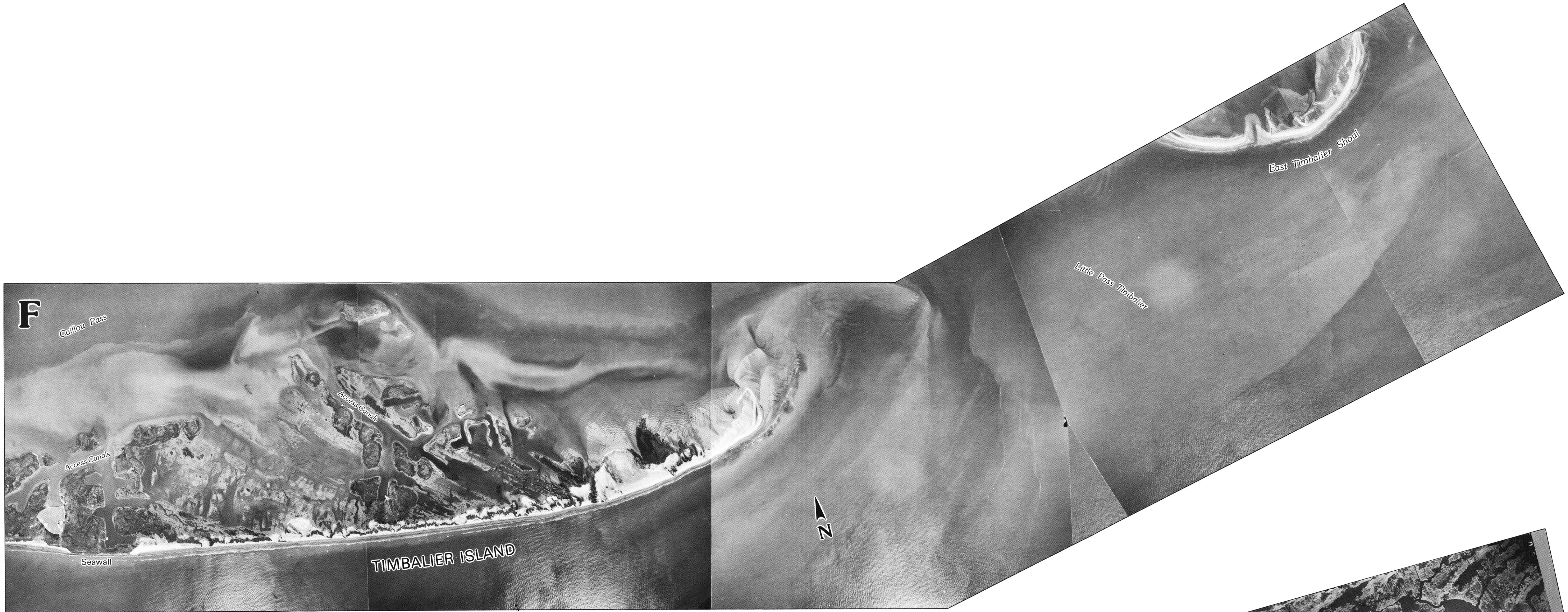
Isles Dernieres Barrier System

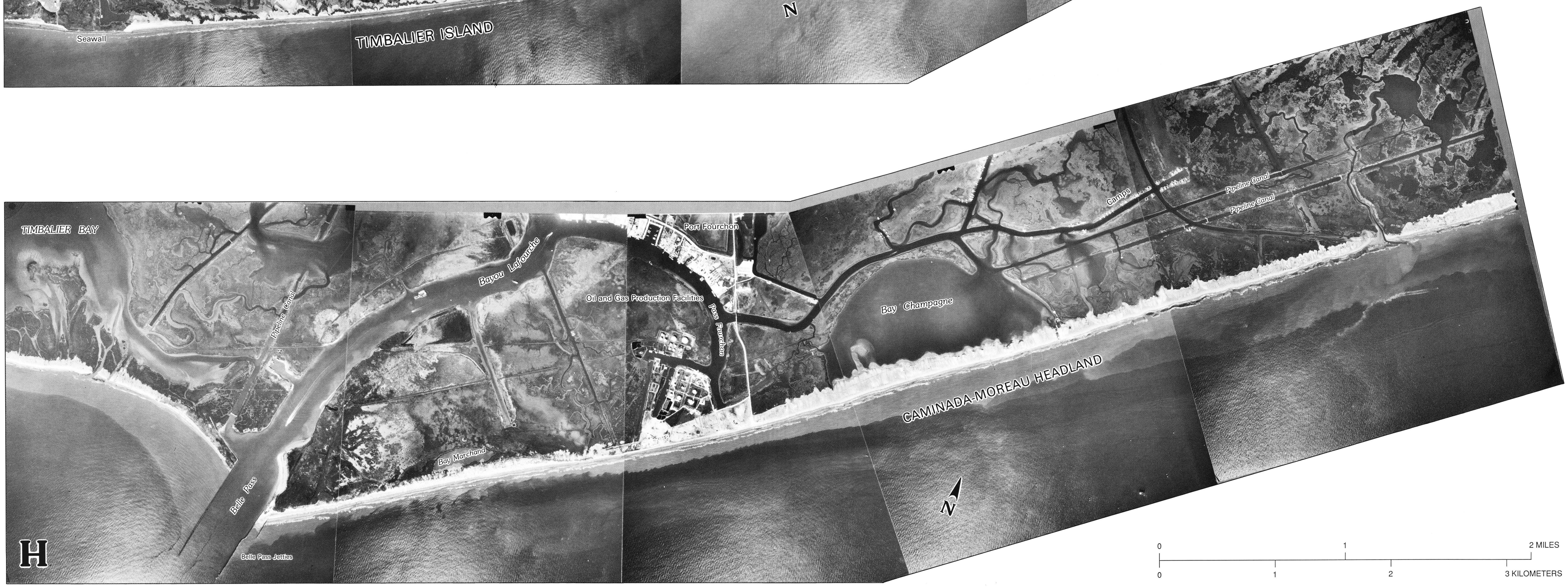


Bayou Lafourche Barrier System

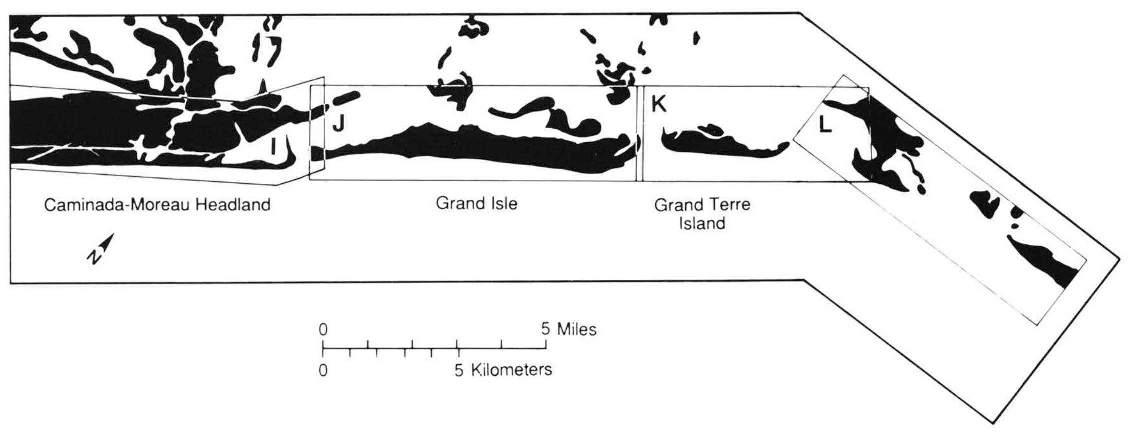


Bayou Lafourche Barrier System



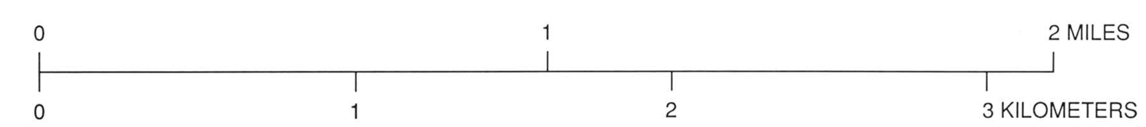


Bayou Lafourche Barrier System

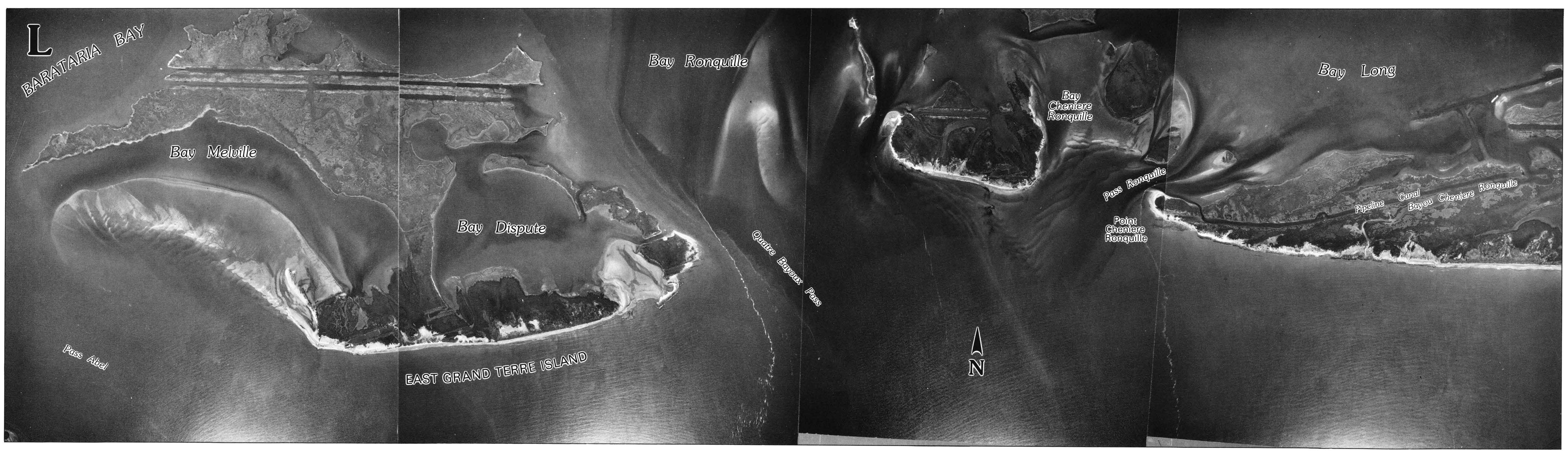


Plaquemines Barrier System

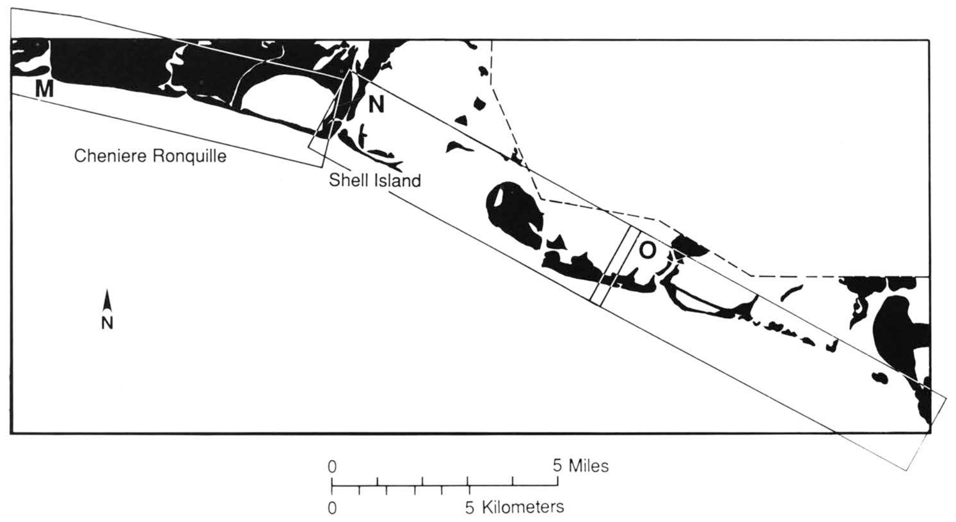
Bayou Lafourche Barrier System

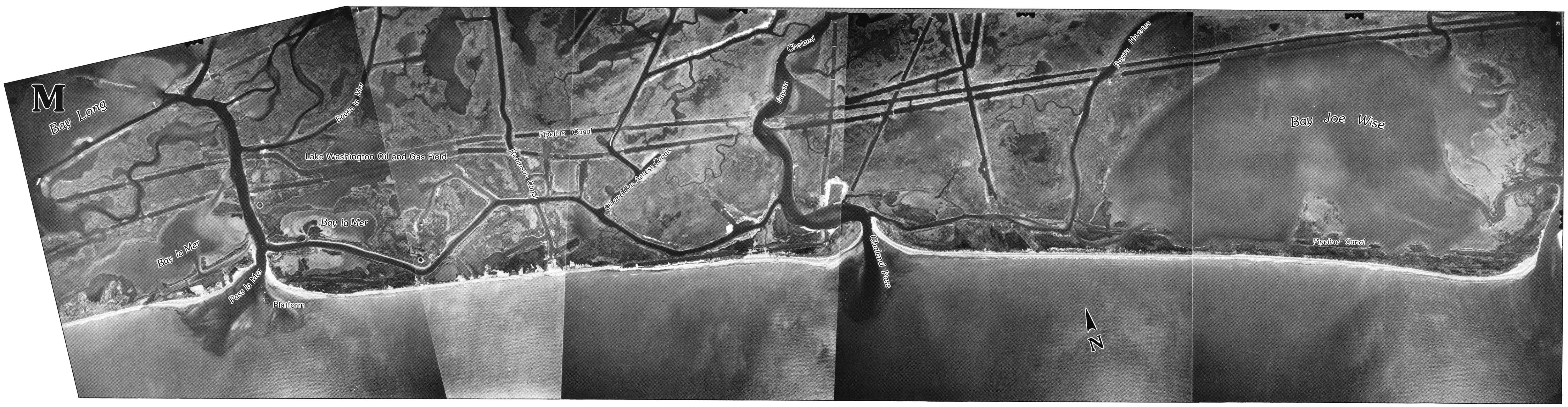


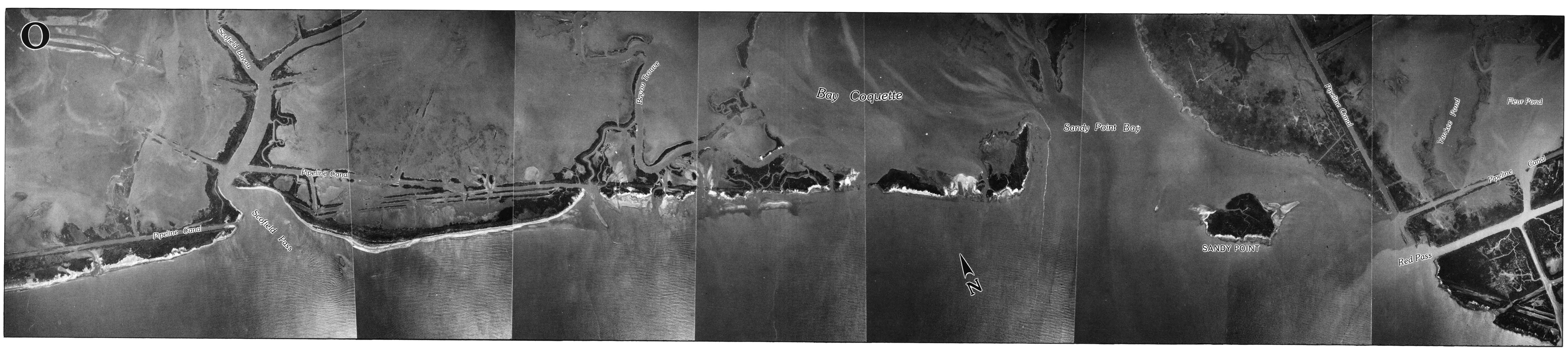
Plaquemines Barrier System



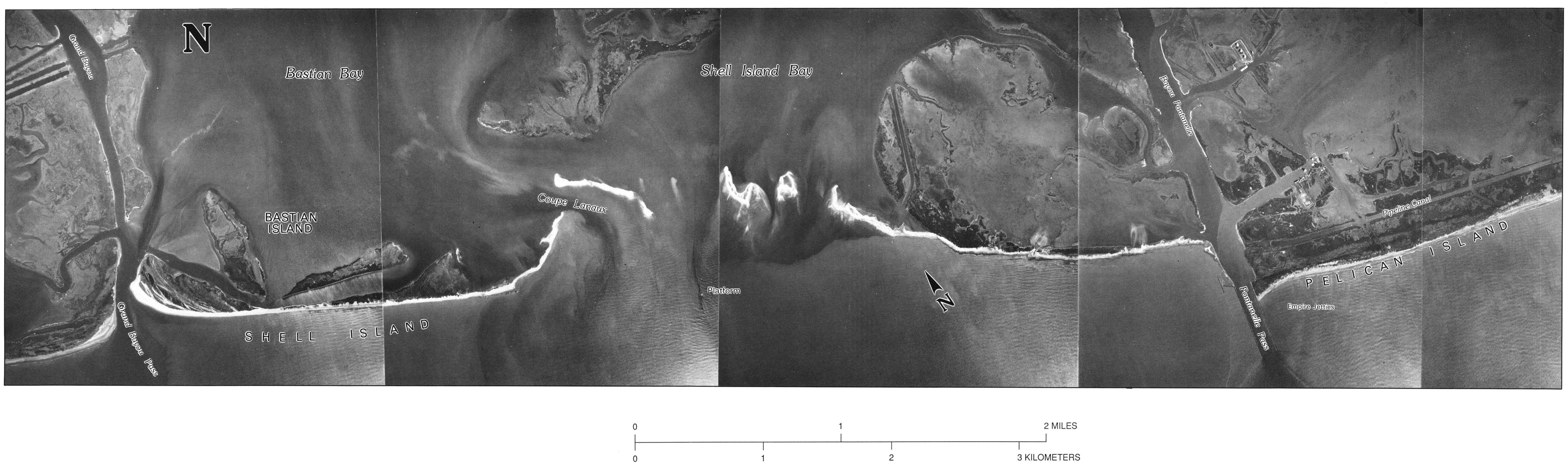
Plaquemines Barrier System



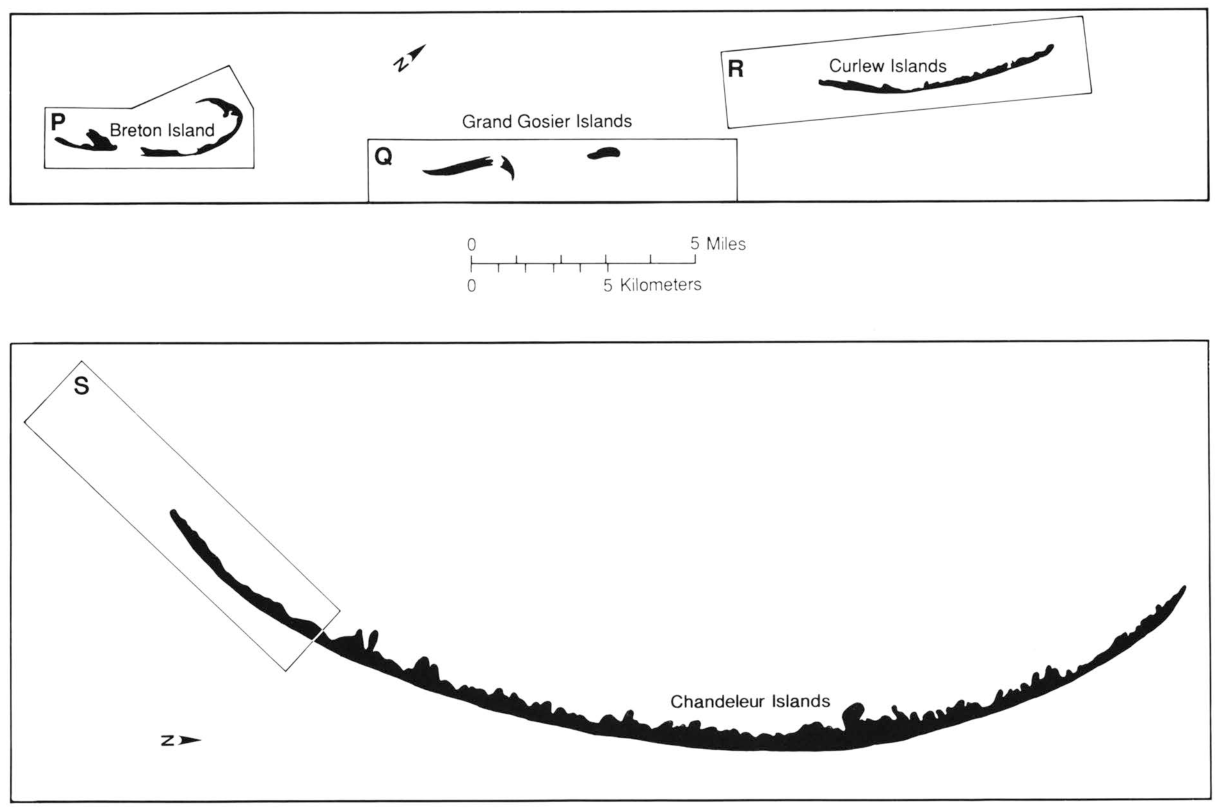


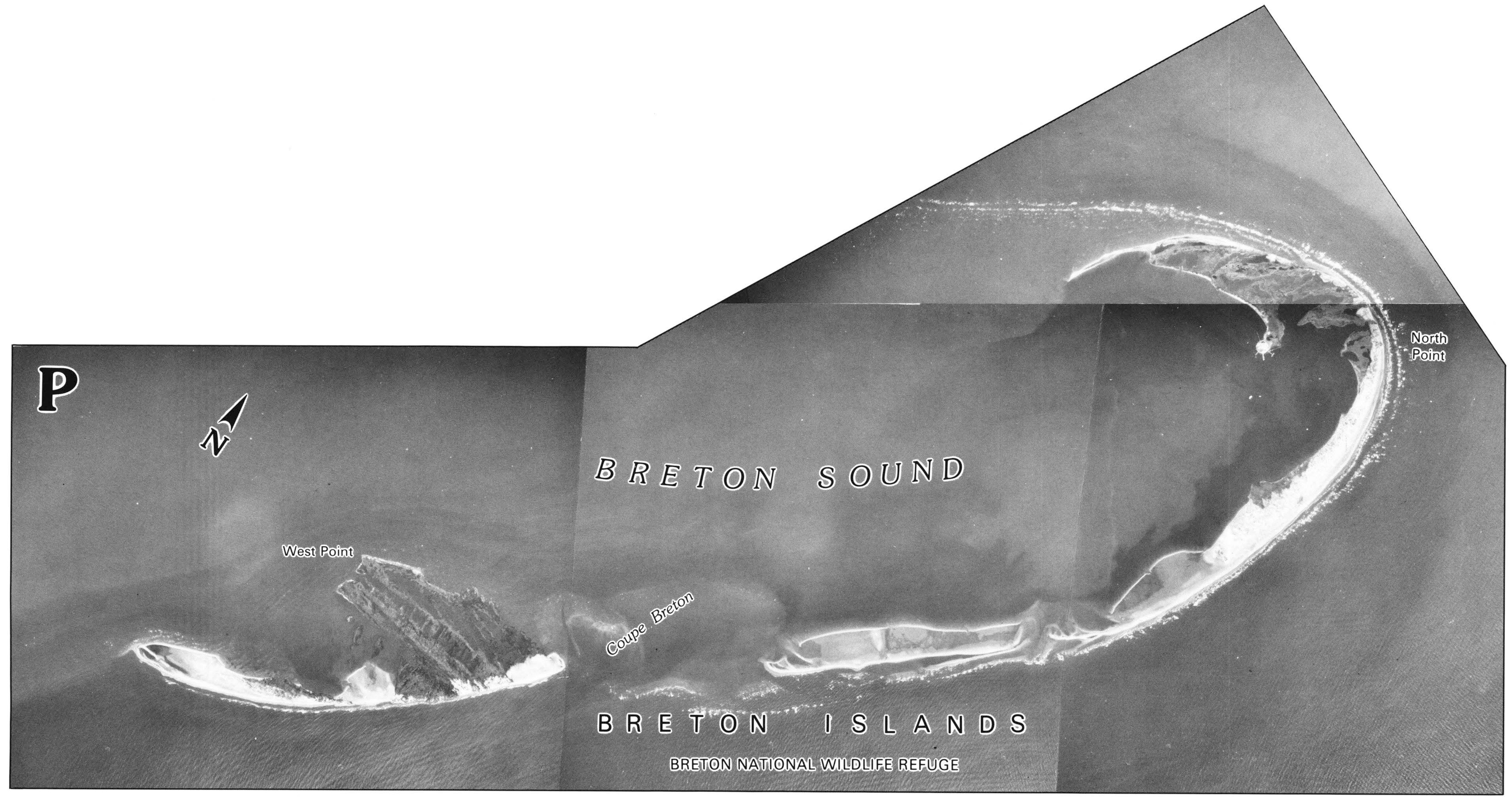


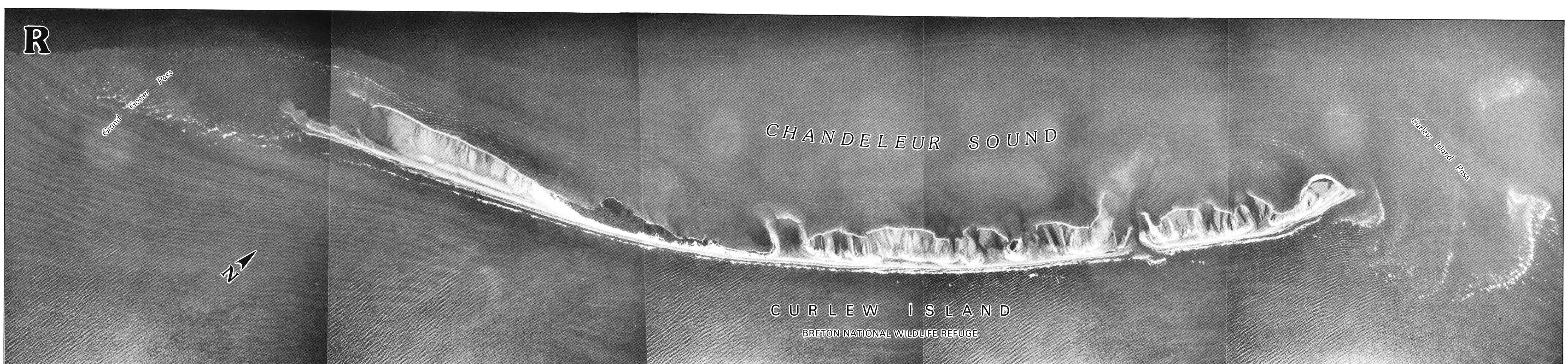
Plaquemines Barrier System



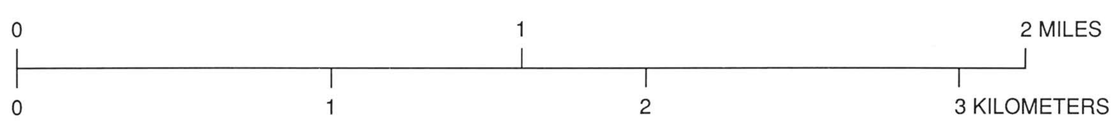
Chandeleur Islands Barrier System

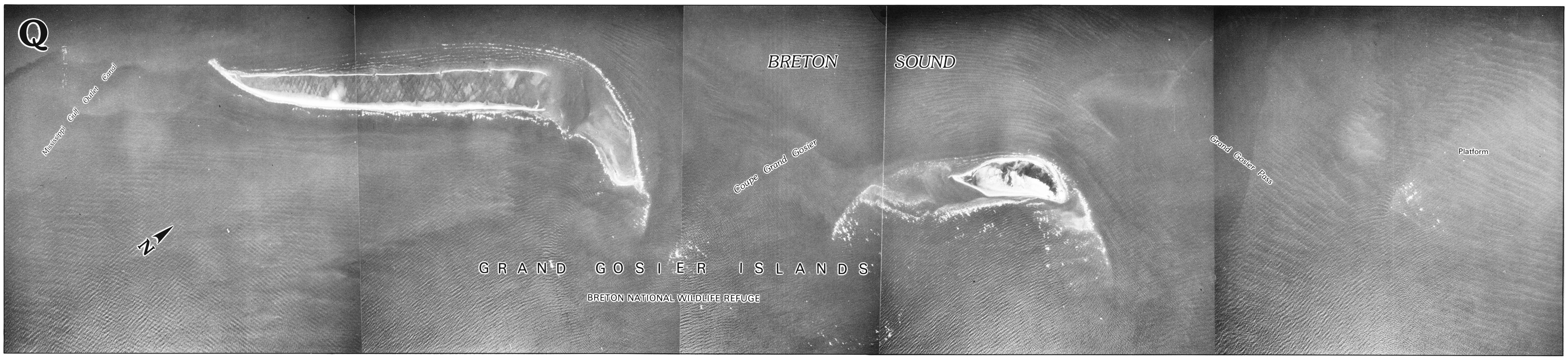


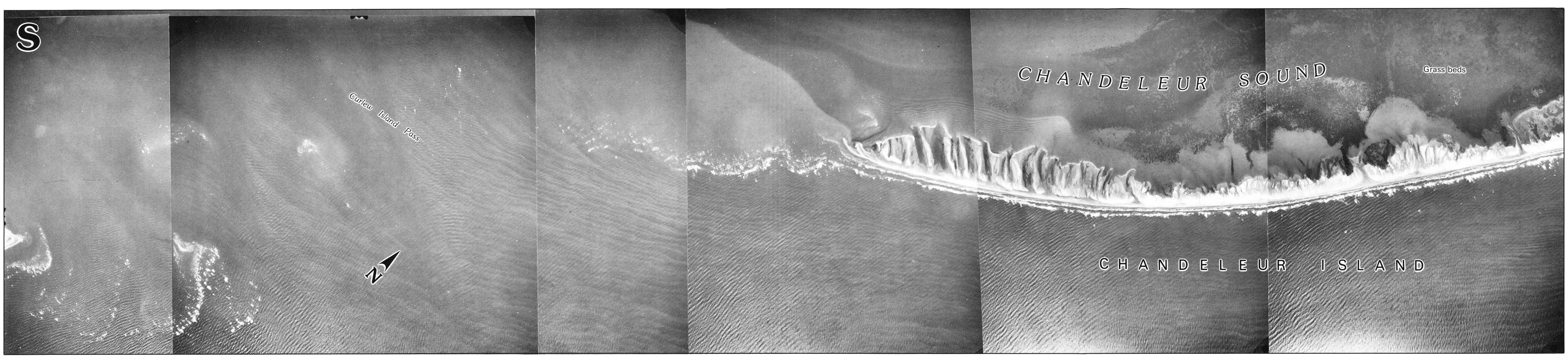




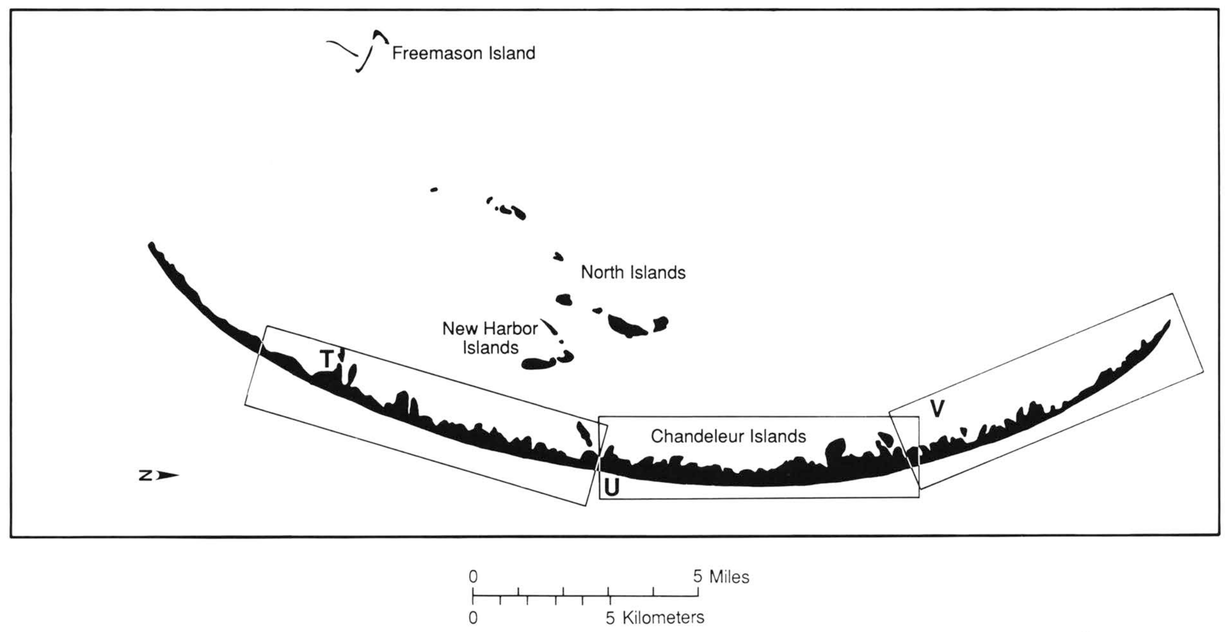
Chandeleur Islands Barrier System

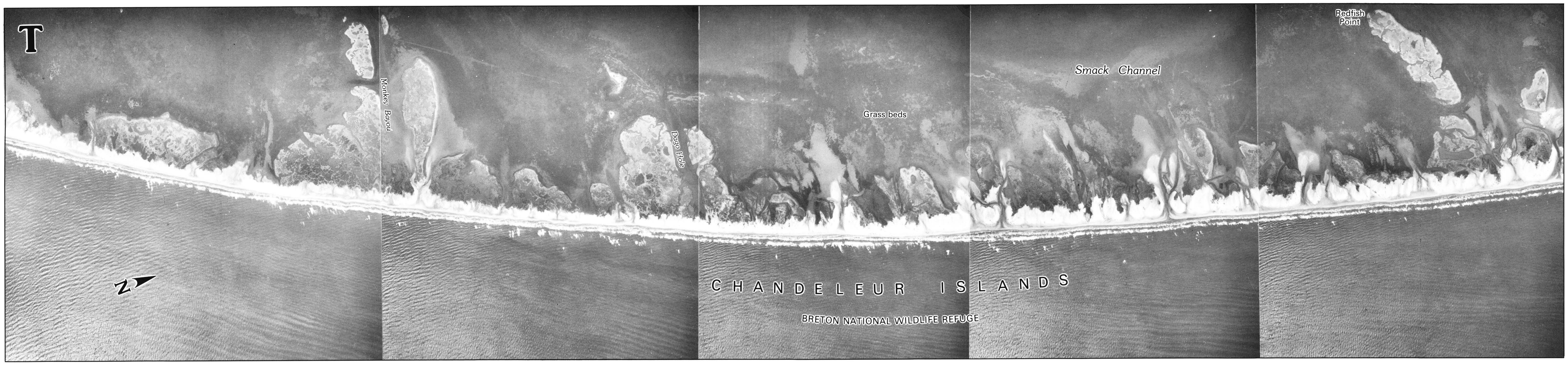


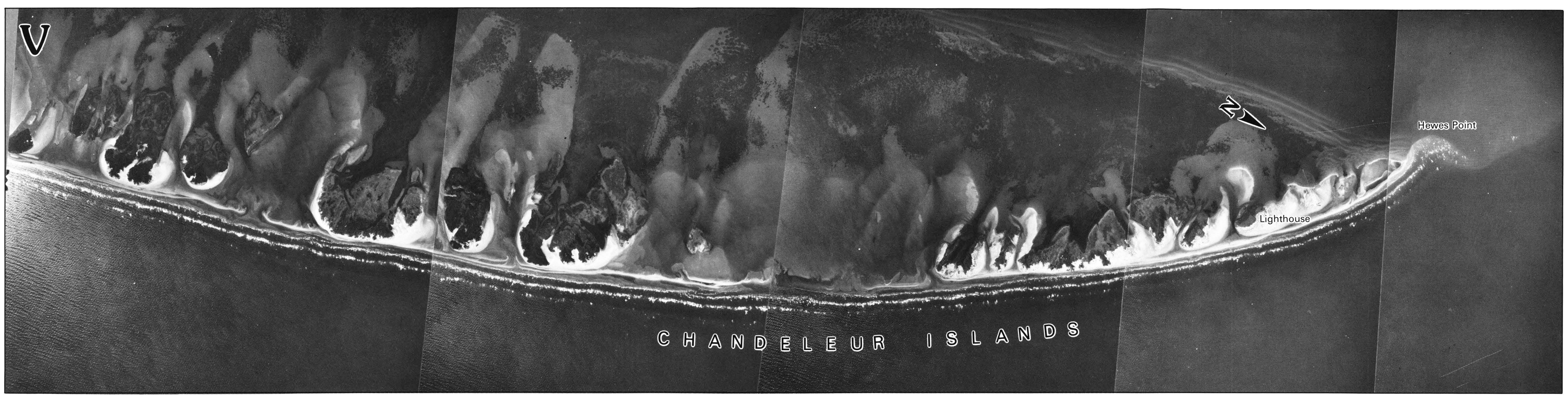




Chandeleur Islands Barrier System







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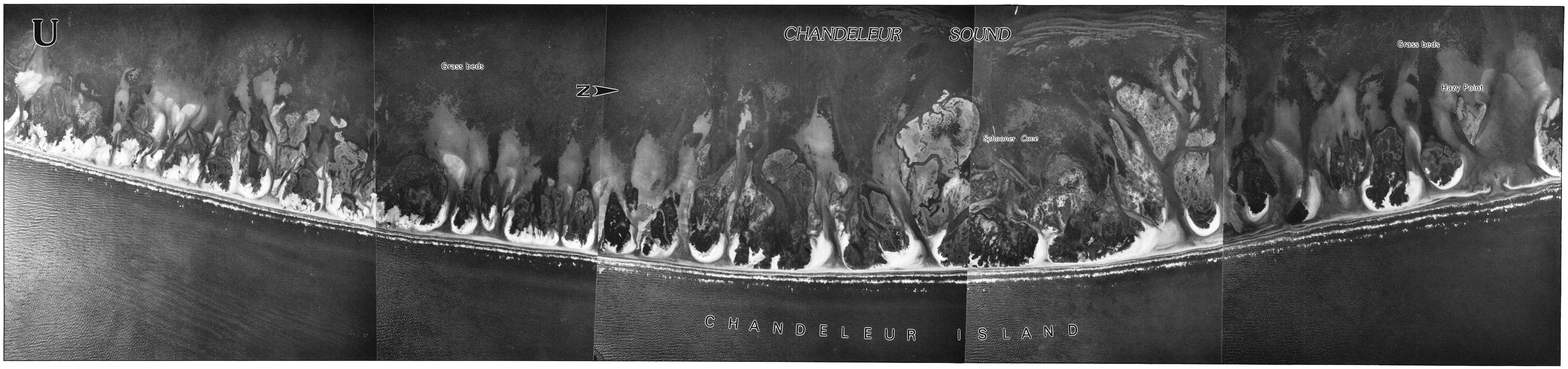
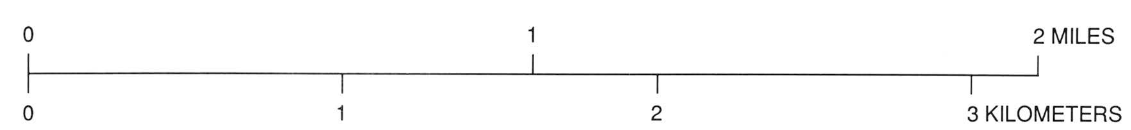




Recommended citation for this chapter:
Westphal, K. A., and Penland, Shea, 1991, Aerial photographic mosaics of Louisiana's barrier shoreline, *in* Williams, S. J., Penland, Shea, and Sallenger, A. H., Jr., eds., Louisiana barrier island erosion study—atlas of barrier shoreline changes in Louisiana from 1853 to 1989: U.S. Geological Survey Miscellaneous Investigations Series I-2150-A, p. 24-35.

Chapter 4 Analysis of Barrier Shoreline Change in Louisiana from 1853 to 1989

by *Randolph A. McBride, Shea Penland, Matteson W. Hiland, S. Jeffress Williams, Karen A. Westphal, Bruce E. Jaffe, and Asbury H. Sallenger, Jr.*

INTRODUCTION

Sandy, open-ocean barrier shorelines commonly exhibit rapid movement in response to natural and human forces. Unconsolidated beach sediment can respond instantly to winter storms and tropical cyclones (Hayes, 1967; Leatherman and others, 1977; Nummedal and others, 1980; Penland and others, 1980; Sexton and Moslow, 1981; Kahn and Roberts, 1982; Byrnes and Gingerich, 1987; Leatherman, 1987; Roberts and others, 1987; Ritchie and Penland, 1988; Penland and others, 1989a) or gradually to normal wave and current processes and relative sea level fluctuations (Morgan and Larimore, 1957; Penland and Boyd, 1981; Griffin and Henry, 1983; Morgan and Morgan, 1983; Everts and others, 1983; May and others, 1983; Shabica and others, 1984; Byrnes and others, 1989; Foster and Savage, 1989a, b; Anders and Reed, 1989; McBride and others, 1989a). Access canals, levees, oil and gas activities, seawalls, and jetties are just a few of the human disturbances that have exacerbated the rapid shoreline change problem in Louisiana (Larson and others, 1980; van Beek and Meyer-Arendt, 1982; Davis, 1986; Meyer-Arendt and Davis, 1988; Davis, 1990). Together these factors control the evolution of Louisiana's barrier shoreline.

The Louisiana coastline is extremely low lying (<3 m) and consists of unconsolidated sediment deposited by the Mississippi River during the past 8,000 years (Fisk, 1944; Kolb and Van Lopik, 1966; Frazier, 1967; Coleman, 1988). Louisiana's outer coast, which directly borders the Gulf of Mexico, extends from the Texas border at Sabine Pass to the Mississippi border at the mouth of the Pearl River and is approximately 624 km long (fig. 1). If measured around the numerous bays and estuaries, however, the shoreline is about 1,488 km long (Morgan and Larimore, 1957). Located along the Mississippi River delta plain are four barrier systems totalling about 240 km. These systems formed in response to reworking of abandoned deltas and play an integral role in the evolution of Louisiana's complex deltaic estuarine system (Penland and others, 1988). These features provide the first line of defense against destructive nearshore processes that would otherwise directly impact productive estuarine environments in the coastal zone. Each kilometer of barrier shoreline in Louisiana protects approximately 30 km^2 of estuarine habitat in the delta plain. Louisiana's four barrier systems are the Isles Dernieres, Bayou Lafourche (Timbalier and East Timbalier islands, Caminada-Moreau Headland, and Grand Isle), Plaquemines, and Chandeleur Islands (north and south) (fig. 1). The largest proportion of these systems is dominated by barrier islands, as defined by Oertel (1985), with a much smaller proportion characterized by abandoned deltaic headlands. This chapter presents methods and procedures for mapping shoreline change with cartographic data sources and near-vertical aerial photography; accurate maps of shoreline change along barrier systems of Louisiana from 1853 to 1989; and a quantitative compilation of linear, area, and width measurements and their rates of change. In addition, it identifies long-term trends for predicting future coastal change in response to wind, waves, and water level.

SHORELINE MAPPING

With the implementation of computer processing and computer cartography, shoreline mapping techniques have evolved extensively over the past 10 years. Powerful mapping and geographic information system (GIS) software packages for personal computers and work stations have revolutionized traditional cartographic techniques. However, computers and mapping software are only as good as the data sources utilized. Computer technology enables coastal scientists to produce maps faster and more precisely, but for mapping shoreline change, the most important step is accurately interpreting the high-water shoreline position on aerial photography. An inaccurately delineated shoreline will remain inaccurate regardless of the precision of the computer mapping system.

Prior to the use of aerial photography, the high-water shoreline was measured using standard field surveying techniques (Shalowitz, 1964). Much care was taken to ensure accurate measurements representing this boundary, but these data were neither continuous nor synoptic due to time- and labor-intensive collection procedures. Monitoring the high-water-line position from aerial photographs is continuous and regionally synoptic, but interpretation of location is more subjective than direct measurement. Accurate delineation of the land-water interface depends on a thorough understanding of coastal processes and human activities, and their effects on the coastline.

Compilation of shoreline change maps involves a variety of techniques and different data sources, which include maps, charts, aerial photographs, and satellite imagery (Karo, 1961; Shalowitz, 1964; Morton, 1977, 1979; Dolan and Hayden, 1978; Dolan and others, 1979, 1980; Leatherman, 1983; Clow and Leatherman, 1984; Shabica and others, 1984; Ritchie and others, 1988; Byrnes and others, 1989; McBride, 1989a, b; Anders and Byrnes, 1991). Differing scales, datums, projections, ellipsoids, and coordinate systems complicate the superimposition of these data. Furthermore, other potential errors are inherent to all shoreline mapping projects (table 1). Recognizing and minimizing these problems ensure more accurate shoreline change data. The following sections discuss the methods, materials, techniques, and sources of error associated with shoreline mapping along the Louisiana barrier shoreline.

MATERIALS AND TECHNIQUES

Shorelines compiled in this atlas were derived from either topographic or near-vertical aerial surveys conducted between 1853 and 1989 (table 2). The high-water line is used as the official shoreline on cartographic data (Shalowitz, 1964; Anders and Byrnes, 1991) and is interpreted and determined on near-vertical aerial photographs according to the location of the wet- and dry-beach contact or the high-water debris line. Because the upper foreshore represents the landward limit of influence by normal wave and current processes, the high-water line is the most appropriate reference for measuring change in shoreline position (Langfelder and others, 1968). Fortunately, it is also the steepest portion of the foreshore, and a small change in water elevation produces a relatively small horizontal displacement of the shoreline.

Several primary data sources were used to establish a shoreline change data base for the barrier systems. Shoreline data compiled prior to 1951 were digitized directly from mylar-based topographic sheets (T-sheets) published by the U.S. Coast and Geodetic Survey, currently known as the National Ocean Service (NOS) within the National Oceanic and Atmo-

Table 1.—***Potential errors associated with shoreline mapping (modified from Anders and Byrnes, 1991)***

ACCURACY		PRECISION
Maps and Charts	Aerial Photographs	
scale	interpretation of high-water line	annotation of high-water line
horizontal datum changes	location of control points	digitizing equipment
shrink/stretch	quality of control points	temporal data consistency
surveying standards	aircraft tilt and pitch	media consistency
publication standards	altitude changes (scale)	operator consistency
photogrammetric standards	topographic relief	
projection	negatives vs. contact prints	
datum		
ellipsoid		

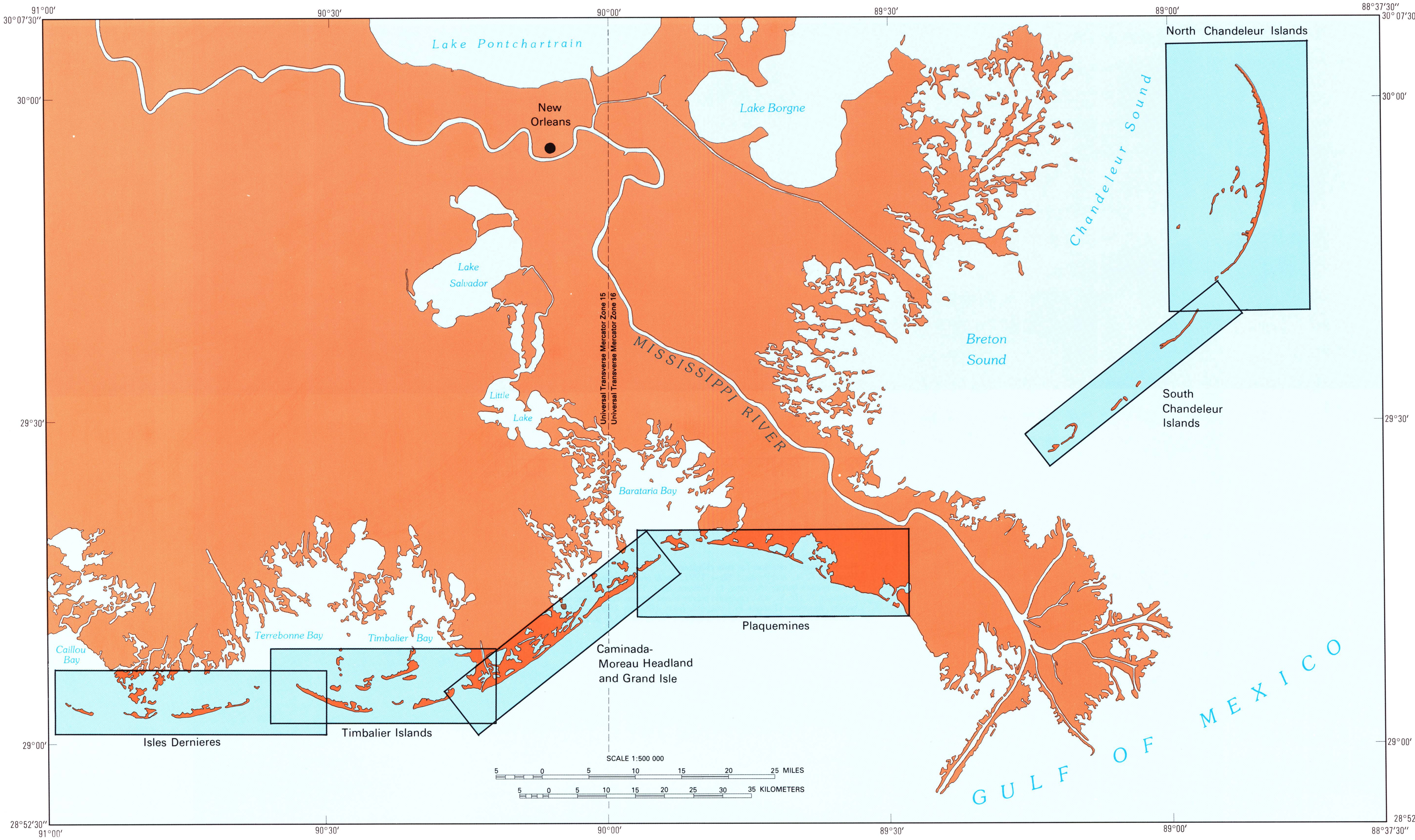


Figure 1.—The four barrier island systems along Louisiana's coastline: Isles Dernieres, Bayou Lafourche (Timbalier and East Timbalier islands, Caminada-Moreau Headland and Grand Isle), Plaquemines, and Chandeleur Islands (north and south).

TABLE 2.—*Cartographic and aerial photography data sources used in this study.*

DATE	MAP NAME	MAP NO.	PROJECTION	SCALE	PHOTOGRAPHY TYPE	PHOTOGRAPHERS
			ISLES DERNIERES			
1853		T-410	Polyconic	1:10,000		
		H-442	Polyconic	1:200,000		
1887		T-1691	Polyconic	1:20,000		
		T-1762	Polyconic	1:20,000		
		T-1763	Polyconic	1:20,000		
1906		T-2752	Polyconic	1:20,000		
1934		T-5291	Polyconic	1:20,000		
		T-5295	Polyconic	1:20,000		
1956	West Derniere	T-9878	Polyconic	1:20,000		
	Derniere	T-9879	Polyconic	1:20,000		
	East Derniere	T-9880	Polyconic	1:20,000		
	Cat Island Pass	T-9881	Polyconic	1:20,000		
1978	Western Isles Dernieres	252-c	Polyconic	1:24,000		
	Central Isles Dernieres	252-d	Polyconic	1:24,000		
	Eastern Isles Dernieres	253-c	Polyconic	1:24,000		
	Cat Island Pass	253-d	Polyconic	1:24,000		
1/21/88		---	---	1:15,000	9" x 9" Black & white vertical aerial photography	Gulf Coast Aerial Mapping, Inc.
			BAYOU LAFOURCHE Timbalier Islands			
1887		T-1764	Polyconic	1:20,000		
		T-1765	Polyconic	1:20,000		
1934		T-5295	Polyconic	1:20,000		
		T-5299	Polyconic	1:20,000		
		T-5303	Polyconic	1:20,000		
1956	Timbalier Island	254-c	Polyconic	1:24,000		
	Calumet Island	254-d	Polyconic	1:24,000		
	Belle Pass	255-c	Polyconic	1:24,000		
1978	Timbalier Island	254-c	Polyconic	1:24,000		
	Calumet Island	254-d	Polyconic	1:24,000		
	Belle Pass	255-c	Polyconic	1:24,000		
1/21/88		---	---	1:15,000	9" x 9" Black & white vertical aerial photography	Gulf Coast Aerial Mapping, Inc.
			Caminada-Moreau Headland			
1877		T-1468a	Polyconic	1:20,000		
1887		T-1765	Polyconic	1:20,000		
		T-1766	Polyconic	1:20,000		
1934		T-5303	Polyconic	1:20,000		
		T-5302	Polyconic	1:20,000		
		T-5311	Polyconic	1:20,000		
1956	Leeville	255-a	Polyconic	1:24,000		
	Caminada Pass	255-b	Polyconic	1:24,000		
	Belle Pass	255-c	Polyconic	1:24,000		
	Grand Isle	256-a	Polyconic	1:24,000		
	Barataria Pass	242-c	Polyconic	1:24,000		
1978	Leeville	255-a	Polyconic	1:24.000		
	Caminada Pass	255-b	Polyconic	1:24,000		
	Belle Pass	255-c	Polyconic	1:24,000		
	Grand Isle	256-a	Lambert Conformal	1:24,000		
	Barataria Pass	242-c	Lambert Conformal	1:24,000		
1/21/88		---	---	1:15,000	9" x 9" Black & white vertical aerial photography	Gulf Coast Aerial Mapping, Inc.
			PLAQUEMINES			
1877		T-1468a	Polyconic	1:20,000		
1883		T-1648	Polyconic	1:30,000		
1884		T-1658	Polyconic	1:20,000		
1932		T-5311	Polyconic	1:20,000		
		T-5432	Polyconic	1:20,000		
		T-5433	Polyconic	1:20,000		
		T-5402	Polyconic	1:20,000		
1956	Bay Ronquille	242-d	Polyconic	1:24,000		
	Bastian Bay	241-c	Polyconic	1:24,000		
	Buras	241-d	Polyconic	1:24,000		
	Bay Coquette	257-b	Polyconic	1:24,000		
	Pass Tante Phine	258-a	Polyconic	1:24,000		
1973	Bay Ronquille	242-d	Lambert Conformal	1:24,000		
	Bastian Bay	241-c	Lambert Conformal	1:24,000		
	Buras	241-d	Lambert Conformal	1:24,000		
	Bay Coquette	257-b	Lambert Conformal	1:24,000		
	Pass Tante Phine	258-a	Lambert Conformal	1:24,000		
1/21/88		---	---	1:15,000	9" x 9" Black & white vertical aerial photography	Gulf Coast Aerial Mapping, Inc.
			CHANDELEUR ISLANDS South Chandeleur Islands			
1869		T-1092	Polyconic	1:20,000		
		T-1097	Polyconic	1:20,000		
1922		T-3919	Polyconic	1:20,000		
		T-3920	Polyconic	1:20,000		
		T-3985	Polyconic	1:20,000		
		H-4223	Polyconic	1:80,000		
1951	Grand Gosier Island	237-d	Polyconic	1:24,000		
	Stake Islands	238-a	Polyconic	1:24,000		
	Breton Island	239-a	Polyconic	1:24,000		
1978		---	---	1:24,000	27" x 27" Color infrared vertical aerial photography	National Aeronautics & Space Administration (NASA)
2/89		---	---	1:24,000	27" x 27" Color infrared vertical aerial photography	NASA
			North Chandeleur Islands			
1855		T-548	Polyconic	1:20,000		
		T-549	Polyconic	1:20,000		
1922		T-3917	Polyconic	1:20,000		
		T-3918	Polyconic	1:20,000		
		T-3919	Polyconic	1:20,000		
		T-3985	Polyconic	1:20,000		
1951	Chandeleur Light	195-d	Lambert Conformal	1:24,000		
	North Islands	196-b	Polyconic	1:24,000		
	Freemason Islands	196-c	Polyconic	1:24,000		
	New Harbor Islands	196-d	Polyconic	1:24,000		
1978		---	---	1:24,000	27" x 27" Color infrared vertical aerial photography	NASA
2/89		---	---	1:24,000	27" x 27" Color infrared vertical aerial photography	NASA

spheric Administration (NOAA). Cartographic shorelines between 1951 and 1978 were recorded from NOS T-sheets and U.S. Geological Survey (USGS) 7.5-minute quadrangle maps. Aerial photography, dated January 1988 and taken at a scale of 1:15,000, was used to construct a shoreline west of the mouth of the Mississippi River from Raccoon Point to Sandy Point. To the east, the 1978 and 1989 Chandeleur Islands shorelines were compiled using National Aeronautic and Space Administration (NASA) high-altitude photography enlarged to scales of 1:33,000 and 1:24,000, respectively. Although aerial photography shorelines can be registered in several ways (Leatherman, 1983), shoreline position for the delta plain was registered to USGS 7.5-minute quadrangle maps using a Bausch and Lomb Zoom Transfer Scope. These data together with cartographic shorelines were digitized by Intergraph's VAX-based Interactive Graphics Design System (IGDS) or work station-based MicroStation software (Wright, 1989, 1990a, b) at a 1:1 scale according to original projection, ellipsoid, and North American Datums (NAD) (fig. 2). Intergraph's World Mapping System (WMS) software can generate 21 map projections or coordinate systems; reference 20 ellipsoid types; convert coordinate systems, datums (NAD 27 and NAD 83 [Morgan, 1987; Wade, 1986; Shalowitz, 1964]), and associated data; and perform area, distance, and perimeter calculations.

WMS software generates a latitude-longitude grid, or graticule, based on the same cartographic parameters as the map being digitized (Intergraph Corporation, 1987). This graticule is mathematically correct and free of any distortion that may be present on printed maps. At least four well-spaced primary control points on the map are registered to equivalent points on the graticule to provide a best fit between the map and the independently generated graticule. Maps digitized for this study are characterized by either Polyconic or Lambert Conformal projections (see Synder, 1987). Using WMS software, shoreline data for each year were converted to a common projection (Polyconic), coordinate system (latitude-longitude), datum (NAD 27), and ellipsoid (Clarke 1866) and superimposed for analysis (McBride, 1989a, b). Shoreline data were then converted to Universal Transverse Mercator (UTM) projection (Zones 15 and 16) for atlas production.

SHORELINE CHANGE MAPPING STRATEGY

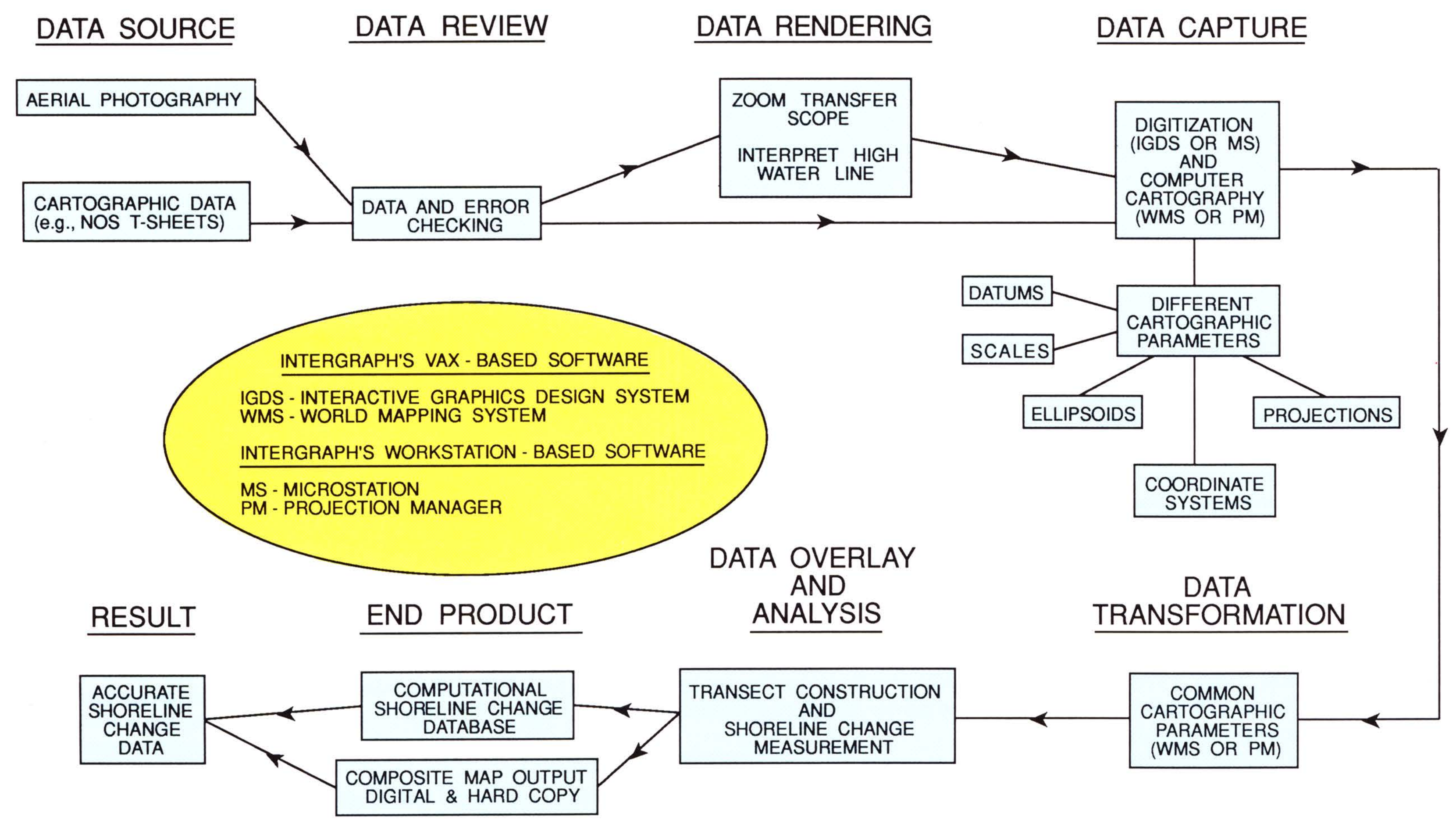


FIGURE 2.—**Shoreline change mapping procedures and strategy at the Louisiana Geological Survey.**

To evaluate change in shoreline position, shore-normal transects were constructed at approximately 15-second intervals of longitude or latitude, depending on shoreline orientation. Isles Dernieres, Bayou Lafourche, and Plaquemines barrier systems (east-west shorelines) were analyzed using 15-second (about 404 m) intervals of longitude, while the Chandeleur Islands (north-south shorelines) were examined using 15-second (about 462 m) intervals of latitude. Also, information is provided about the location of transects near entrance areas (for example, tidal inlets, distributaries, etc.). Measurements of shoreline movement and change in island width were taken along transects perpendicular to the composite shoreline trend (fig. 3). A plus sign indicates progradation while a minus sign indicates recession (fig. 4). Average rates of movement and area change were calculated by dividing absolute measurements by elapsed time (year, month, and day—where available). For this study, shoreline change maps were produced to determine the spatial and temporal distribution of shoreline movement (magnitude, direction, and rate of change) and document geomorphologic evolution.

SOURCES OF ERROR

Errors are inherent to the compilation and analysis of shoreline change maps and occur from 1) interpretation of the shoreline position, 2) resolution of source material, and 3) precision of digitizing equipment. Superimposing cartographic data and near-vertical aerial photography can cause large potential errors as a result of the different techniques used to delineate shoreline position. On early historical NOS T-sheets, the high-water line was mapped to within 10 m horizontally, but in many cases, these measurements were probably more accurate (Shalowitz, 1964). On aerial photography, the high-water line is determined by interpreting the wet- and dry-beach contact or the high-water debris line. This boundary will vary throughout the year depending on tide cycle, beach slope, sediment supply, wind direction, wave conditions, and human activities (Stafford, 1971; Morton, 1977). An aerial survey of an eroding shoreline could depict accretion simply from changes in wind direction at the time of the survey. Normal wind shifts can depress or elevate the water surface in several hours and cause the water line to move horizontally tens of meters. Therefore, to develop realistic cause-and-effect relationships, it is important to understand the impact of local processes on system response.

Interpretation of shoreline position along the bay side poses some additional difficulties. Because emergent vegetation is mapped as land regardless of actual water depth, a minimum density and size of individual stands of vegetation must be established and mapped consistently. Therefore, delineating the shoreline becomes subjective without extensive ground truthing when a mixture of vegetation, sand, and water exists, or when the water line is hidden by lush vegetation. Aerial video surveys, however, can provide an alternative to ground truthing (Penland and others, 1988, 1989b; McBride and others, 1989b). This low-oblique color footage is taken at about 70 m and is viewed during air photo interpretation to aid in determining coastal habitats and delineating the high-water line along the gulf and bay sides. Although ground truthing is time consuming and expensive, it should be conducted in conjunction with any overflight.

Pen-line width is another source of error during air photo interpretation. A typical pen width of 0.25 mm results in a potential error of 2.5 m at 1:10,000 scale, 6.0 m at 1:24,000 scale, or 16.3 m at 1:65,000 scale. A pen line 0.18 mm wide was used on the 1978 photography (1:33,000 scale) for the Chandeleur Islands, a potential error of 5.9 m. This is comparable to the potential error of 6.0 m on the 1989 photography (1:24,000 scale). In this study, a photo interpreter centered the pen line along the wetted boundary to delineate its position and subsequently digitized along the center of the pen line. The digitizer is precise and accurate to within 0.1 mm, a potential error of 2.4 m at a scale of 1:24,000. Errors associated with the digitizing equipment are amplified by operator error.

Loss of control points along a rapidly changing coastline also impedes accurately mapping shoreline change. Potential errors have been minimized by overlaying many different controlled shoreline data sources and by field checking when no other method was satisfactory. A controlled survey for the Chandeleur Islands was completed in 1951; however, considerable erosion and landward barrier island migration have occurred since then as a result of Hurricanes Betsy (1965), Camille (1969), Frederic (1979), Elena (1985), Juan (1985), and Florence (1988). These events removed all but a few control points along the southern half of the barrier chain (Penland and others, 1989b; McBride and others, 1989b). Grand Gosier, for example, has migrated about 1 km west since 1951.

The 1978 and 1989 Chandeleur shorelines were constructed from NASA high-altitude, color-infrared aerial photography and interpreted at 1:33,000 and 1:24,000 scales, respectively. Because a limited number of control points were available, the Zoom Transfer Scope could not be used. Therefore, photomosaics of the 1978 and 1989 shorelines were constructed and photographically scaled. To minimize error, the two shorelines were overlaid with the most recent topographic maps, using the few available control points. Large oil platforms, visible on both sets of photographs, were used as additional control points. These positions were registered on 7.5-minute quadrangle maps by latitude and longitude acquired in the field using a Loran-C navigation system, calibrated to known points in the study area. The largest margin of mapping error along the Louisiana shoreline is found where lack of control points is common from the southern portion of Chandeleur Island to Breton Island. In these isolated areas of minimal control, shoreline position may be in error by as much as 50 m.

Cartographic data sources for this study were digitized using a graticule digitizer setup. Intergraph mapping software provides an error calculation associated with the digitizer setup. The average error and maximum error of the digitizer setup are expressed as percentages. This represents the difference among control points placed on the digitizer table (map) using the cursor and corresponding points located in the graphics file coordinate system (latitude-longitude). If the coordinate system in the graphics file is identical to the coordinate system on the map, error is negligible. Larger setup errors can occur for a number of other reasons, including shrink and swell of the original map (older mylar T-sheets are actually copies of original paper maps on a stable base); errors in plotted positions on the map; and errors in point placement during digitizer setup.

For an Intergraph digitizer setup, a 0.01 percent error corresponds to 1 m of displacement in a distance of 10,000 m on the ground. Because NOS T-sheets are generally no larger than 1.2 m, a maximum distance of approximately 12,000 m is covered by a map at 1:10,000 scale. Thus, a 0.01 percent digitizer setup error would give a maximum error of 1.2 m on a 1:10,000 scale map. This error, however, will decrease with proximity to digitizer setup points, thus assuring that setup errors will be considerably less than this maximum. Digitizing errors associated with NOS T-sheets will be within National Map Accuracy standards (5 m at 1:10,000) (Ellis, 1978). In contrast, USGS 7.5-minute quadrangle maps measure approximately 20" X 23" (0.5 m X 0.6 m), and a maximum distance of approximately 14,400 m is covered by a map at 1:24,000 scale. Thus, a 0.01 percent digitizer setup error would give a maximum error of 1.44 m on a 1:24,000 scale map, and digitizing errors would be within National Map Accuracy standards (12.2 m at 1:24,000) for the location of the shoreline on USGS 7.5-minute quadrangle maps (Ellis, 1978). Although errors in map construction cannot be completely removed, they can be quantified and minimized during this digitizer setup. A combined error of 0.01 percent (approximately 1 m of displacement at a 1:10,000 scale) or less is usually attained for NAD 27 maps. Errors of greater than 0.03 percent (about 3 m) are unacceptable on NAD 27 maps. For North American datum maps, setup errors of greater than 0.05 percent (about 5 m) are not allowed, and the criterion for pre-North American datum maps is no greater than 0.07 percent setup error (about 7 m). The majority of maps used have a digitizer setup error of 0.04 percent (about 4 m) or less.

Other potential errors associated with factors listed in table 1 have been addressed in detail by Morton (1977, 1979), Tanner (1978), Anders and Leatherman (1982), and Anders and Byrnes (1991). These include photogrammetry problems, surveying standards, temporal data consistency, natural and human impacts of coastal processes, and others. These errors can be minimized by making sensible decisions about data sources (comparing data sources that are seasonally consistent) and interpretation techniques (using the center 2 inches of the photo and annotating with small pen line width).

Because total potential error is a result of time-independent variables (data source, measurement technique, interpretation of high-water line, etc.) and the magnitude of change is a time-dependent (1887 vs. 1934), long-term rates of shoreline movement will have the lowest rate of potential error, and short-term rates will have the highest. The maximum potential error for this study was ±52 m, when quantifying the difference between shorelines, but one shoreline will have a potential error of ±26 m. Root mean square of this value is ±13 m (see Merchant, 1987 for discussion of root mean square). The maximum value includes error associated with shoreline placement, line width, digitizer setup, operator inconsistencies, and equipment. Therefore, the maximum rate of potential error for long-term rates (>100 years) is ±0.4 to ±0.5 m/yr; short-term rates (10 to 15 years) are accurate to within ±3.4 to ±5.1 m/yr.

Finally, shorelines published in this atlas are drafted representations of the original digital shorelines used for quantitative measurements. They have been subjected to the printing process, which involves hand scribing at a scale of 1:100,000. They contain no gross errors, but these representations cannot approach the accuracy of the original computer-generated shorelines mapped at larger scale.

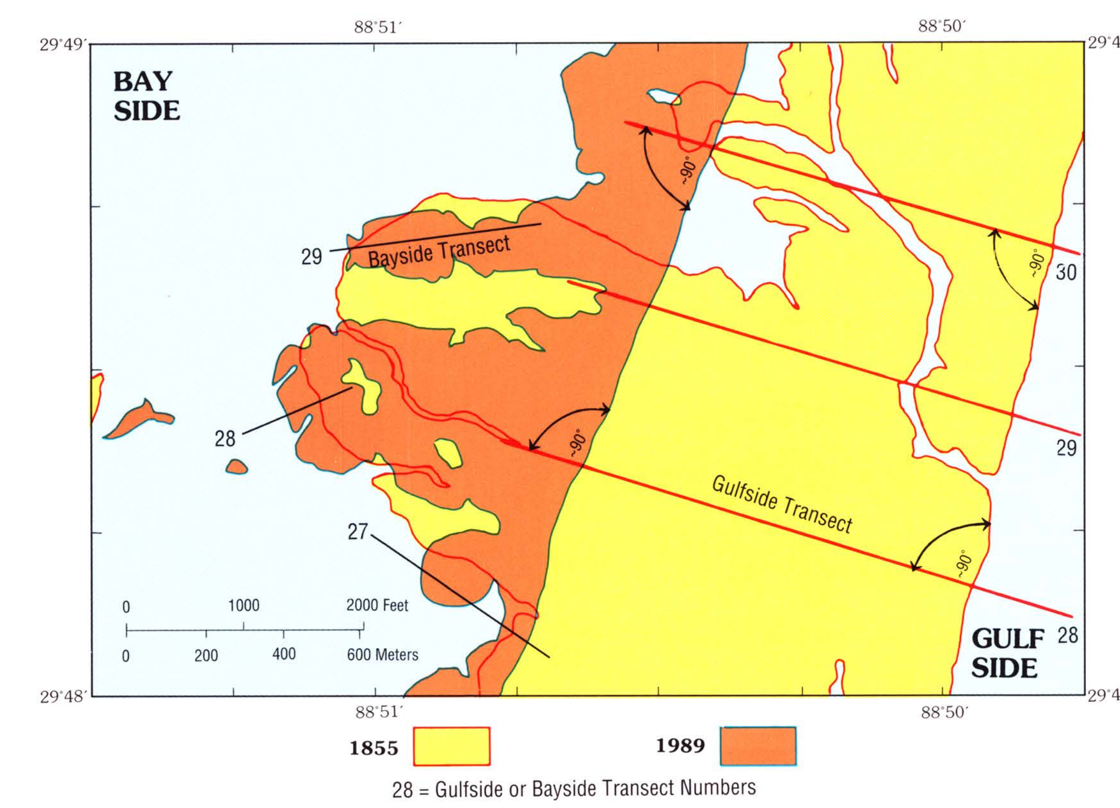


FIGURE 3.—**Shore-normal transects used to measure linear distances between shoreline positions. Transects were placed at 15-second intervals of latitude or longitude along the gulf and bay sides.**

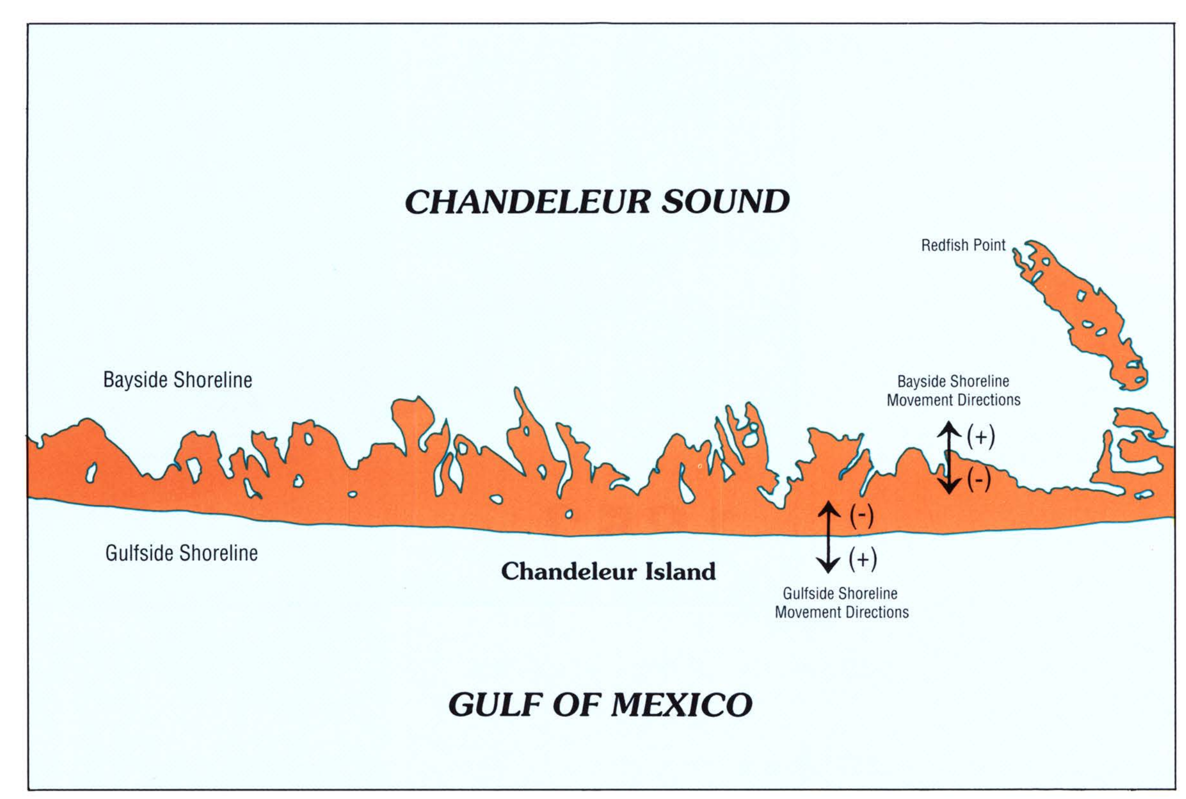


FIGURE 4.—**Explanation of shoreline retreat or advance along the bay or gulf side.**

Isles Dernieres Barrier System—1853 to 1988

Isles Dernieres is located about 100 km west of the mouth of the Mississippi River and about 120 km southwest of New Orleans (fig. 1). The island arc is 36 km long and extends from Raccoon Point to Wine Island Shoal (chapter 1, fig. 17). Tidal inlet development has fragmented the Isles Dernieres into an arc comprising five smaller islands: Raccoon, Whiskey, Trinity, and East islands and Wine Island Shoal. These islands range from 0.25 to 2 km wide and are separated by five tidal inlets: Coupe Colin, Whiskey Pass, Coupe Carmen, Coupe Juan, and Wine Island Pass. The inlets range from 0.3 to 6.0 km wide and are 2 to 16 m deep. The barrier shoreline is undergoing rapid geomorphologic change and severe coastal erosion (Peyronnin, 1962; Kwon, 1969; Neese, 1982; Penland and others, 1985, 1989a; McBride and others, 1989a; Ritchie and others, 1989; Dingler and Reiss, 1990).

Maps presented in this section show morphologic changes along the Isles Dernieres for the years 1853, 1887, 1906, 1934, 1956, 1978, and 1988. All maps referenced in the text are labelled by date. Although the 1853 shoreline represents a reconnaissance of the area surveyed by the U.S. Coast and Geodetic Survey at a scale of 1:200,000, the map provides important morphologic information. This source of information, however, was not used for quantitative purposes. The gulf side was surveyed in 1887, and the remaining bay side was finished in 1906. Because these surveys were incomplete, the 1887 and 1906 shorelines were combined and are referred to as the 1890's shoreline. Linear, area, and width measurements were obtained, and rates of change were calculated to determine the extent of modification for the 134-year period.

BARRIER SYSTEM MORPHOLOGY

Isles Dernieres experienced significant erosion and fragmentation between 1853 and 1988. In 1853, the barrier island arc was a continuous shoreline except for Wine Island, which was located to the east of Wine Island Pass (1853 map). By 1887, an unnamed tidal inlet had developed along the island's west central portion. Meanwhile, submergence enlarged Lake Pelto to result in marsh deterioration (1890's map).

By 1934, Whiskey Pass had formed in the center portion of Isles Dernieres, possibly in response to major hurricanes that struck the Louisiana coast in 1909, 1915, and 1926 (1934 map) (Neumann and others, 1985). Between 1934 and 1956, Coupe Colin developed to the west of the unnamed tidal inlet (1956 map). Continued widening of existing tidal inlets and further deterioration of the interior marsh caused significant land loss and landscape change. As a result of Hurricane Carmen, Coupe Carmen formed on the eastern portion of the arc (1978 map). Along the western Isles Dernieres, the land area between Coupe Colin and the unnamed inlet became subaqueous, and most of Wine Island had become a shallow sandy shoal. The inlet referred to as Coupe Juan emerged when Hurricane Juan (1985) breached Isles Dernieres east of Coupe Carmen. By 1988, the once continuous barrier island had deteriorated into five narrow barrier islands separated by wide tidal inlets (1988 map).

SHORELINE MOVEMENT

The Isles Dernieres shoreline is one of the most rapidly deteriorating barrier shorelines in the United States. A comparison of shoreline positions is made for five periods: 1890's vs. 1934, 1934 vs. 1956, 1956 vs. 1978, 1978 vs. 1988, and 1890's vs. 1988. The magnitude of change, island width, and rate of change were obtained from 184 shore-normal transects at approximately 15-second intervals of longitude along both the gulf and bay shorelines (transects map, tables 3, 4, 5, 6, and 7).

The average rate of bayside change was 0.8 m/yr between 1906 and 1934, while the average gulfside rate of change for Isles Dernieres between 1887 and 1934 was -11.7m/yr (tables 5 and 7). The gulfside rate decreased to -7.8 m/yr between 1934 and 1956, and the gulf and bay shorelines remained relatively constant through 1978. The gulfside rate, however, increased to -19.2 m/yr between 1978 and 1988, and the rate of bay shoreline retreat increased to 5.2 m/yr, presumably in response to repeated hurricane impacts in 1985 (figs. 5 and 6) (see Penland and others, 1989a).

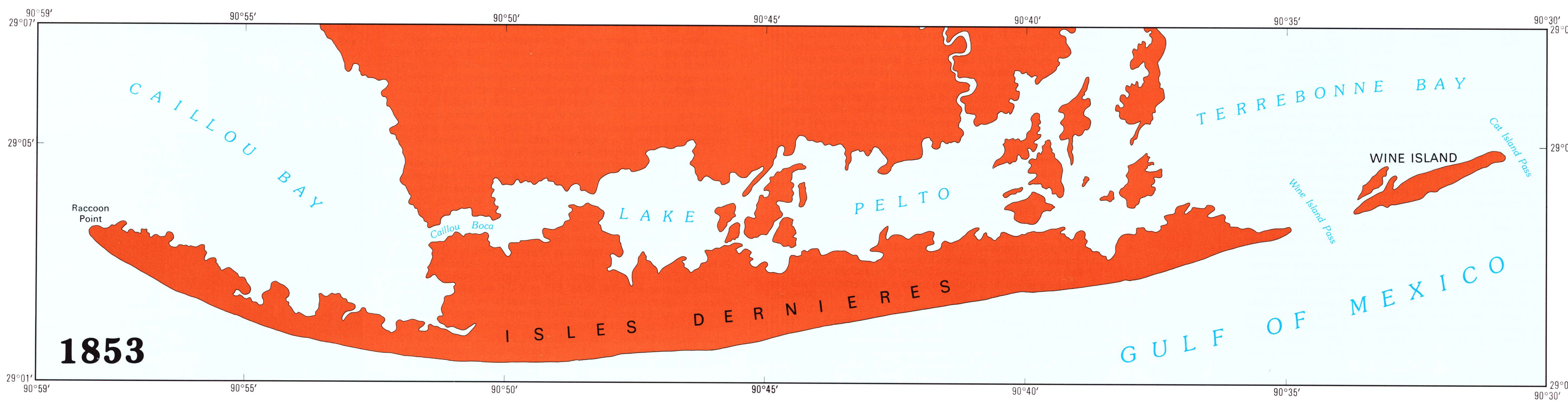
The 1890's vs. 1988 map illustrates land loss and summarizes cumulative quantitative changes along the gulf and bay shorelines. The gulf shoreline retreated between 1887 and 1988, except for the eastern end of East Island, and movement ranged from 3.4 to -23.2 m/yr to produce an average rate of -11.1 m/yr (table 7). Between 1906 and 1988, the rate of bay shoreline change ranged from 23.5 to -4.9 m/yr, with an average retreat rate of -0.6 m/yr (table 5). As a result, the gulf and bay shorelines are converging.

AREA AND WIDTH CHANGE

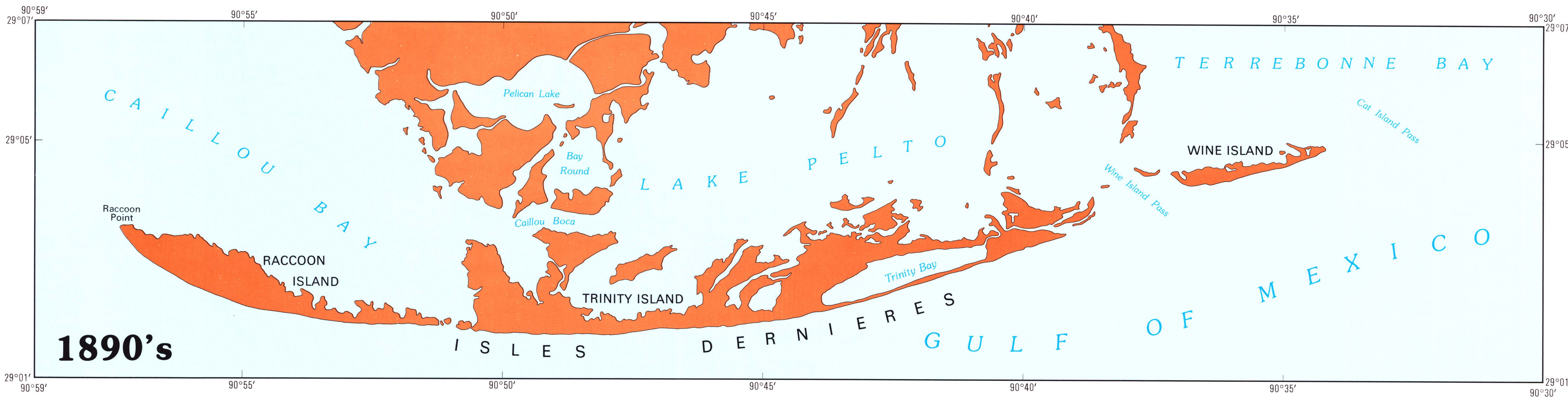
Changes in island area are a function of length and width adjustments in the barrier system. For the 1890's map, island width along the barrier arc ranged between 52 and 3,203 m (table 6). In general, the barrier island arc was narrower at both ends and widest in the middle, with an average width of 1,171 m. The average rate of land loss between the 1890's and 1934 was 35.8 ha/yr (table 8). By 1934, the complex had narrowed to 815 m wide. Slow but steady deterioration of the system continued through 1978 when its average width decreased to 585 m. The average rate of land loss decreased to a low of 9.8 ha/yr between 1956 and 1978. Island width decreased dramatically between 1978 and 1988 to result in an average width of 375 m and an increase in land loss to 47.2 ha/yr (fig. 7). This period of high rate of area loss included Hurricanes Danny and Juan in 1985.

Erosion of the gulf and bay shorelines is causing the island to narrow. From the 1890's to 1988, the barrier width decreased 796 m (figs. 8 and 9). This represents an average narrowing rate of 8.6 m/yr for approximately the last century. Similarly, the area of Isles Dernieres decreased continuously from 3,532 ha in the 1890's to 771 ha in 1988 (fig. 10). This is a land loss of 78 percent or 2,761 ha at an average rate of 28.2 ha/yr (table 8).

• Historic Shorelines •



Isles Dernieres



SCALE 1:100 000

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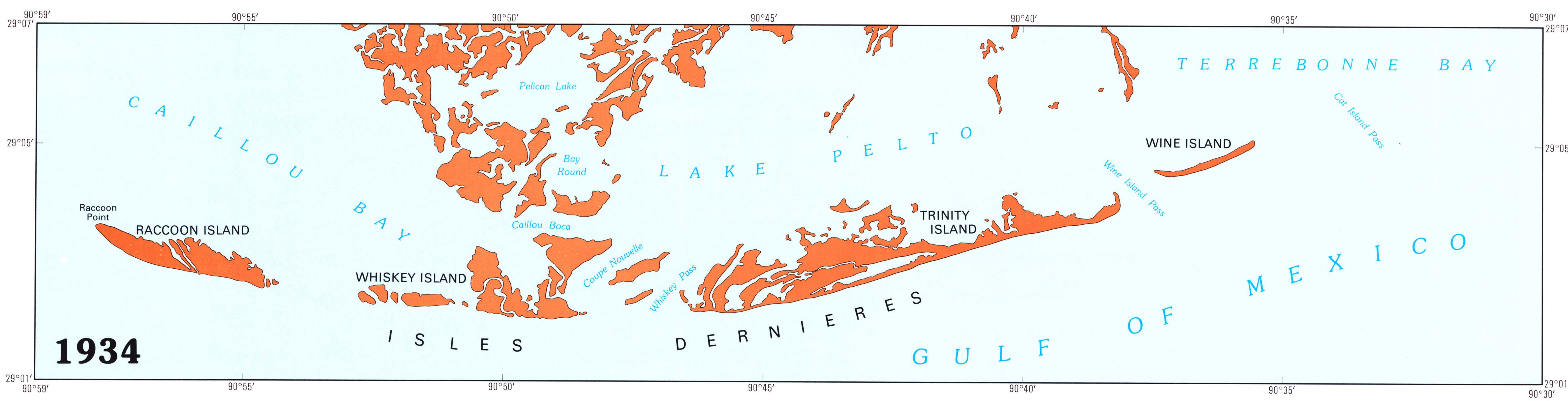
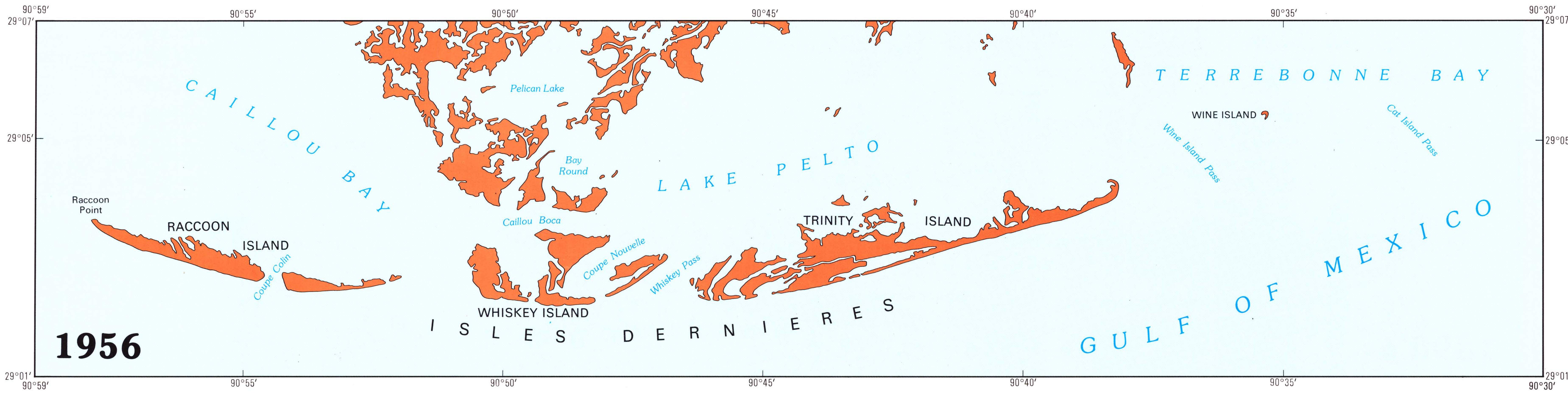
1 0 1 2 3 4 5 6 7 KILOMETERS



Isles Dernieres



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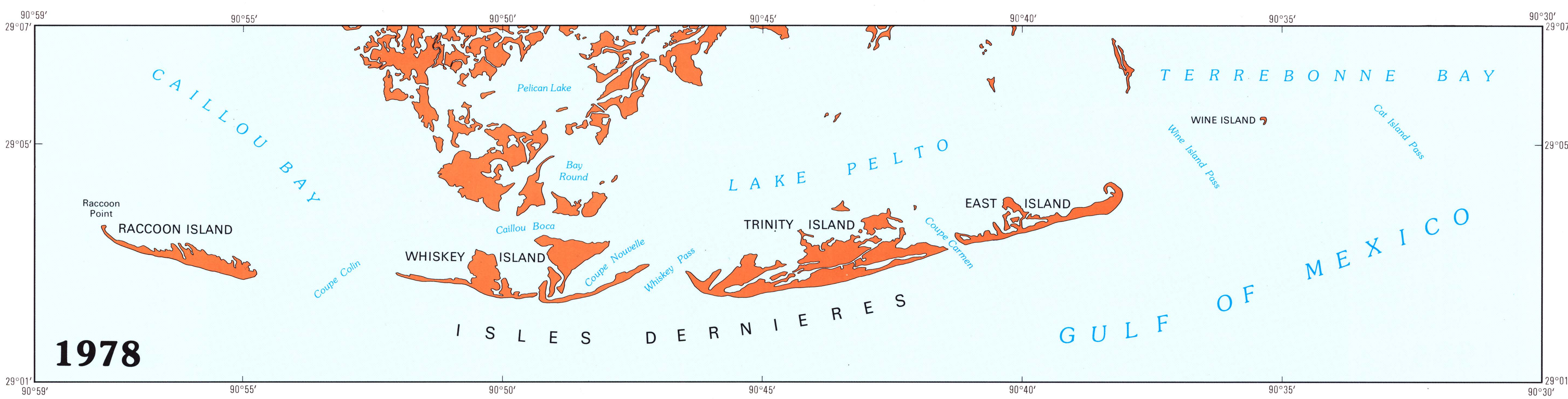
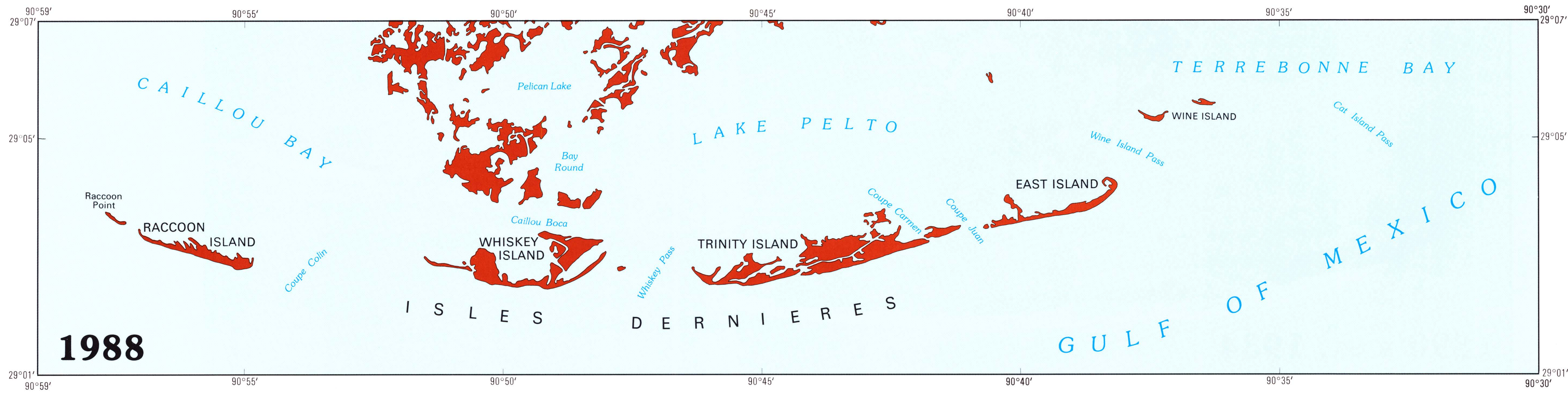


Isles Dernieres



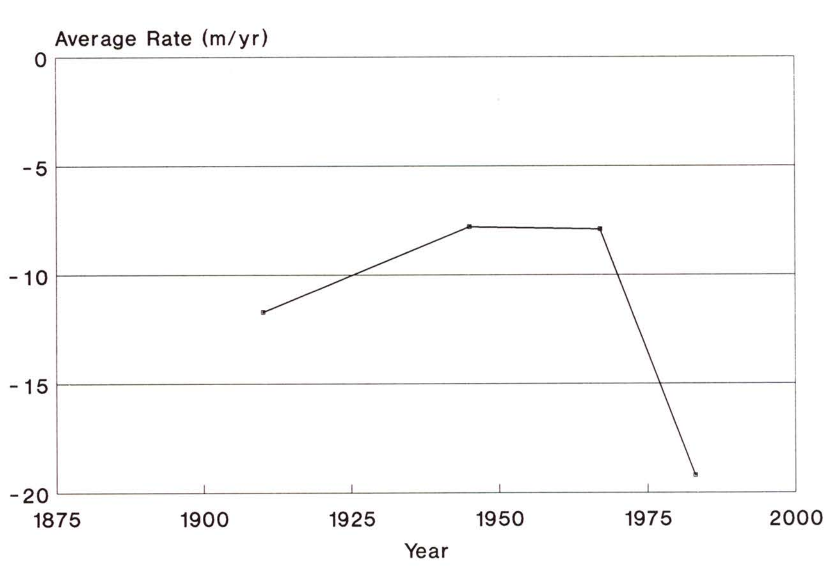


Figure 5.—Average gulfside rate of change along Isles Dernieres between 1887 and 1988.

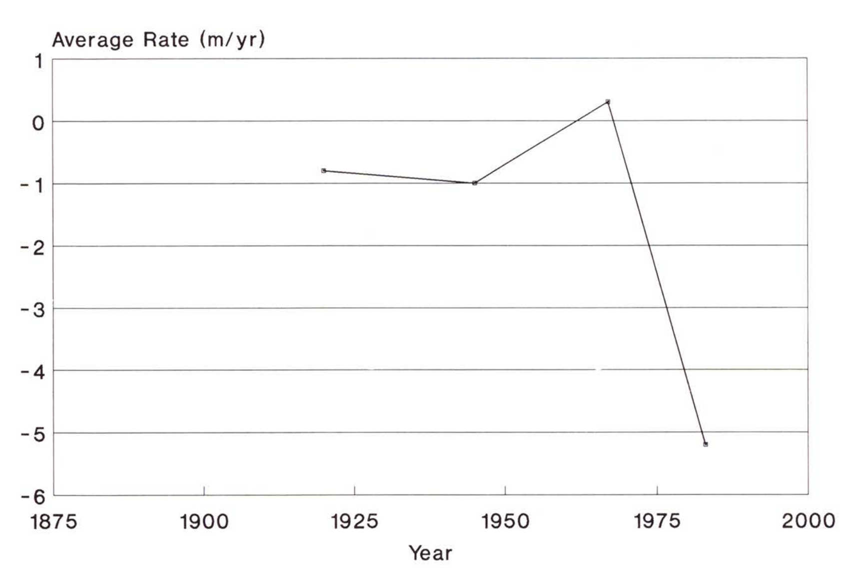


Figure 6.—Average bayside rate of change along Isles Dernieres between 1906 and 1988.

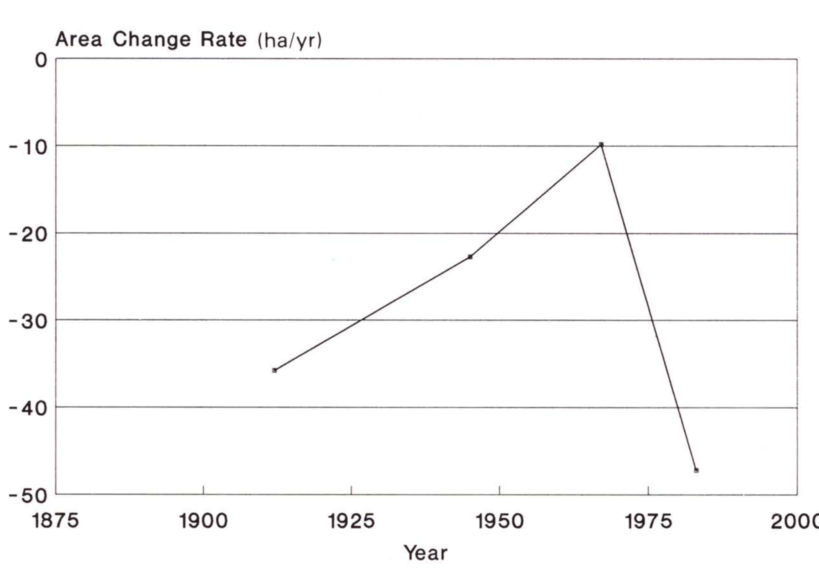


Figure 7.—Rate of area change for Isles Dernieres between the 1890's and 1988.

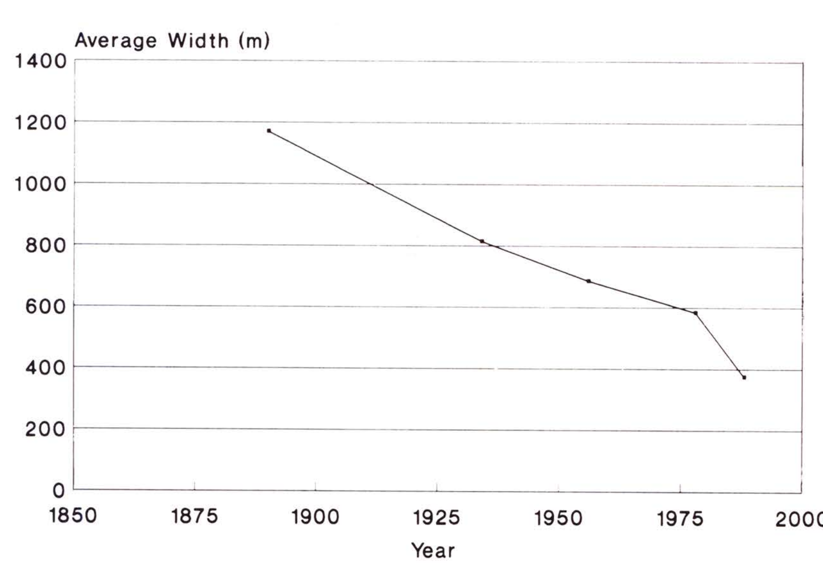
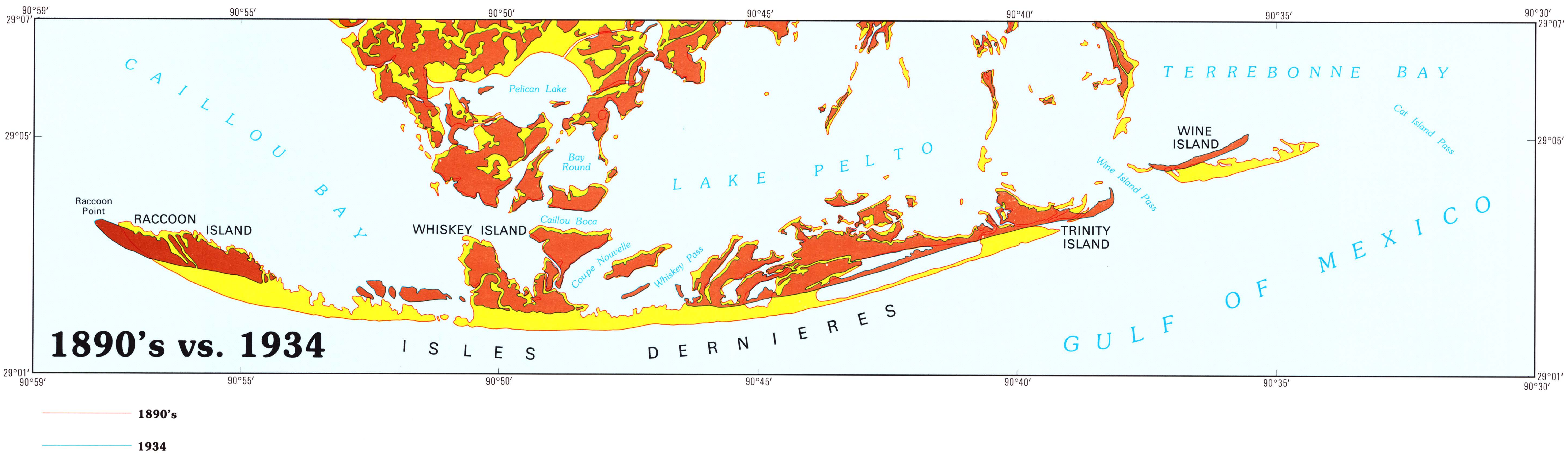


Figure 8.—Average barrier width of Isles Dernieres between the 1890's and 1988.

Isles Dernieres

• Shoreline Change and Land Loss •



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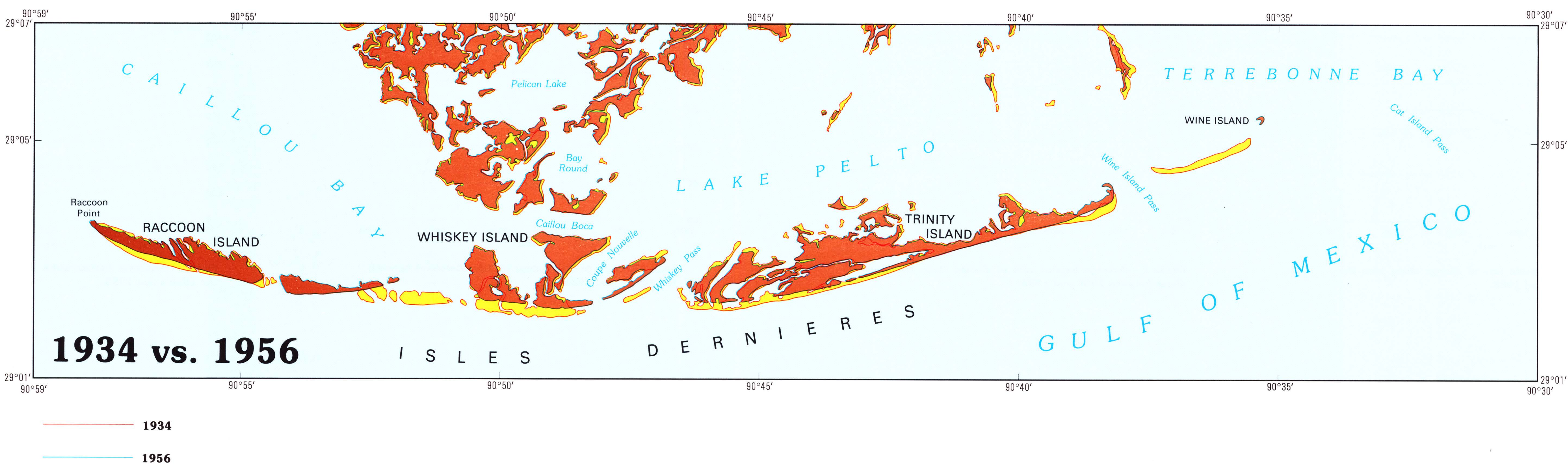
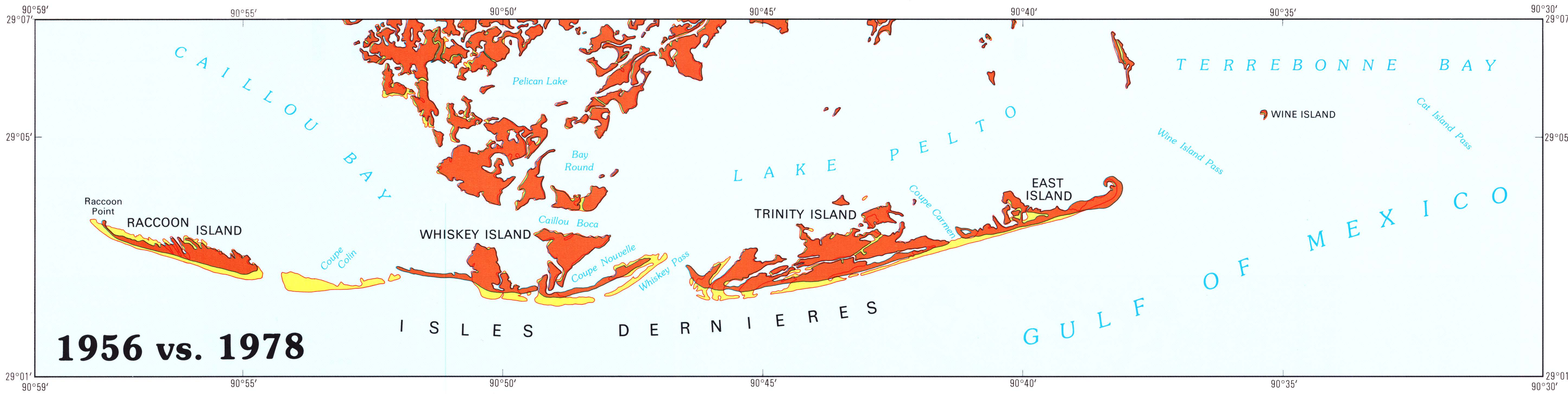


Isles Dernieres

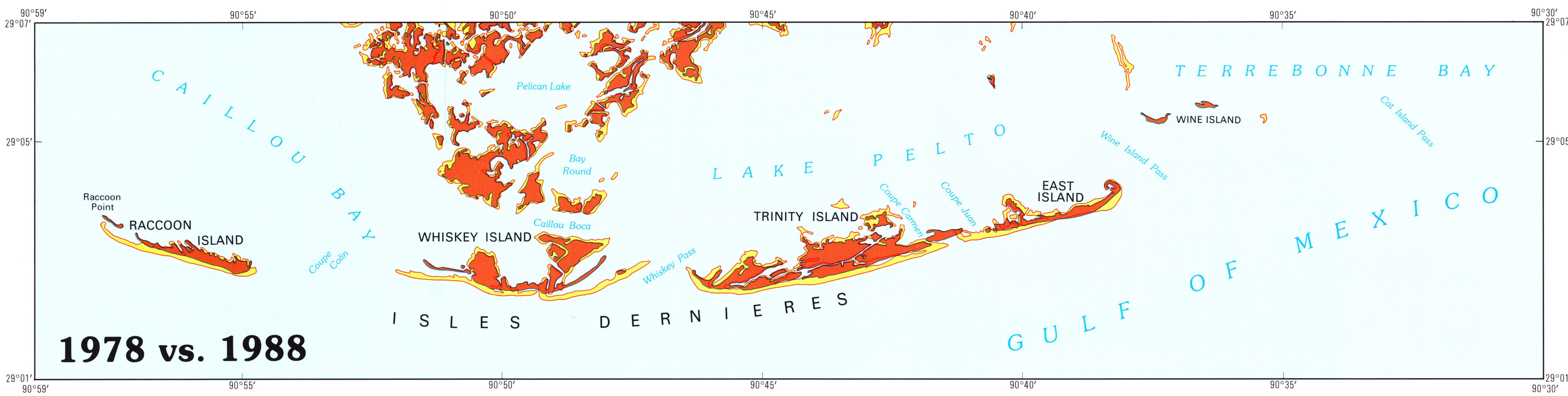


1956

1978

Land

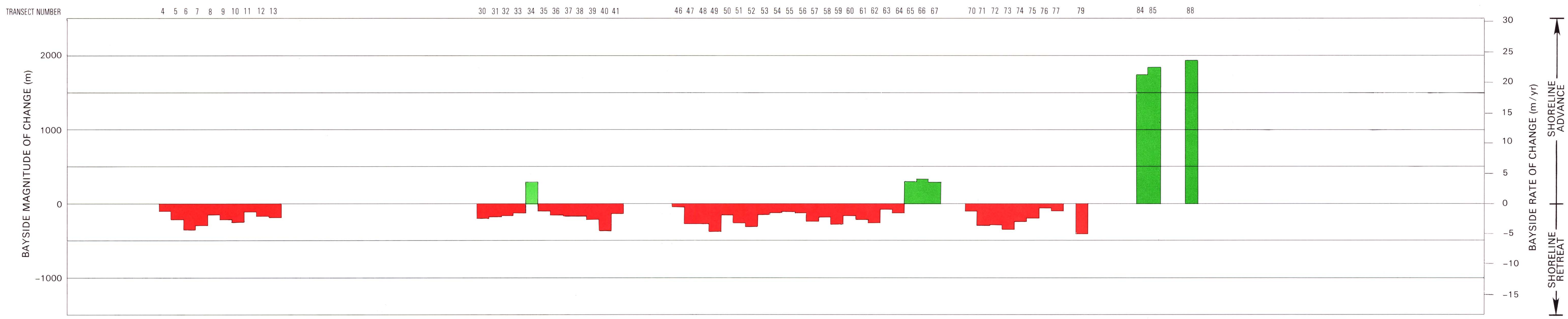
Land Loss

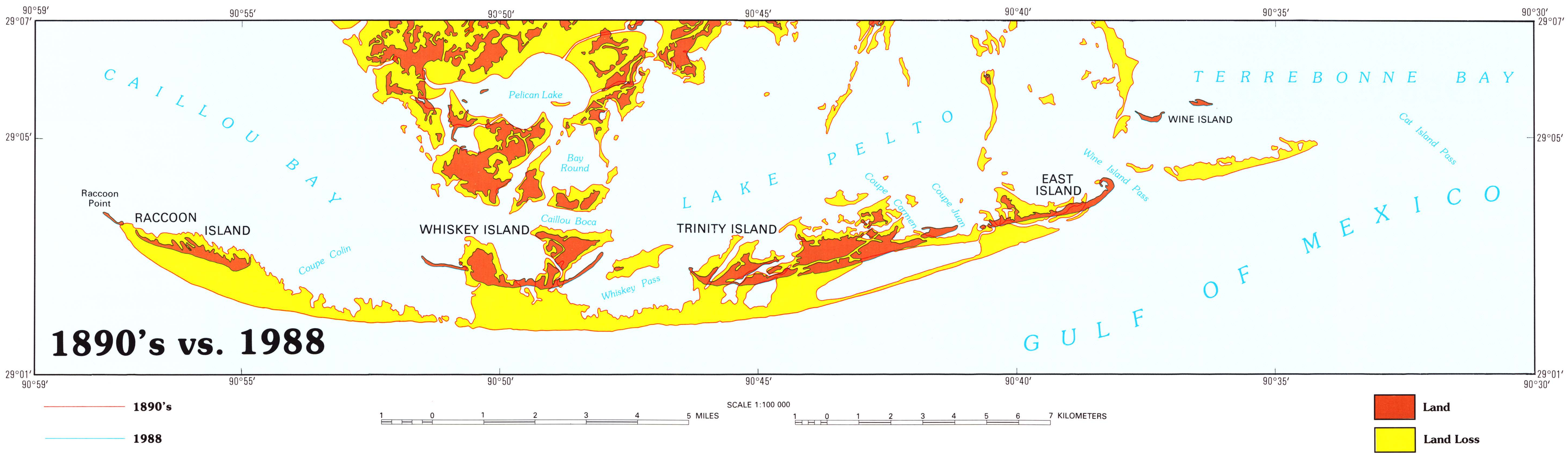


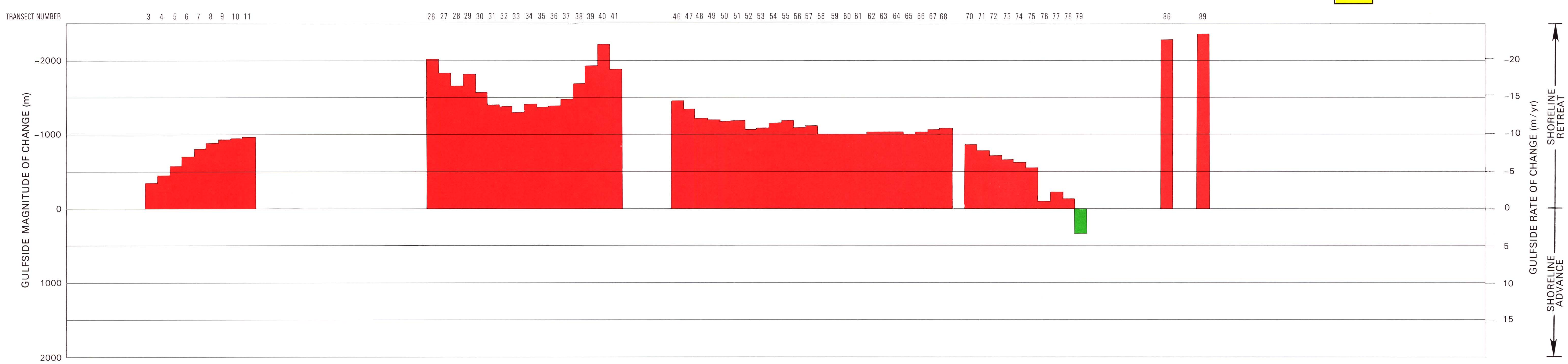
1978

1988

Isles Dernieres







Isles Dernieres

TABLE 3.—*Isles Dernieres bayside magnitude of change (meters)*

Transect #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinate	90° 57′ 45″	30″	15″	90° 57′ 00″	45″	30″	15″	90° 56′ 00″	45″	30″	15″	90° 55′ 00″	45″	30″	15″	90° 54′ 00″	45″	30″	15″	90° 53′ 00″	45″	30″	15″	90° 52′ 00″
Years 1906-1934	n.a.	n.a.	-142	-172	-86	-186	-45	-2	-42	-110	-4	-59	-10	6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	314	181	683	722
1934-1956	-86	-67	-48	-74	-11	-18	-215	-64	-12	-82	-30	-29	-42	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	107	73	21	428
1956-1978	145	-95	-187	-111	-199	-165	185	-68	-10	-4	-6	-14	4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	255
1978-1988	223	314	n.a.	257	89	20	-219	-6	-148	-42	-58	-61	-127	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1906-1988	n.a.	n.a.	n.a.	-100	-207	-349	-294	-140	-212	-238	-98	-163	-175	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

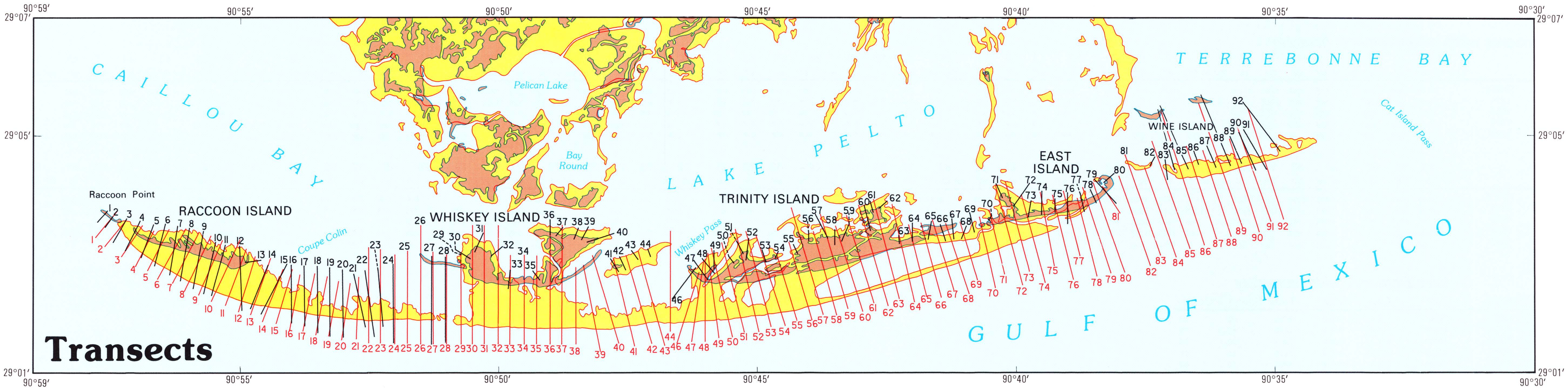
Transect #	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate	45″	30″	15″	90° 51′ 00″	45″	30″	15″	90° 50′ 00″	45″	30″	15″	90° 49′ 00″	45″	30″	15″	90° 48′ 00″	45″	30″	15″	90° 47′ 00″	45″	30″	15″	90° 46′ 00″
Years 1906-1934	614	836	804	672	696	-115	-43	-74	-218	-284	-65	-58	-86	-63	-82	-96	-41	-61	-27	-39	n.a.	-752	-90	-25
1934-1956	n.a.	n.a.	n.a.	n.a.	n.a.	-6	-35	-24	2	207	4	-23	-43	-34	-19	-71	32	-94	-26	-48	n.a.	525	-33	-73
1956-1978	n.a.	n.a.	n.a.	n.a.	n.a.	-10	-7	-7	-8	147	-8	-6	-4	4	-9	-11	-97	-39	-46	n.a.	n.a.	159	-15	-3
1978-1988	n.a.	434	261	228	326	-65	-83	-55	108	219	-27	-65	-44	-75	-94	-190	-20	n.a.	n.a.	n.a.	n.a.	20	-136	-172
1906-1988	n.a.	1879	1606	1603	1619	-196	-168	-160	-116	289	-96	-152	-177	-168	-204	-368	-126	n.a.	n.a.	n.a.	n.a.	-48	-274	-273

Transect #	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Transect coordinate	45″	30″	15″	90° 45′ 00″	45″	30″	15″	90° 44′ 00″	45″	30″	15″	90° 43′ 00″	45″	30″	15″	90° 42′ 00″	45″	30″	15″	90° 41′ 00″	45″	30″	15″
Years 1906 - 1934	-85	-26	-26	-32	-33	-35	-45	-52	-37	-35	-20	-28	-71	-35	-26	-24	-41	-53	-49	-56	-47	-29	-57
1934 - 1956	-72	10	-6	-74	-40	-35	-29	3	-24	-27	-10	-24	-26	-57	-54	-54	-70	-46	-50	-57	-34	-35	-64
1956 - 1978	-73	-12	-27	-24	11	11	16	-8	-4	-5	-5	-3	-4	-3	21	9	22	n.a.	354	288	8	17	-9
1978 - 1988	-149	-124	-201	-187	-73	-63	-48	-58	-168	-110	-243	-99	-114	-166	-21	-61	384	n.a.	33	n.a.	n.a.	-44	-161
1906 - 1988	-379	-152	-260	-317	-135	-122	-106	-115	-233	-177	-278	-154	-215	-261	-80	-130	295	324	288	n.a.	n.a.	-91	-291

Transect #	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Transect coordinate	90° 40′ 00″	45″	30″	15″	90° 39′ 00″	45″	30″	15″	90° 38′ 00″	45″	30″	15″	90° 37′ 00″	45″	30″	15″	90° 36′ 00″	45″	30″	15″	90° 35′ 00″
Years 1906 - 1934	-98	-80	-97	-93	-153	-401	n.a.	-641	n.a.	n.a.	74	74	112	186	227	469	389	689	753	948	n.a.
1934 - 1956	-53	-54	-55	-58	-89	322	162	251	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956 - 1978	17	29	22	29	234	37	57	-6	-12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1978 - 1988	-148	-242	-107	-66	-51	-53	-99	-3	1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1906 - 1988	-282	-347	-237	-188	-59	-95	n.a.	-399	n.a.	n.a.	n.a.	n.a.	1746	1838	n.a.	n.a.	1931	n.a.	n.a.	n.a.	n.a.

Isles Dernieres bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1906 - 1934	-1655	-23.6	237.0	948	-752	70
1934 - 1956	-986	-15.9	104.1	525	-215	62
1956 - 1978	502	8.2	92.3	354	-199	61
1978 - 1988	-2878	-51.4	128.1	384	-243	56
1906 - 1988	-2894	-51.7	474.9	1931	-399	56



Gulfside Transects

Bayside Transects

TABLE 4.—*Isles Dernieres gulfside magnitude of change (meters)*

Transect #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinate	90° 57′ 45″	30″	15″	90° 57′ 00″	45″	30″	15″	90° 56′ 00″	45″	30″	15″	90° 55′ 00″	45″	30″	15″	90° 54′ 00″	45″	30″	15″	90° 53′ 00″	45″	30″	15″	90° 52′ 00″
Years 1887-1934	n.a.	433	215	65	-72	-218	-370	-499	-585	-687	-732	-764	-843	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-816	-745	-805	n.a.
1934-1956	-30	-95	-184	-226	-250	-215	-162	-108	-42	-7	23	-7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-254	-424	-443	n.a.
1956-1978	-140	-65	-97	-94	-94	-111	-105	-140	-147	-150	-144	-316	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-321
1978-1988	-340	n.a.	-282	-193	-154	-156	-159	-137	-145	-82	-125	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1887-1988	n.a.	n.a.	-348	-448	-570	-700	-796	-884	-919	-926	-978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate	45″	30″	15″	90° 51′ 00″	45″	30″	15″	90° 50′ 00″	45″	30″	15″	90° 49′ 00″	45″	30″	15″	90° 48′ 00″	45″	30″	15″	90° 47′ 00″	45″	30″	15″	90° 46′ 00″
Years 1887-1934	-630	-676	-692	-735	-812	-1299	-655	-674	-723	-578	-584	-552	-575	-643	n.a.	n.a.	-948	-1080	-1280	n.a.	n.a.	-651	-600	-558
1934-1956	n.a.	n.a.	n.a.	n.a.	n.a.	-61	-322	-339	-228	-510	-299	-267	-306	-203	n.a.	n.a.	-339	-418	-438	n.a.	n.a.	-380	-278	-221
1956-1978	n.a.	n.a.	n.a.	n.a.	n.a.	-86	-254	-222	-239	-153	-311	-276	-241	-372	-379	-390	-407	-385	-339	n.a.	n.a.	-259	-310	-323
1978-1988	n.a.	-529	-318	-289	-274	-122	-167	-141	-116	-179	-172	-291	-365	-468	-563	-643	-182	n.a.	n.a.	n.a.	n.a.	-162	-153	-109
1887-1988	n.a.	-2019	-1823	-1657	-1814	-1568	-1398	-1376	-1306	-1420	-1366	-1386	-1487	-1686	-1926	-2222	-1876	n.a.	n.a.	n.a.	n.a.	-1452	-1341	-1211

Transect #	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
Transect coordinate	45″	30″	15″	90° 45′ 00″	45″	30″	15″	90° 44′ 00″	45″	30″	15″	90° 43′ 00″	45″	30″	15″	90° 42′ 00″	45″	30″	15″	90° 41′ 00″	45″	30″	15″
Years 1887-1934	-523	-492	-484	-561	-581	-618	-598	-549	-556	-569	-578	-570	-574	-589	-594	-625	-643	-633	-600	-605	-579	-582	-556
1934-1956	-223	-283	-293	-185	-512	-118	-123	-107	-122	-92	-101	-100	-97	-70	-83	-45	-19	-14	-35	-17	-11	13	23
1956-1978	-292	-280	-176	-210	109	-293	-292	-249	-182	-166	-135	-143	-137	-140	-126	-125	-136	-178	-172	n.a.	-178	-116	-66
1978-1988	-150	-120	-230	-115	-99	-133	-177	-186	-253	-167	-178	-176	-177	-221	-223	-230	-203	-197	-252	n.a.	n.a.	-173	-174
1887-1988	-1188	-1175	-1183	-1071	-1083	-1162	-1190	-1091	-1113	-994	-992	-989	-985	-1020	-1026	-1025	-1001	-1022	-1059	-1083	n.a.	-858	-773

Transect #	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Transect coordinate	90° 40′ 00″	45″	30″	15″	90° 39′ 00″	45″	30″	15″	90° 38′ 00″	45″	30″	15″	90° 37′ 00″	45″	30″	15″	90° 36′ 00″	45″	30″	15″	90° 35′ 00″
Years 1887-1934	-501	-449	-442	-394	36	-63	54	592	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-445	-487	-597	-670	-750	-825	n.a.
1934-1956	22	3	-9	-15	-31	-110	-211	-311	-262	-182	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956-1978	-74	-83	-69	-115	-119	-95	-8	89	189	108	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1978-1988	-153	-121	-102	-18	27	60	47	-28	-199	-210	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1887-1988	-706	-650	-622	-542	-87	-208	-118	342	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-2270	n.a.	n.a.	-2348	n.a.	n.a.	n.a.

Isles Dernieres gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-39568	-549.6	309.9	592	-1299	72
1934 - 1956	-10753	-170.7	144.2	23	-512	63
1956 - 1978	-10730	-173.1	124.4	189	-407	62
1978 - 1988	-11547	-192.5	126.6	60	-643	60
1887 - 1988	-67195	-1119.9	527.5	342	-2348	60

See page 46 for explanation of numbers.

Isles Dernieres

TABLE 5.—*Isles Dernieres bayside rate of change (meters per year)*

Transect #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate	90° 57' 45"	30"	15"	90° 57' 00"	45"	30"	15"	90° 56' 00"	45"	30"	15"	90° 55' 00"	45"	30"	15"	90° 54' 00"	45"	30"	15"	90° 53' 00"	45"	30"	15"	90° 52' 00"	45"	30"	15"	90° 51' 00"	45"	30"	15"	90° 50' 00"	45"	30"	15"	90° 49' 00"	45"	30"	15"	90° 48' 00"	45"	30"	15"	90° 47' 00"	45"	30"	15"	90° 46' 00"
Years 1906-1934	n.a.	n.a.	-5.1	-6.1	-3.1	-6.6	-1.6	-0.1	-1.5	-3.9	-0.1	-2.1	-0.4	0.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	11.2	6.5	24.4	25.8	21.9	29.9	28.7	24.0	24.9	-4.1	-1.5	-2.6	-7.8	-10.1	-2.3	-2.1	-3.1	-2.3	-2.9	-3.4	-1.5	-2.2	-1.0	-1.4	n.a.	-26.9	-3.2	-0.9
1934-1956	-3.9	-3.0	-2.2	-3.4	-0.5	-0.8	-9.8	-2.9	-0.5	-3.7	-1.4	-1.3	-1.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4.9	3.3	1.0	19.5	n.a.	n.a.	n.a.	n.a.	n.a.	-0.3	-1.6	-1.1	0.1	9.4	0.2	-1.0	-2.0	-1.5	-0.9	-3.2	1.5	-4.3	-1.2	-2.2	n.a.	23.9	-1.5	-3.3
1956-1978	6.6	-4.3	-8.5	-5.0	-9.0	-7.5	8.4	-3.1	-0.5	-0.2	-0.3	-0.6	0.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	11.6	n.a.	n.a.	n.a.	n.a.	n.a.	-0.5	-0.3	-0.3	-0.4	6.7	-0.4	-0.3	-0.2	0.2	-0.4	-0.5	-4.4	-1.8	-2.1	n.a.	n.a.	7.2	-0.7	-0.1
1978-1988	22.3	31.4	n.a.	25.7	8.9	2.0	-21.9	-0.6	-14.8	-4.2	-5.8	-6.1	-12.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	43.4	26.1	22.8	32.6	-6.5	-8.3	-5.5	10.8	21.9	-2.7	-6.5	-4.4	-7.5	-9.4	-19.0	-2.0	n.a.	n.a.	n.a.	n.a.	2.0	-13.6	-17.2
1906-1988	n.a.	n.a.	n.a.	-1.2	-2.5	-4.3	-3.6	-1.7	-2.6	-2.9	-1.2	-2.0	-2.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	22.9	19.6	19.5	19.7	-2.4	-2.0	-2.0	-1.4	3.5	-1.2	-1.9	-2.2	-2.0	-2.5	-4.5	-1.5	n.a.	n.a.	n.a.	n.a.	-0.6	-3.3	-3.3

Transect #	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Transect coordinate	45"	30"	15"	90° 45' 00"	45"	30"	15"	90° 44' 00"	45"	30"	15"	90° 43' 00"	45"	30"	15"	90° 42' 00"	45"	30"	15"	90° 41' 00"	45"	30"	15"	90° 40' 00"	45"	30"	15"	90° 39' 00"	45"	30"	15"	90° 38' 00"	45"	30"	15"	90° 37' 00"	45"	30"	15"	90° 36' 00"	45"	30"	15"	90° 35' 00"
Years 1906 - 1934	-3.0	-0.9	-0.9	-1.1	-1.2	-1.3	-1.6	-1.9	-1.3	-1.3	-0.7	-1.0	-2.5	-1.3	-0.9	-0.9	-1.5	-1.9	-1.8	-2.0	-1.7	-1.0	-2.0	-3.5	-2.9	-3.5	-3.3	-5.5	-14.3	n.a.	-22.9	n.a.	n.a.	2.6	2.6	4.0	6.6	8.1	16.8	13.9	24.6	26.9	33.9	n.a.
1934 - 1956	-3.3	0.5	-0.3	-3.4	-1.8	-1.6	-1.3	0.1	-1.1	-1.2	-0.5	-1.1	-1.2	-2.6	-2.5	-2.5	-3.2	-2.1	-2.3	-2.6	-1.5	-1.6	-2.9	-2.4	-2.5	-2.5	-2.6	-4.0	14.6	7.4	11.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956 - 1978	-3.3	-0.5	-1.2	-1.1	0.5	0.5	0.7	-0.4	-0.2	-0.2	-0.2	-0.1	-0.2	-0.1	1.0	0.4	1.0	n.a.	16.1	13.1	0.4	0.8	-0.4	0.8	1.3	1.0	1.3	10.6	1.7	2.6	-0.3	-0.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1978 - 1988	-14.9	-12.4	-20.1	-18.7	-7.3	-6.3	-4.8	-5.8	-16.8	-11.0	-24.3	-9.9	-11.4	-16.6	-2.1	-6.1	38.4	n.a.	3.3	n.a.	n.a.	-4.4	-16.1	-14.8	-24.2	-10.7	-6.6	-5.1	-5.3	-9.9	-0.3	0.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1906 - 1988	-4.6	-1.9	-3.2	-3.9	-1.6	-1.5	-1.3	-1.4	-2.8	-2.2	-3.4	-1.9	-2.6	-3.2	-1.0	-1.6	3.6	4.0	3.5	n.a.	n.a.	-1.1	-3.5	-3.4	-4.2	-2.9	-2.3	-0.7	-1.2	n.a.	-4.9	n.a.	n.a.	n.a.	n.a.	21.3	22.4	n.a.	n.a.	23.5	n.a.	n.a.	n.a.	n.a.

Isles Dernieres bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1906 - 1934	-59.1	-0.8	8.5	33.9	-26.9	70
1934 - 1956	-62.3	-1.0	3.7	14.6	-9.8	62
1956 - 1978	17.5	0.3	4.1	16.1	-9.0	61
1978 - 1988	-289.6	-5.2	12.8	38.4	-24.3	56
1906 - 1988	-35.3	-0.6	5.8	23.5	-4.9	56

TABLE 6.—*Isles Dernieres width measurements (meters)*

Transect #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate	90° 57' 45"	30"	15"	90° 57' 00"	45"	30"	15"	90° 56' 00"	45"	30"	15"	90° 55' 00"	45"	30"	15"	90° 54' 00"	45"	30"	15"	90° 53' 00"	45"	30"	15"	90° 52' 00"	45"	30"	15"	90° 51' 00"	45"	30"	15"	90° 50' 00"	45"	30"	15"	90° 49' 00"	45"	30"	15"	90° 48' 00"	45"	30"	15"	90° 47' 00"	45"	30"	15"	90° 46' 00"
Years 1890's	n.a.	239	561	677	1037	1261	1426	1334	1358	1482	1498	1305	1013	970	2080	607	669	373	302	331	706	746	616	325	439	170	179	112	263	2801	2677	2066	1520	1044	1738	3203	3084	717	548	536	335	560	620	495	n.a.	767	1916	1854
1934	365	511	687	642	908	1051	848	844	610	784	738	548	199	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	256	560	469	n.a.	422	368	335	58	129	1422	1869	1151	649	431	1055	2585	2467	67	n.a.	n.a.	133	125	68	n.a.	n.a.	883	1108	1214
1956	283	344	390	405	411	826	700	681	562	739	734	495	n.a.	257	510	455	344	261	168	88	75	88	26	113	n.a.	n.a.	n.a.	n.a.	n.a.	1333	1517	781	405	130	758	2301	2157	216	127	47	115	619	533	n.a.	n.a.	495	786	846
1978	50	104	122	135	205	490	537	518	419	595	579	173	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	38	137	128	100	121	172	1240	1228	543	195	123	439	2016	1896	148	99	179	297	145	114	n.a.	n.a.	339	460	521
1988	25	n.a.	33	74	78	308	369	286	221	473	392	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	57	35	59	59	850	980	345	79	128	244	1663	1489	60	92	89	97	n.a.	n.a.	n.a.	n.a.	153	191	260

Transect #	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Transect coordinate	45"	30"	15"	90° 45' 00"	45"	30"	15"	90° 44' 00"	45"	30"	15"	90° 43' 00"	45"	30"	15"	90° 42' 00"	45"	30"	15"	90° 41' 00"	45"	30"	15"	90° 40' 00"	45"	30"	15"	90° 39' 00"	45"	30"	15"	90° 38' 00"	45"	30"	15"	90° 37' 00"	45"	30"	15"	90° 36' 00"	45"	30"	15"	90° 35' 00"
Years 1890's	2040	2121	2170	2672	2364	1838	1865	1811	2824	2134	2299	2090	2137	1899	2638	2289	1350	1193	1021	926	817	860	1054	1870	1686	1193	885	396	581	304	111	n.a.	n.a.	n.a.	79	52	n.a.	419	437	439	537	292	245	189
1934	1394	1541	1656	2013	1747	1184	1213	1236	2204	1623	1624	1485	1506	1964	2010	1622	686	511	378	257	168	463	417	1306	1199	656	405	338	360	143	229	318	186	n.a.	n.a.	n.a.	164	159	196	202	196	198	192	n.a.
1956	1060	1185	1299	1540	743	1026	1052	1093	1940	1393	1497	1354	1403	1858	1831	1526	605	448	272	194	122	446	420	1257	992	463	348	247	130	167	185	179	226	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	238
1978	756	457	817	1300	827	740	767	844	1779	1162	1356	1196	1264	1719	1709	1390	487	283	127	n.a.	250	342	360	1183	922	511	240	151	279	280	351	404	348	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1988	84	221	450	923	634	539	322	364	1137	863	1007	947	839	1435	1359	184	208	127	266	177	n.a.	112	174	164	566	99	111	125	295	256	202	155	137	n.a.	n.a.	n.a.	121	23	n.a.	n.a.	185	n.a.	n.a.	n.a.

Isles Dernieres width summary

Years	Sum	Avg	STD	Total	Range	Count
1890's	100687	1170.8	826.2	3203	52	86
1934	61908	814.6	643.5	2585	58	76
1956	50860	687.3	559.0	2301	26	74
1978	39206	585.2	512.8	2016	38	67
1988	24000	375.0	401.0	1663	23	64

TABLE 7.—*Isles Dernieres gulfside rate of change (meters per year)*

Transect #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate	90° 57' 45"	30"	15"	90° 57' 00"	45"	30"	15"	90° 56' 00"	45"	30"	15"	90° 55' 00"	45"	30"	15"	90° 54' 00"	45"	30"	15"	90° 53' 00"	45"	30"	15"	90° 52' 00"	45"	30"	15"	90° 51' 00"	45"	30"	15"	90° 50' 00"	45"	30"	15"	90° 49' 00"	45"	30"	15"	90° 48' 00"	45"	30"	15"	90° 47' 00"	45"	30"	15"	90° 46' 00"
Years 1887-1934	n.a.	9.2	4.6	1.4	-1.5	-4.6	-7.9	-10.6	-12.4	-14.6	-15.6	-16.3	-17.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-17.4	-15.9	-17.1	n.a.	-13.4	-14.4	-14.7	-15.6	-17.3	-27.6	-13.9	-14.3	-15.4	-12.3	-12.4	-11.7	-12.2	-13.7	n.a.	n.a.	-20.2	-23.0	-27.2	n.a.	n.a.	-13.9	-12.8	-11.9
1934-1956	-1.4	-4.3	-8.4	-10.3	-11.4	-9.8	-7.4	-4.9	-1.9	-0.3	1.0	-0.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-11.5	-19.3	-20.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-2.8	-14.6	-15.4	-10.4	-23.2	-13.6	-12.1	-13.9	-9.2	n.a.	n.a.	-15.4	-19.0	-19.9	n.a.	n.a.	-17.3	-12.6	-10.0
1956-1978	-6.4	-3.0	-4.4	-4.3	-4.3	-5.0	-4.8	-6.4	-6.7	-6.8	-6.5	-14.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-14.6	n.a.	n.a.	n.a.	n.a.	n.a.	-3.9	-11.5	-10.1	-10.9	-7.0	-14.1	-12.5	-11.0	-16.9	-17.2	-17.7	-18.5	-17.5	-15.4	n.a.	n.a.	-11.8	-14.1	-14.7
1978-1988	-34.0	n.a.	-28.2	-19.3	-15.4	-15.6	-15.9	-13.7	-14.5	-8.2	-12.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-52.9	-31.8	-28.9	-27.4	-12.2	-16.7	-14.1	-11.6	-17.9	-17.2	-29.1	-36.5	-46.8	-56.3	-64.3	-18.2	n.a.	n.a.	n.a.	n.a.	-16.2	-15.3	-10.9
1887-1988	n.a.	n.a.	-3.4	-4.4	-5.6	-6.9	-7.9	-8.8	-9.1	-9.2	-9.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-20.0	-18.0	-16.4	-18.0	-15.5	-13.8	-13.6	-12.9	-14.1	-13.5	-13.7	-14.7	-16.7	-19.1	-22.0	-18.6	n.a.	n.a.	n.a.	n.a.	-14.4	-13.3	-12.0

Transect #	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
Transect coordinate	45"	30"	15"	90° 45' 00"	45"	30"	15"	90° 44' 00"	45"	30"	15"	90° 43' 00"	45"	30"	15"	90° 42' 00"	45"	30"	15"	90° 41' 00"	45"	30"	15"	90° 40' 00"	45"	30"	15"	90° 39' 00"	45"	30"	15"	90° 38' 00"	45"	30"	15"	90° 37' 00"	45"	30"	15"	90° 36' 00"	45"	30"	15"	90° 35' 00"
Years 1887-1934	-11.1	-10.5	-10.3	-11.9	-12.4	-13.1	-12.7	-11.7	-11.8	-12.1	-12.3	-12.1	-12.2	-12.5	-12.6	-13.3	-13.7	-13.5	-12.8	-12.9	-12.3	-12.4	-11.8	-10.7	-9.6	-9.4	-8.4	0.8	-1.3	1.1	12.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-9.5	-10.4	-12.7	-14.3	-16.0	-17.6	n.a.
1934-1956	-10.1	-12.9	-13.3	-8.4	-23.3	-5.4	-5.6	-4.9	-5.5	-4.2	-4.6	-4.5	-4.4	-3.2	-3.8	-2.0	-0.9	-0.6	-1.6	-0.8	-0.5	0.6	1.0	1.0	0.1	-0.4	-0.7	-1.4	-5.0	-9.6	-14.1	-11.9	-8.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956-1978	-13.3	-12.7	-8.0	-9.5	5.0	-13.3	-13.3	-11.3	-8.3	-7.5	-6.1	-6.5	-6.2	-6.4	-5.7	-5.7	-6.2	-8.1	-7.8	n.a.	-8.1	-5.3	-3.0	-3.4	-3.8	-3.1	-5.2	-5.4	-4.3	-0.4	4.0	8.6	4.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1978-1988	-15.0	-12.0	-23.0	-11.5	-9.9	-13.3	-17.7	-18.6	-25.3	-16.7	-17.8	-17.6	-17.7	-22.1	-22.3	-23.0	-20.3	-19.7	-25.2	n.a.	n.a.	-17.3	-17.4	-15.3	-12.1	-10.2	-1.8	2.7	6.0	4.7	-2.8	-19.9	-21.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1887-1988	-11.8	-11.6	-11.7	-10.6	-10.7	-11.5	-11.8	-10.8	-11.0	-9.8	-9.8	-9.8	-9.8	-10.1	-10.2	-10.1	-9.9	-10.1	-10.5	-10.7	n.a.	-8.5	-7.7	-7.0	-6.4	-6.2	-5.4	-0.9	-2.1	-1.2	3.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-22.5	n.a.	n.a.	-23.2	n.a.	n.a.	n.a.

Isles Dernieres gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-841.9	-11.7	6.6	12.6	-27.6	72
1934 - 1956	-488.8	-7.8	6.6	1.0	-23.3	63
1956 - 1978	-487.7	-7.9	5.7	8.6	-18.5	62
1978 - 1988	-1154.7	-19.2	12.7	6.0	-64.3	60
1887 - 1988	-665.3	-11.1	5.2	3.4	-23.2	60

EXPLANATION

Description of shoreline change data

1439	Shoreline advance or island width as measured at points subject to the influence of entrances (e.g., tidal inlets, bayous, bays, etc.)
158	Shoreline advance or island width as measured at points not subject to the influence of entrances
0	Black zeroes, italicized or non-italicized, represent no shoreline movement
-345	Shoreline retreat as measured at points not subject to the influence of entrances
-942	Shoreline retreat as measured at points subject to the influence of entrances

Abbreviations in shoreline change data tables

n.a.	No shoreline data exist because of entrance location
n.a.	No bayside shoreline exists (e.g., headland areas)
n.d.	No survey exists or maps unavailable

Isles Dernieres

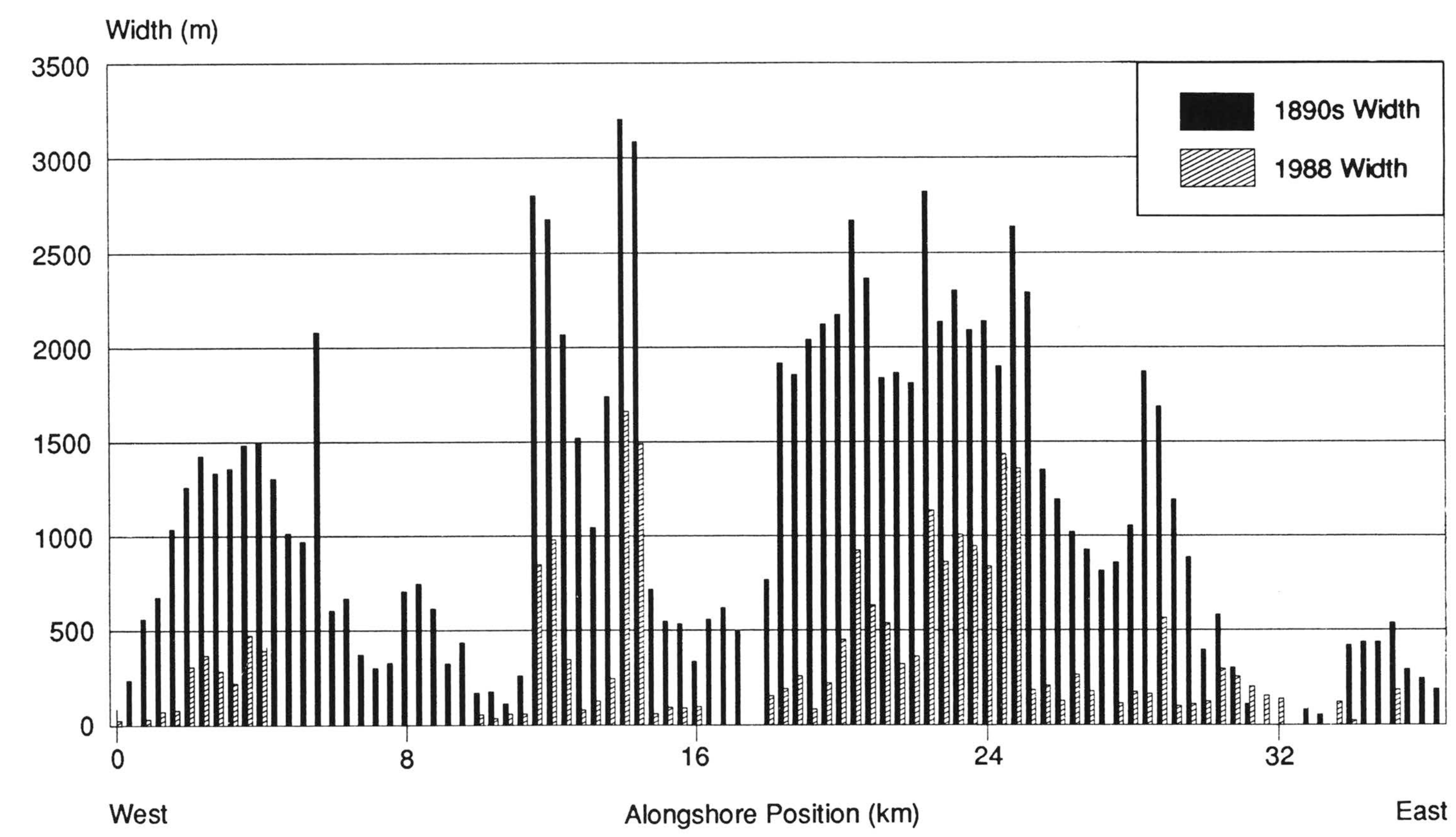


FIGURE 9.—Comparison of the 1890's and 1988 barrier widths for Isles Dernieres.

TABLE 8.—Area changes for Isles Dernieres from the 1890's to 1988

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1890's	3,532				
1934	1,958	-1,574	-45%	-35.8	1989
1934	1,958				
1956	1,458	-500	-26%	-22.7	2020
1956	1,458				
1978	1,243	-215	-15%	-9.8	2105
1978	1,243				
1988	771	-472	-38%	-47.2	2004
1890's	3,532				
1988	771	-2,761	-78%	-28.2	2015

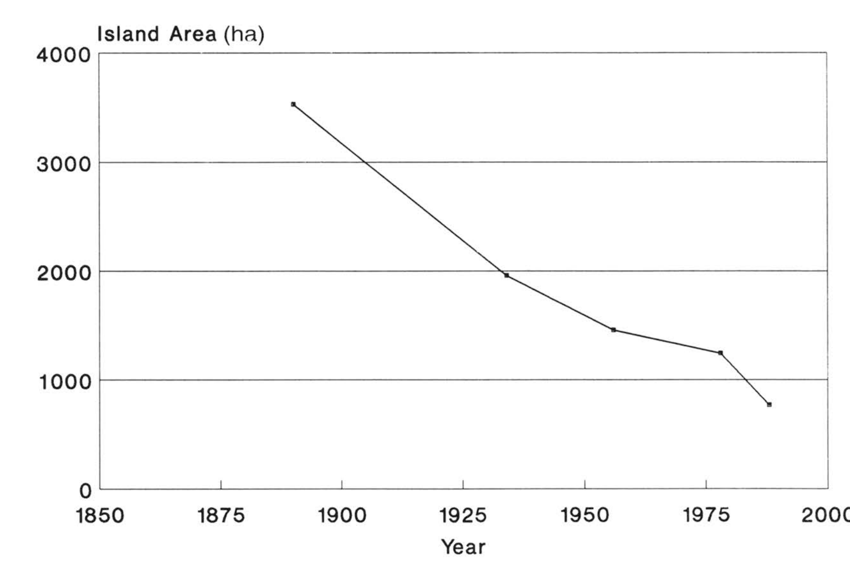


FIGURE 10.—Area change for Isles Dernieres between the 1890's and 1988.

Bayou Lafourche Barrier System

The Bayou Lafourche barrier system lies about 75 km west of the mouth of the Mississippi River and about 80 km south of New Orleans. The system encompasses Timbalier and East Timbalier islands, Caminada-Moreau Headland, and Grand Isle (fig. 1). The shoreline is approximately 65 km long and extends east from Cat Island Pass to Barataria Pass (chapter 1, fig. 11). Timbalier and East Timbalier islands, and Grand Isle are downdrift flanking barrier islands located to the west and east, respectively, of the Caminada-Moreau erosional headland. These islands range from 0.2 to 1.2 km wide. Cat Island Pass, Little Pass Timbalier, Raccoon Pass, Belle Pass, Caminada Pass, and Barataria Pass connect the Gulf of Mexico to Terrebonne, Timbalier, Caminada, and Barataria bays. Belle Pass represents the distal end of the abandoned Bayou Lafourche distributary system. The Bayou Lafourche barrier system is dominated by landward and lateral movement. Inadequate sediment supply, subsidence, and storm and human impacts are the major factors causing shoreline change in this region (Mossa and others, 1985; Penland and others, 1986; Ritchie and Penland, 1988; McBride, 1989b).

The Bayou Lafourche shoreline is divided into two sections: the Timbalier Islands and the Caminada-Moreau Headland and Grand Isle. The Timbalier Islands extend east from Cat Island Pass to Belle Pass and consist of Timbalier and East Timbalier islands (Peyronnin, 1962; Kwon, 1969; Isacks, 1989). The Caminada-Moreau Headland and Grand Isle extend from Raccoon Pass to Barataria Pass (Kwon, 1969; Conaster, 1971; Harper, 1977; Gerdes, 1982; Shamban, 1982; Jeffrey, 1984; Combe and Soileau, 1987; Ritchie and Penland, 1990a, b). Maps presented show shoreline change for both sections in the years 1887, 1934, 1956, 1978, and 1988. From these maps, magnitude of shoreline movement, width, and island area measurements were obtained, and rates of change were calculated to determine the extent and rapidity of change to the barrier system.

Timbalier Islands—1887 to 1988

Morphology

The Timbalier Islands have experienced more lateral morphological change than any other island in Louisiana. In 1887, the barrier shoreline included Caillou, Timbalier, and East Timbalier islands (1887 map). At that time, Caillou Pass separated Caillou and Timbalier islands. In 1934, Caillou Pass was partially blocked by the westward lateral migration of Timbalier Island; Little Pass Timbalier was much wider; and Raccoon Pass consisted of a series of breaches (1934 map). By 1956, Timbalier Island completely shielded Caillou Pass, and Caillou Pass evolved into a back-barrier channel (1956 map). Timbalier Island continued to migrate west while other areas only experienced land loss because of mangrove die-offs during the hard freezes of 1983 and 1985 (1978 and 1988 maps).

Shoreline Movement

Comparisons of shoreline position are made for the periods 1887 vs. 1934, 1934 vs. 1956, 1956 vs. 1978, 1978 vs. 1988, and 1887 vs. 1988. Shoreline position and barrier width were monitored at 164 shore-normal transects along the gulf and bay shorelines (transects map; tables 9, 10, 11, 12, and 13).

Timbalier and East Timbalier islands were examined separately to provide a more accurate representation of barrier shoreline response to dominant coastal processes. Both islands formed as a result of lateral spit accretion and breaching; however, once formed, the mechanisms by which they migrated differed. Washover processes caused East Timbalier Island to rapidly migrate landward. In contrast, Timbalier Island continued migrating west in response to local processes (wind and waves). Therefore, the western end of the island grows laterally at the expense of erosion on the eastern end. Moreover, the dominance of lateral migration was enhanced by the width and elevation of the west-central portion of Timbalier Island, which inhibited washover processes from transporting sediment across the island to the bay shoreline.

Timbalier Island

Along its gulf side, Timbalier Island generally exhibits a lower average rate of change because erosion on the east and accretion on the west cancel each other. More importantly, Timbalier Island is rapidly migrating west while its length slowly decreases (table 14). The average rate of change for Timbalier Island between 1887 and 1934 along the gulf shoreline was only -1.4 m/yr; the average bayside rate of change was -2.9 m/yr. (tables 11 and 13). This average gulfside rate of change decreased slightly to -1.2 m/yr, while the average bayside rate of seaward-directed movement decreased slightly to -2.1 m/yr. Between 1956 and 1978, the gulf shoreline migrated landward at an increased average rate of -3.1 m/yr and then increased over twofold to -7.0 m/yr between 1978 and 1988 (fig. 11). For the period 1956 to 1978, the average bayside rate further decreased to -1.3 m/yr; however, between 1978 and 1988, the average rate escalated over tenfold to -14.1 m/yr (fig. 12). The rate of change along the bay indicates a net seaward movement, causing the gulf and bay sides to converge slowly.

East Timbalier Island

Rates of gulf and bayside movement are much higher along East Timbalier Island than Timbalier Island and, in fact, are the highest in the United States. The average gulfside rate of change for East Timbalier Island was -44.4 m/yr between 1887 and 1934 but decreased by about eightfold to -5.5 m/yr between 1934 and 1956 (table 13). Since 1956, the average rate of shoreline retreat has increased steadily to -16.2 m/yr and -21.2 m/yr for the periods 1956 vs. 1978 and 1978 vs. 1988, respectively (fig. 13).

Along the bay side, the average rate of change decreased continuously from 45.1 to 18.3, 15.8, and -1.2 m/yr for the periods 1887 vs. 1934, 1934 vs. 1956, 1956 vs. 1978, and 1978 vs. 1988, respectively (fig. 14, table 11). This suggests a slow reversal in the natural and human processes along the back-barrier shoreline. Washover processes probably swept sand across the island and caused the bay shoreline to migrate landward at a rate consistent with gulfside retreat. At some point, after the construction of seawalls on the island in the late 1950's, this natural process was terminated, and the bay shoreline experienced recession.

Timbalier Islands Summary

The average change rate along the gulf shoreline was -16.3 m/yr between 1887 and 1934, but decreased -3.8 m/yr between 1934 and 1956 (table 13). Migration increased steadily for the periods 1956 vs. 1978 and 1978 vs. 1988 (fig. 15). The rate of change along the bay shoreline was net progradational at 12.4 m/yr between 1887 and 1934 (table 11). This rate declined by half to 5.6 m/yr for the period 1934 vs. 1956 and raised slightly to 7.1 m/yr between 1956 and 1978. For the period 1978 to 1988, bayside change remained relatively constant at -7.8 m/yr; however, a reversal in direction resulted in extensive changes in back-barrier morphology (fig. 16).

The 1887 vs. 1988 map presents cumulative shoreline position changes for the Timbalier Islands shoreline. The gulf shoreline of the Timbalier Islands experienced landward movement, except for the western end of Timbalier Island which exhibited lateral accretion. Gulfside change rates were highest along East Timbalier Island and the eastern end of Timbalier Island.

The magnitude and direction of bay shoreline movement depends on island width and geomorphology, with low and narrow areas exhibiting the greatest change. The western end of Timbalier Island is undergoing lateral migration by spit-building processes at the expense of erosion along the eastern end. Between 1887 and 1988, the eastern and western ends of Timbalier Island migrated rapidly to the west (table 14).

Area and Width Change

Area change becomes more meaningful along the Timbalier Islands because of the dominance of lateral versus cross-shore sediment transport. Extreme amounts of lateral migration characterize Timbalier Island; therefore, area and width measurements are probably better indicators of change than data derived from shore-normal transects.

Timbalier Island

In 1887, the average width of Timbalier Island was 1,341 m, and by 1934, the barrier island narrowed to 946 m (table 12). Between 1887 and 1934, the rate of area change was -8.8 ha/yr (table 15). The average width of Timbalier Island decreased to 916 m by 1956. Between 1956 and 1978, the island grew at a rate of 3.8 ha/yr; however, island width decreased to 850 m by 1978. This land gain indicates that, while narrowing, Timbalier Island increased its length by spit processes. For the period 1978 to 1988, Timbalier Island experienced rapid land loss (fig. 17). During this period, island width decreased by over 50 percent to result in an average width of 415 m. This trend will eventually lead to fragmentation because storms easily overwash and breach inlets across narrow islands.

The average width of Timbalier Island decreased 926 m between 1887 and 1988, an average island narrowing rate of 9.2 m/yr (fig. 18). During the period, the area of Timbalier Island decreased from 1,485 to 542 ha (fig. 19, table 15).

East Timbalier Island

East Timbalier has experienced extreme changes in island area and width. In 1887, its width ranged from 80 to 649 m, with an average width of 283 m (table 12). The rate of area change between 1887 and 1934 was -2.1 ha/yr (fig. 20, table 16). By 1934, the width ranged between 94 and 441 m, with an average width that narrowed to 248 m. The rate of area change increased to 14.5 ha/yr between 1934 and 1956 to result in land gain. By 1956, average island width dramatically increased to 506 m with a range between 118 and 1,240 m. Land gain continued between 1956 and 1978 but slowed to 3.7 ha/yr. This land gain was reflected in a continual increase to 547 m wide by 1978. Island area showed a sharp decline between 1978 and 1988 with a loss of 257 ha, a 52 percent decrease at an average rate of -25.7 ha/yr.

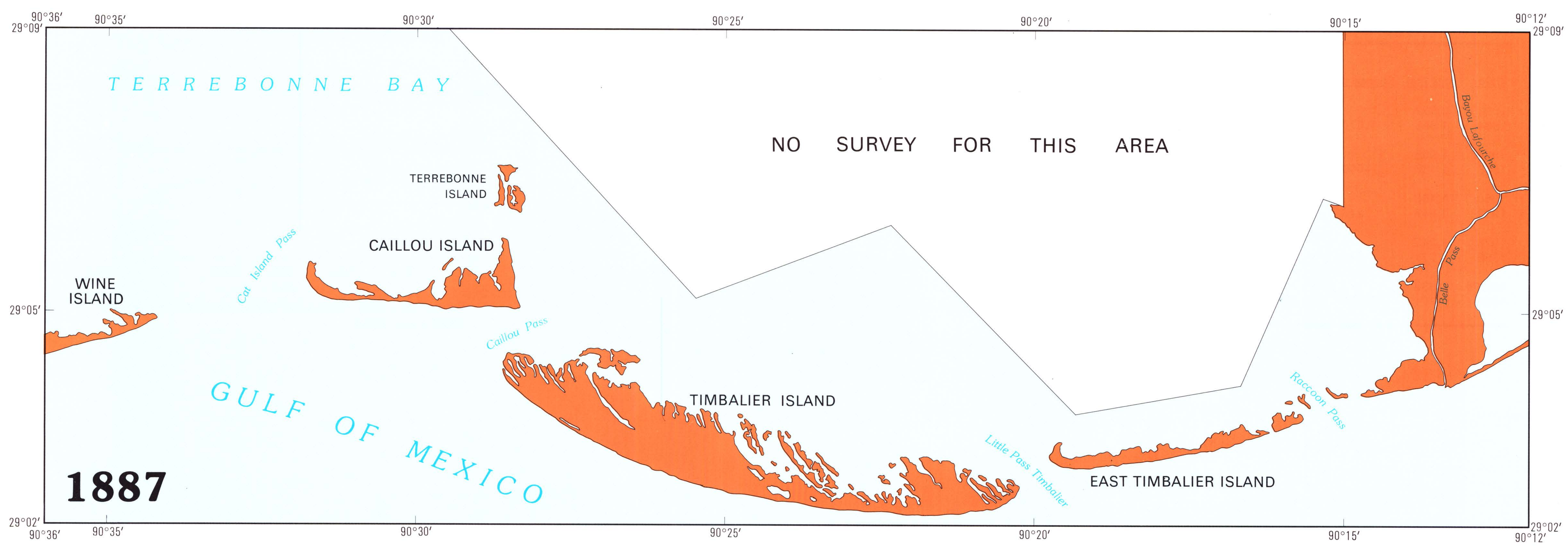
Average width along East Timbalier Island increased from 283 m in 1887 to 333 m in 1988 (fig. 21, table 12). This represents an average widening of 0.5 m/yr. Likewise, the island exhibited a slight area increase between 1887 and 1988, with major fluctuations (fig. 22). Overall, East Timbalier Island has conserved land area to show a slight land gain (table 16).

Timbalier Islands Summary

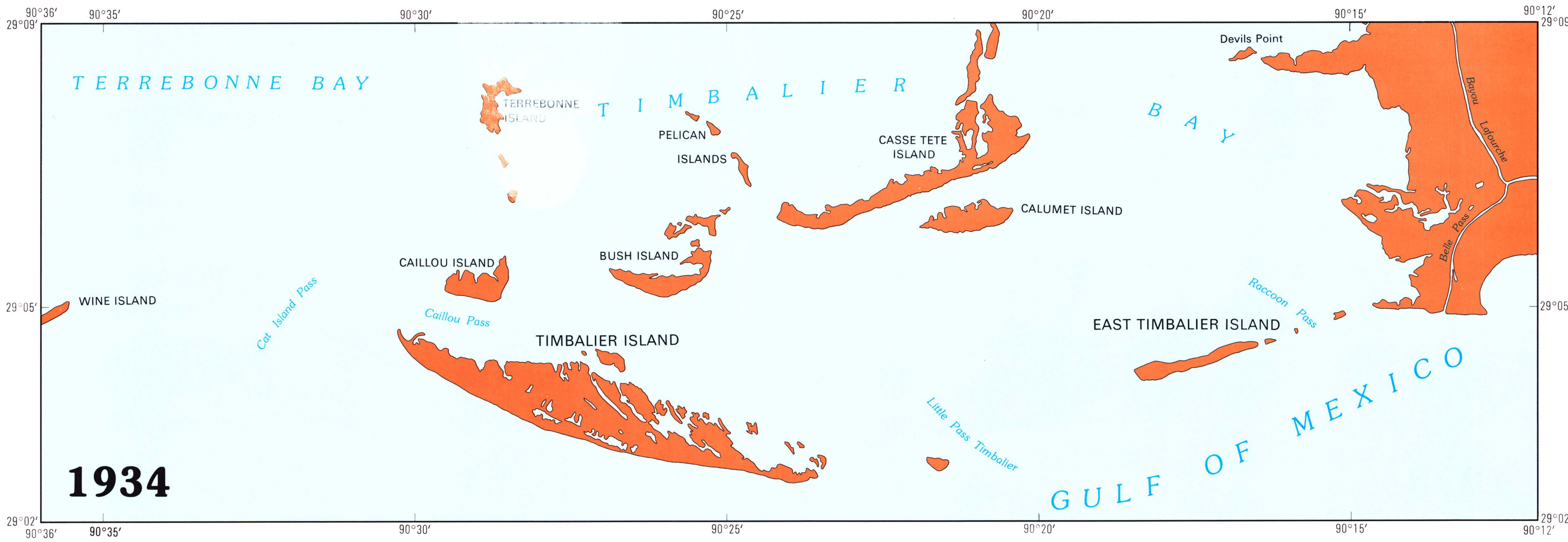
In 1887, island width along the Timbalier Islands ranged between 80 and 2,355 m, with an average width of 945 m (table 12). By 1934, average width narrowed to between 94 and 1,906 m with an average width of 756 m. The average rate of area change for this period was -10.9 ha/yr (table 17). The average rate of area change reversed from land loss to land gain between 1934 and 1956 to 7.5 ha/yr, stabilized at 7.6 ha/yr between 1956 and 1978 but dramatically increased -71.5 ha/yr between 1978 and 1988 (fig. 23). The average width of the barrier islands decreased continuously from 1956 to 1988 (fig. 24). Although barrier width narrowed between 1934 and 1978, the islands experienced land gain because rapid lateral spit accretion is capable of depositing sediment faster than the narrowing process can remove it. High land loss rates occurred between 1978 and 1988 primarily because Hurricanes Danny and Juan struck the area in 1985 (Case, 1986). During this short time, 715 ha were lost.

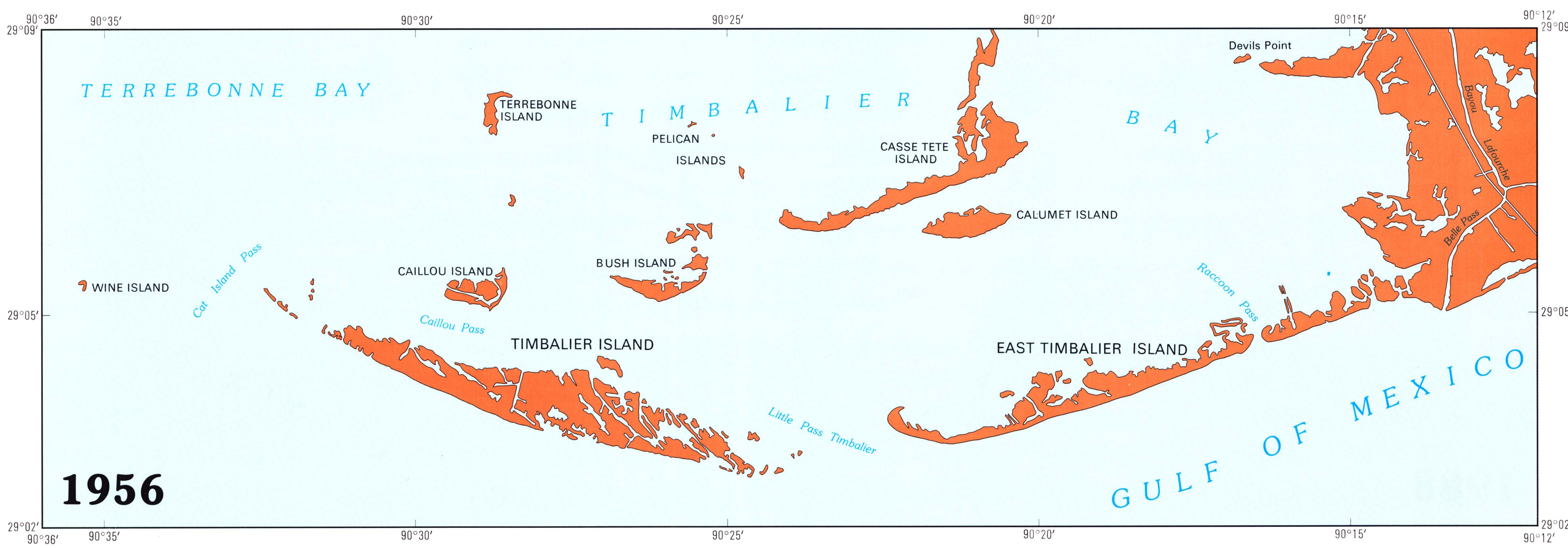
Combined area of the Timbalier Islands has decreased 897 ha from 1887 to 1988 (fig. 24, table 17). Shoreline changes between 1887 and 1988 along the gulf and bay shorelines caused the Timbalier Islands to narrow 5.6 m/yr (fig. 25, table 12). Barrier island widths for 1887 and 1988 are shown in figure 26.

• Historic Shorelines •

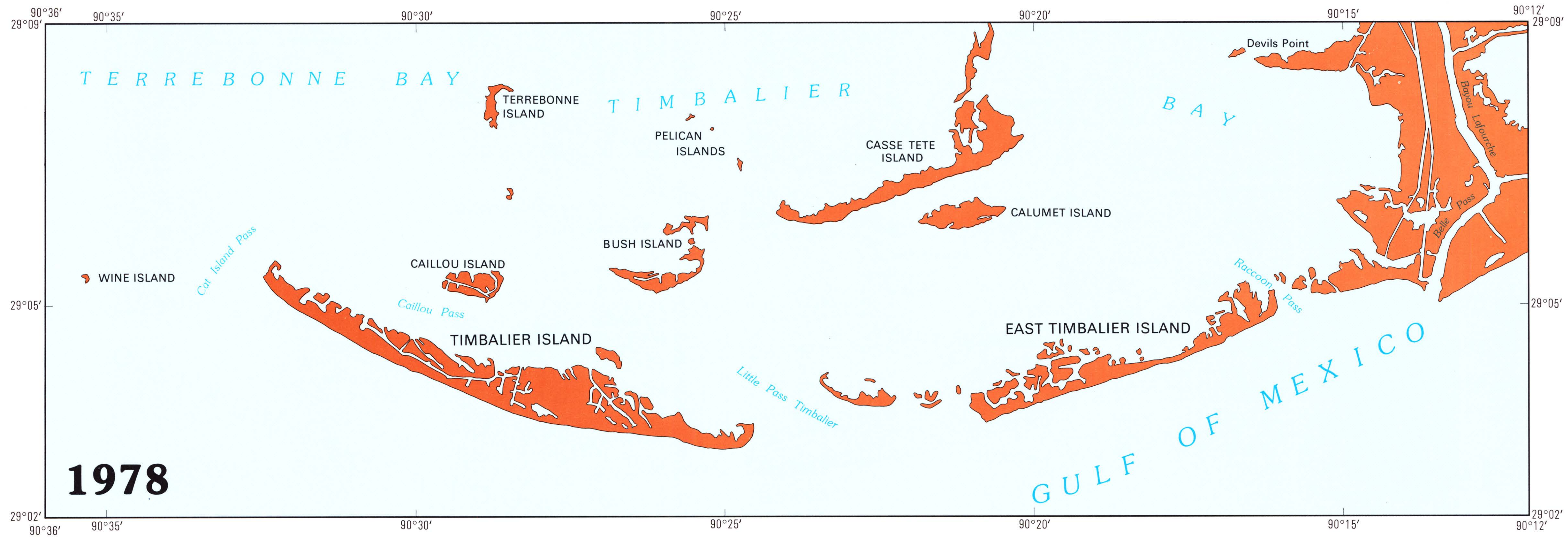


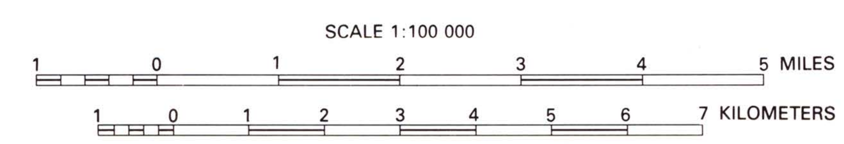
Timbalier Islands

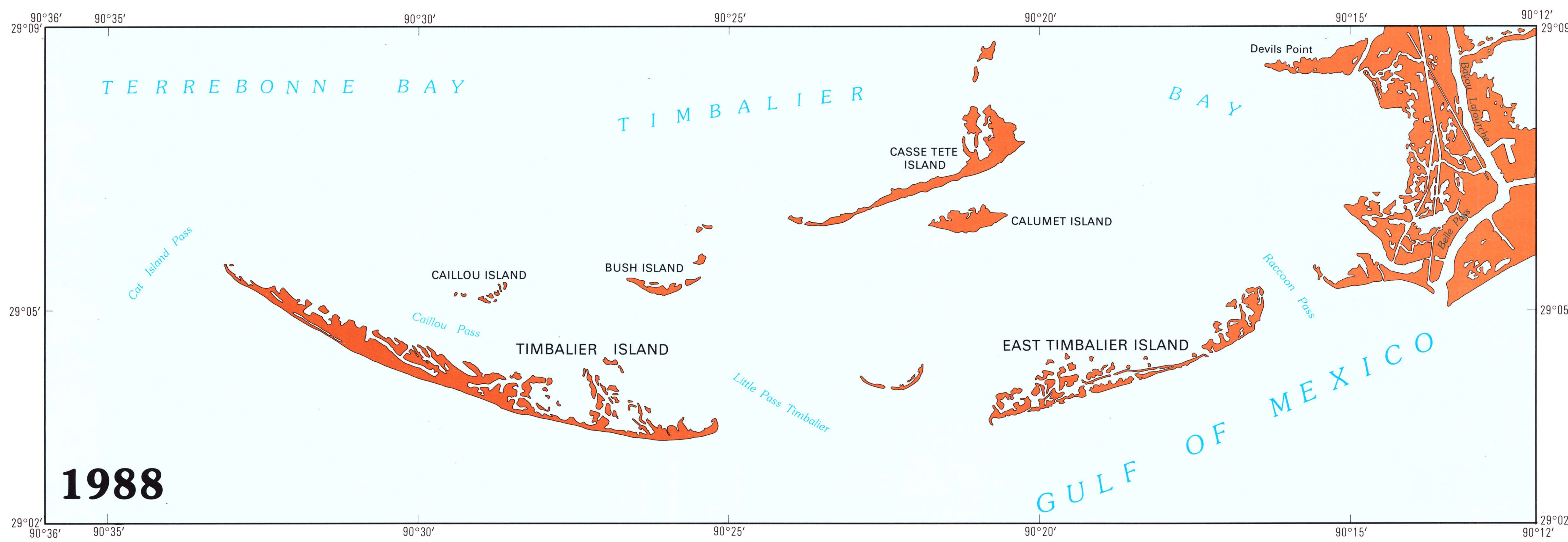




Timbalier Islands







Timbalier Islands

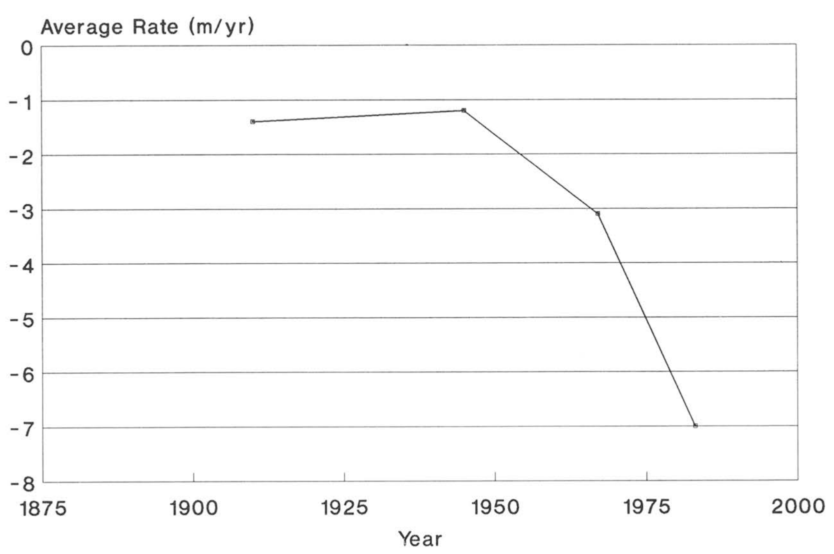


FIGURE 11.—Average gulfside rate of change between 1887 and 1988 along Timbalier Island.

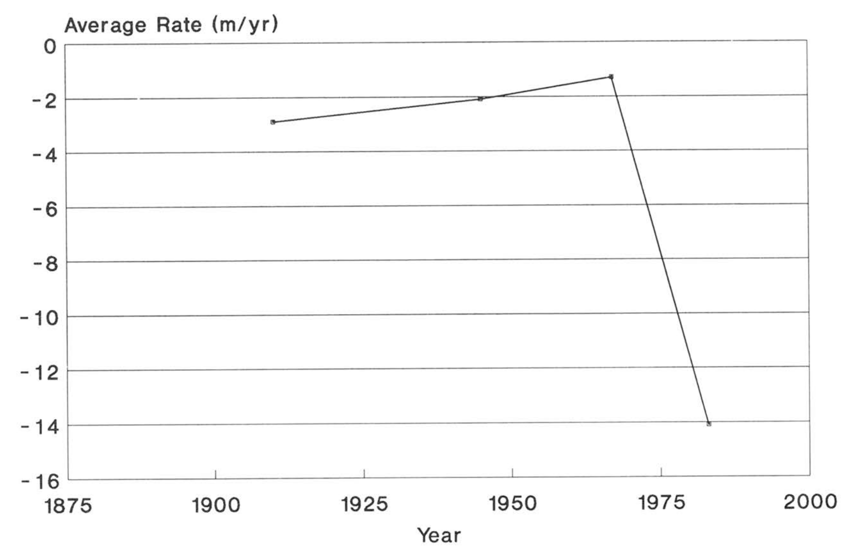


FIGURE 12.—Average bayside rate of change between 1887 and 1988 along Timbalier Island.

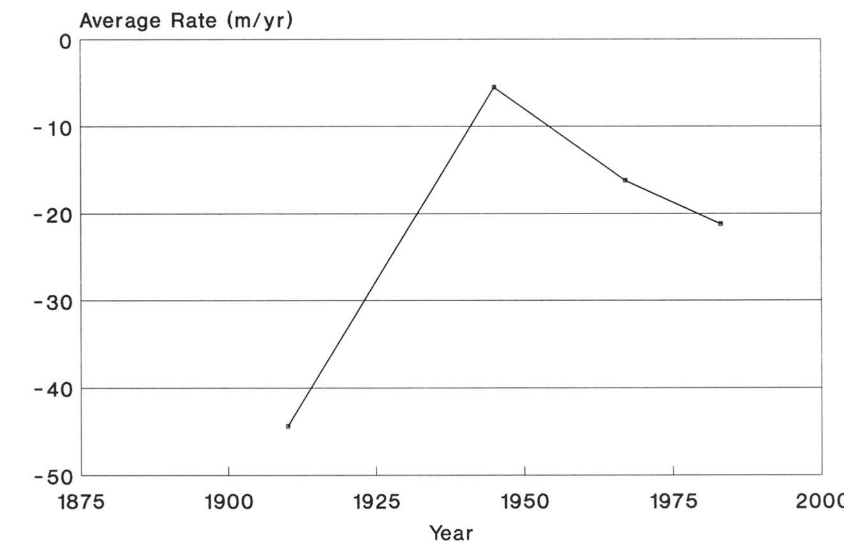


FIGURE 13.—Average gulfside rate of change between 1887 and 1988 along East Timbalier Island.

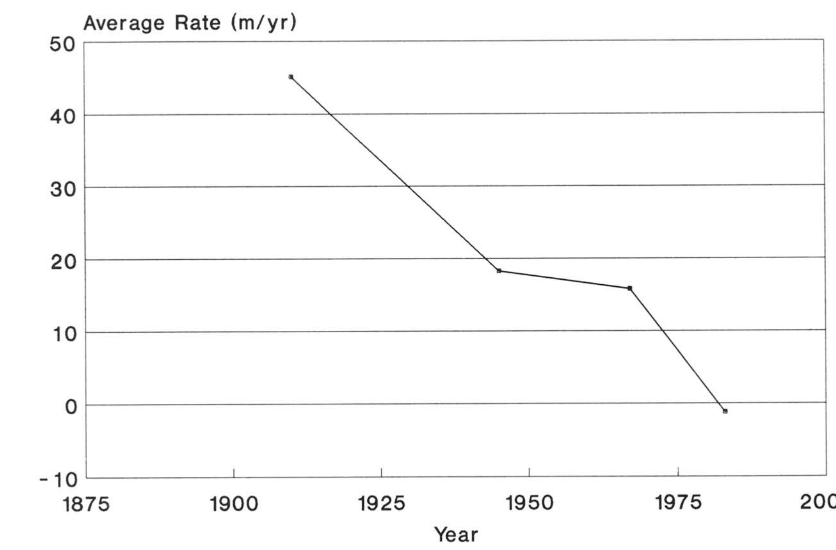


FIGURE 14.—Average bayside rate of change between 1887 and 1988 along East Timbalier Island.

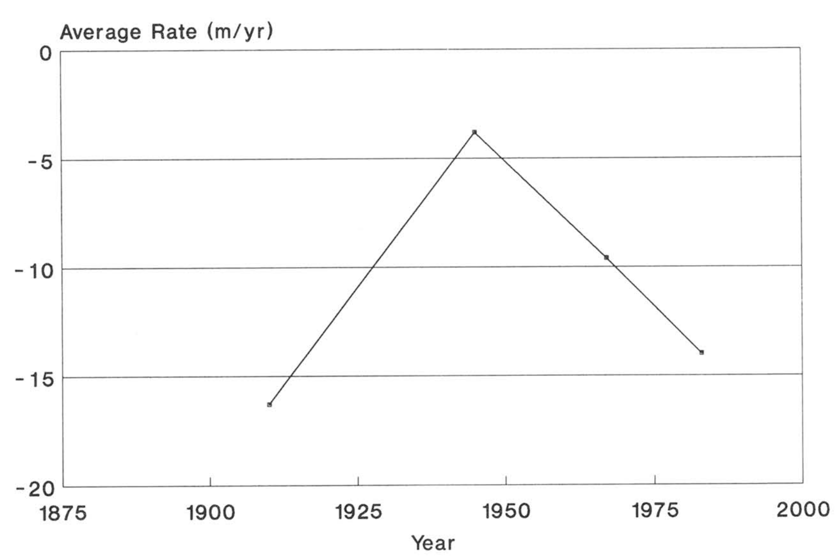


FIGURE 15.—Average gulfside rate of change between 1887 and 1988 along the Timbalier Islands shoreline.

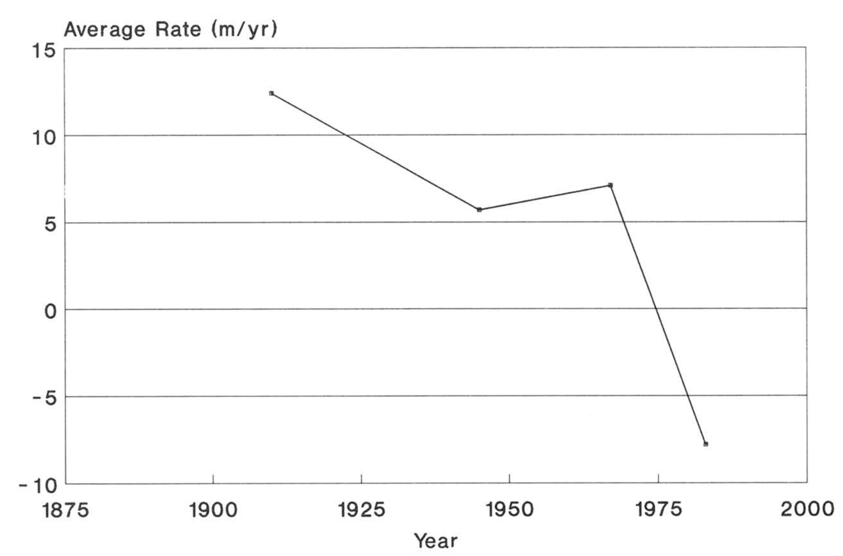


FIGURE 16.—Average bayside rate of change between 1887 and 1988 along the Timbalier islands shoreline.

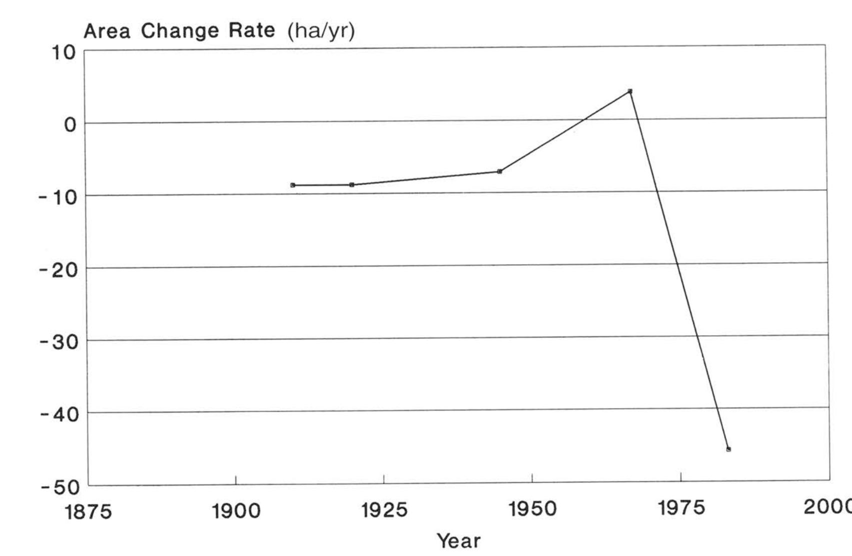


FIGURE 17.—Rate of area change between 1887 and 1988 of Timbalier Island.

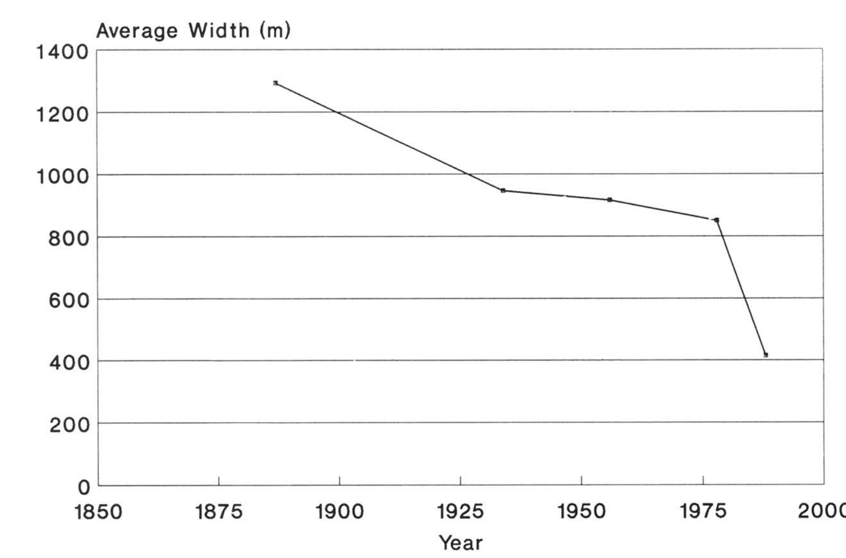


FIGURE 18.—Average barrier width between 1887 and 1988 of Timbalier Island.

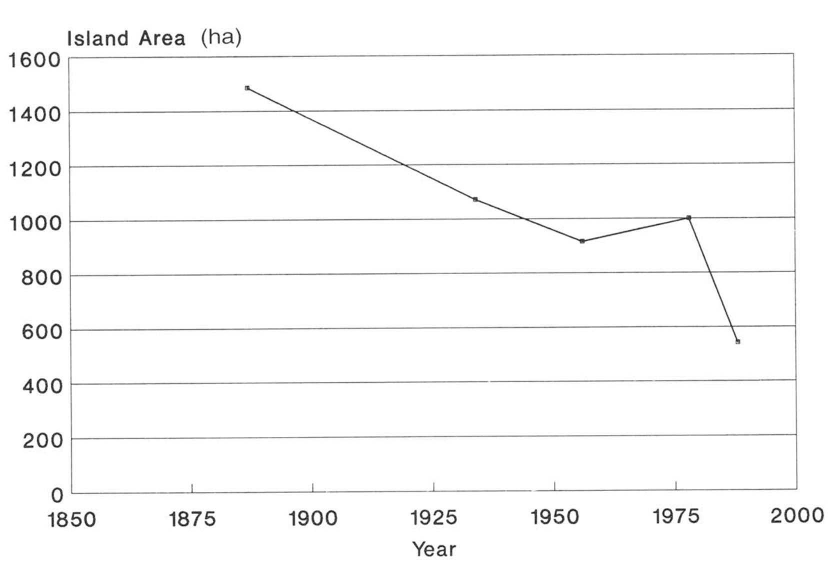


FIGURE 19.—Area changes of Timbalier Island between 1887 and 1988.

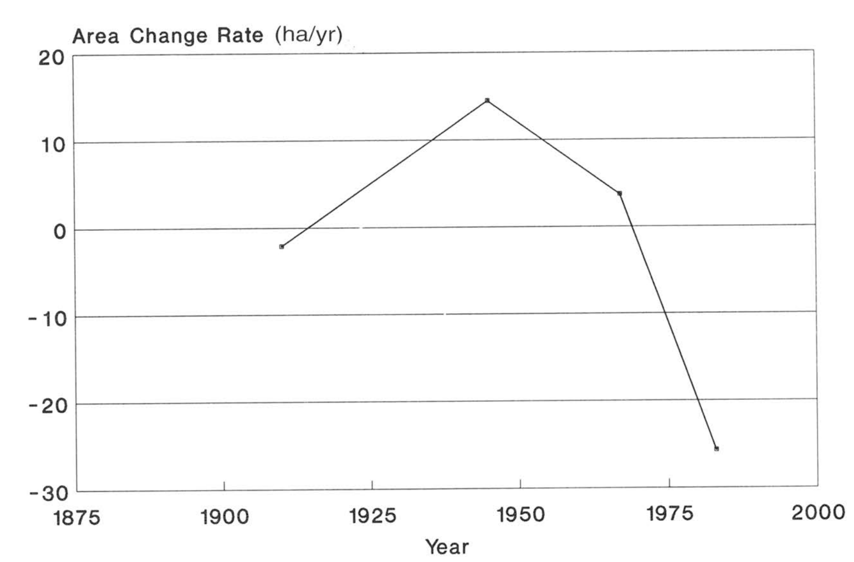


FIGURE 20.—Rate of area change between 1887 and 1988 for East Timbalier Island.

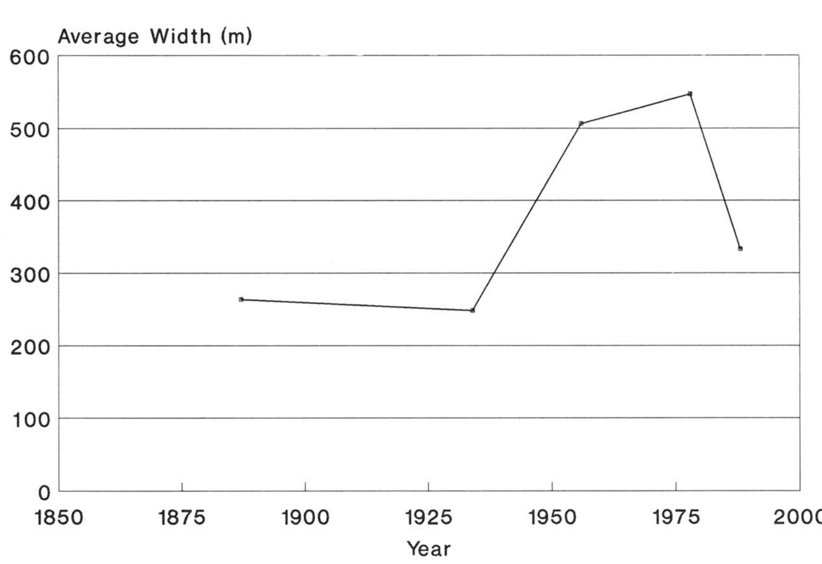


FIGURE 21.—Average barrier width between 1887 and 1988 for East Timbalier Island.

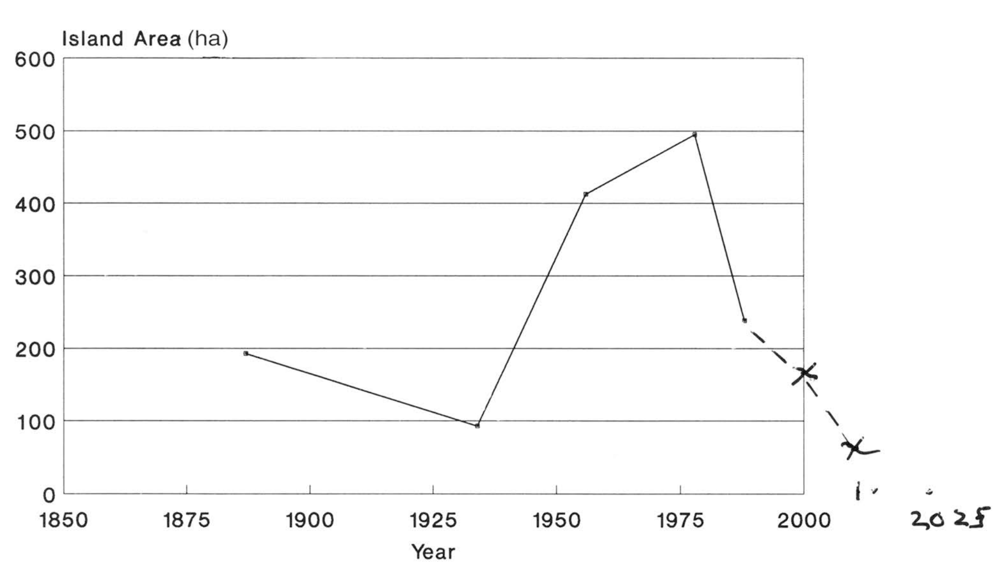
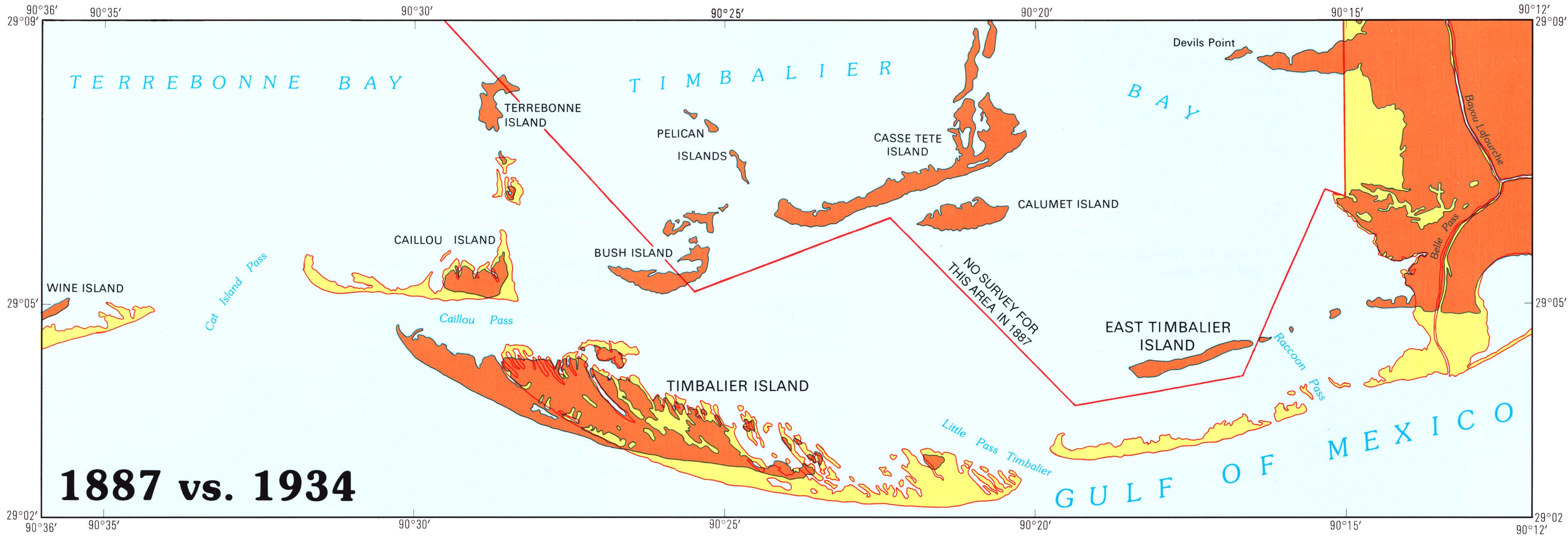


FIGURE 22.—Area changes of East Timbalier Island between 1887 and 1988.

Timbalier Islands

• Shoreline Change and Land Loss •



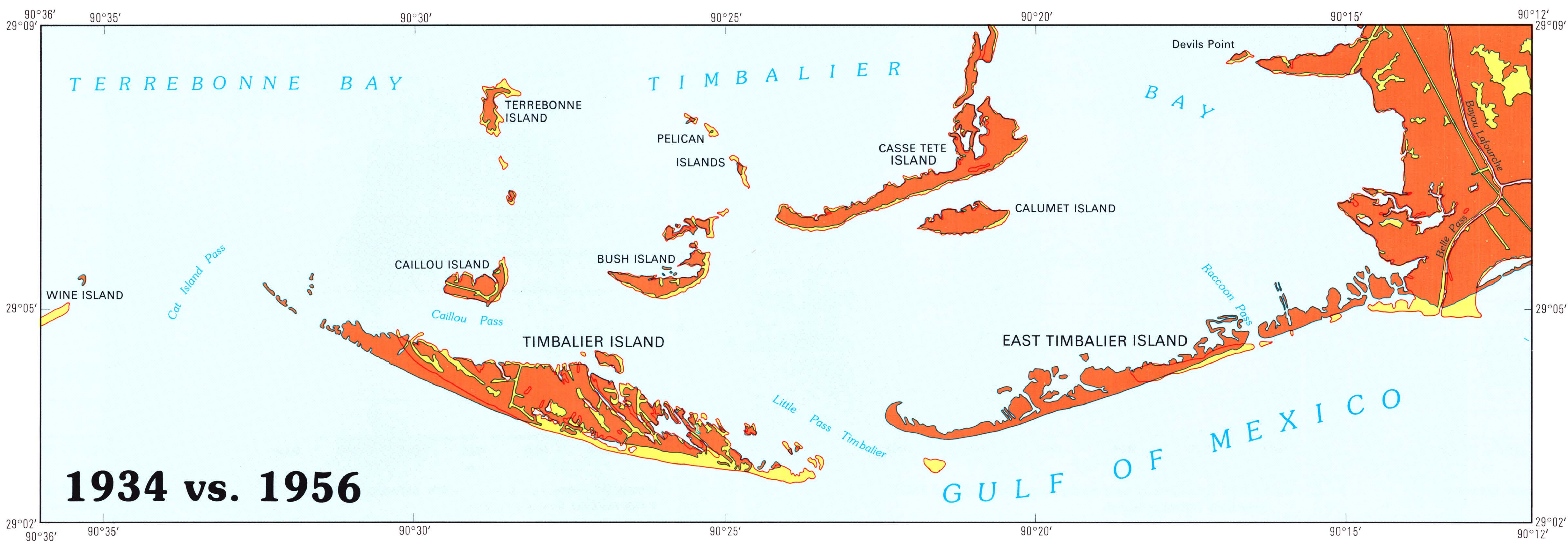
1887

1934

SCALE 1:100 000

1 0 1 2 3 4 5 MILES

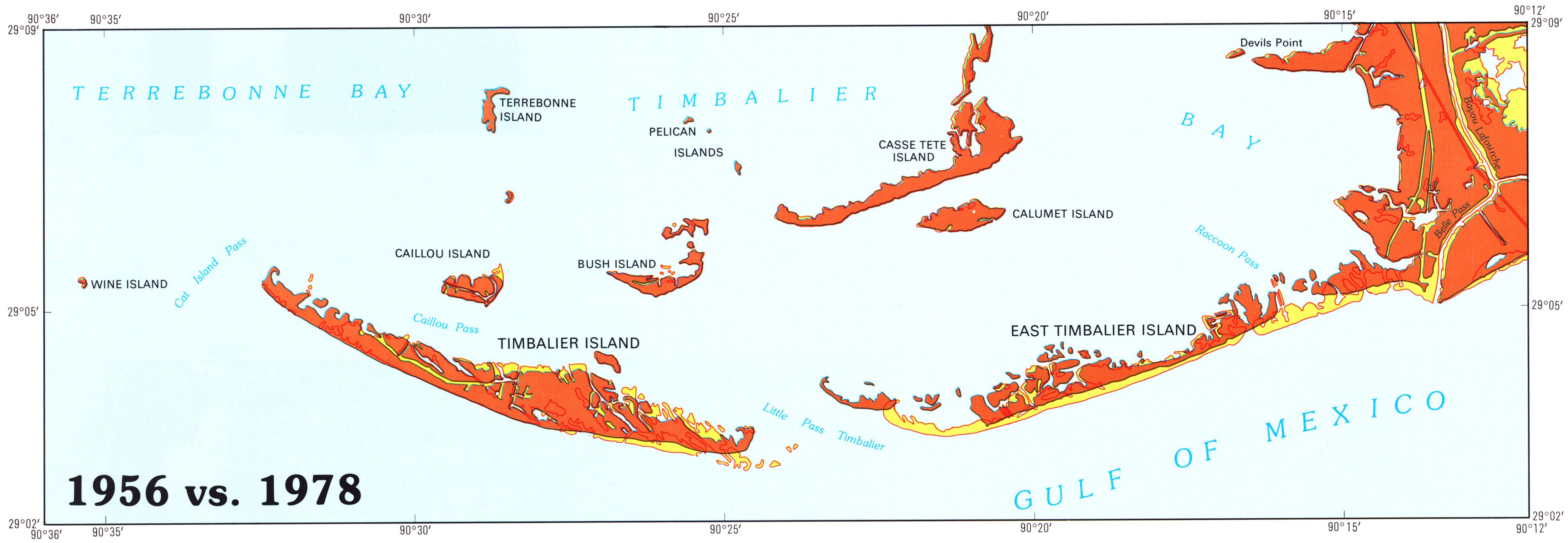
1 0 1 2 3 4 5 6 7 KILOMETERS



1934

1956

Timbalier Islands

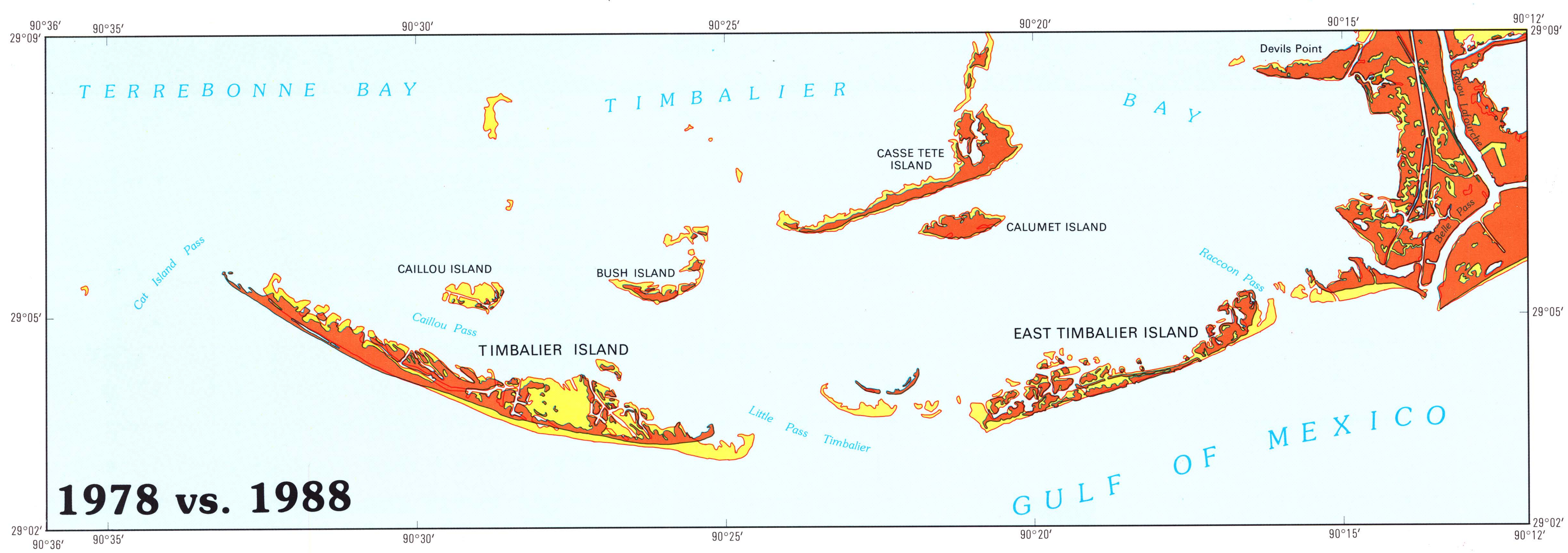


1956

1978

Land

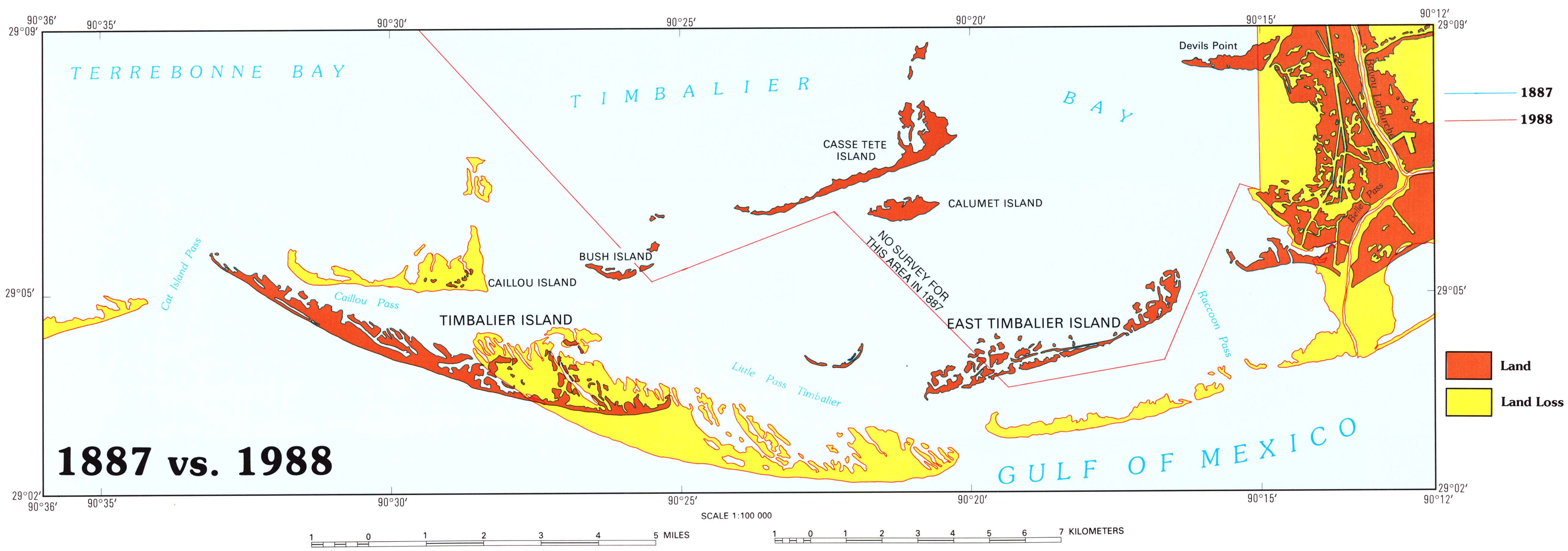
Land Loss

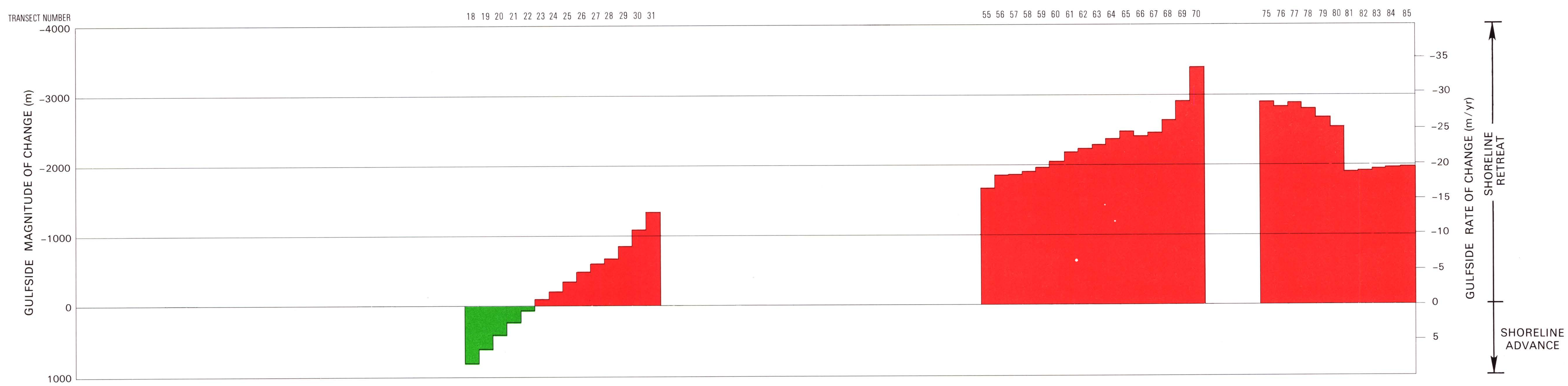


1978

1988

Timbalier Islands





Timbalier Islands

TABLE 9.—*Timbalier Islands bayside magnitude of change (meters)*

Transect #	1	2	3	4	5	6	7	8	9	10	11	12
Transect coordinates	90° 33' 00"	45"	30"	15"	90° 32' 00"	45"	30"	15"	90° 31' 00"	45"	30"	15"
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-127	-134
1956 - 1978	n.a.	n.a.	182	320	586	n.a.	343	30	269	58	43	-4
1978 - 1988	n.a.	n.a.	-76	-116	-402	-230	-170	34	-476	-130	-146	-368
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinates	90° 30' 00"	45"	30"	15"	90° 29' 00"	45"	30"	15"	90° 28' 00"	45"	30"	15"
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-270	-328	-84	-31	-163	-106
1934 - 1956	-58	-55	-106	-46	-49	-14	-54	-73	-16	-50	-33	-17
1956 - 1978	12	6	-6	-4	-10	-8	-194	-11	-208	-170	-136	-162
1978 - 1988	-52	-7	-20	-15	-25	-238	-9	-190	-158	-1227	-363	-81
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-527	-602	-466	-1478	-695	-366

Transect #	25	26	27	28	29	30	31	32	33	34	35	36
Transect coordinates	90° 27' 00"	45"	30"	15"	90° 26' 00"	45"	30"	15"	90° 25' 00"	45"	30"	15"
Years 1887 - 1934	-120	-100	-196	-40	24	-203	-52	-216	-10	-178	-169	-174
1934 - 1956	-10	12	54	-1	-23	-6	-7	-249	6	-4	n.a.	62
1956 - 1978	-12	-13	-331	-13	-507	-165	-401	-547	19	140	n.a.	n.a.
1978 - 1988	-2	-39	-118	-143	-8	10	27	522	n.a.	n.a.	n.a.	n.a.
1887 - 1988	-144	-140	-591	-197	-514	-364	-433	-490	n.a.	n.a.	n.a.	n.a.

Transect #	37	38	39*	40*	41*	42*	43*	44*	45*	46*	47*	48*
Transect coordinates	90° 24' 00"	45"	30"	15"	90° 23' 00"	45"	30"	15"	90° 22' 00"	45"	30"	15"
Years 1887 - 1934	-136	-101	-204	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1934 - 1956	-186	-60	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956 - 1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	72	571	434	769	968
1978 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	411	268	363	n.a.	n.a.	n.a.	n.a.
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #	49*	50*	51*	52*	53	54	55	56	57	58	59	60
Transect coordinates	90° 21' 00"	45"	30"	15"	90° 20' 00"	45"	30"	15"	90° 19' 00"	45"	30"	15"
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2132
1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	57
1956 - 1978	n.a.	n.a.	n.a.	1012	745	311	-76	495	-5	166	-62	242
1978 - 1988	n.a.	n.a.	n.a.	n.a.	-133	-42	-66	-613	-85	-117	-10	-31
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1768	2239	2092	2210	1954	2400

Transect #	61	62	63	64	65	66	67	68	69	70	71	72
Transect coordinates	90° 18' 00"	45"	30"	15"	90° 17' 00"	45"	30"	15"	90° 16' 00"	45"	30"	15"
Years 1887 - 1934	2119	2089	2188	2026	1981	2019	2267	2236	n.a.	n.a.	n.a.	n.a.
1934 - 1956	-41	11	170	381	454	783	763	785	n.a.	n.a.	n.a.	n.a.
1956 - 1978	-6	17	-109	-12	4	-41	7	324	n.a.	652	825	715
1978 - 1988	-16	-16	-38	-231	-37	-12	-16	-347	-3	n.a.	n.a.	n.a.
1887 - 1988	2056	2101	2130	2164	2402	2749	3021	2998	3302	n.a.	n.a.	n.a.

Transect #	73	74	75	76	77	78	79	80	81	82	83	84	85
Transect coordinates	90° 15' 00"	45"	30"	15"	90° 14' 00"	45"	30"	15"	90° 13' 00"	45"	30"	15"	90° 12' 00"
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a	1657	1475	-43	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1934 - 1956	n.a.	671	n.a.	n.a.	969	1124	27	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956 - 1978	898	116	710	322	172	388	57	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1978 - 1988	232	281	-25	-10	8	20	23	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1887 - 1988	n.a.	n.a.	2908	2753	2806	3007	64	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Timbalier Island bayside summary

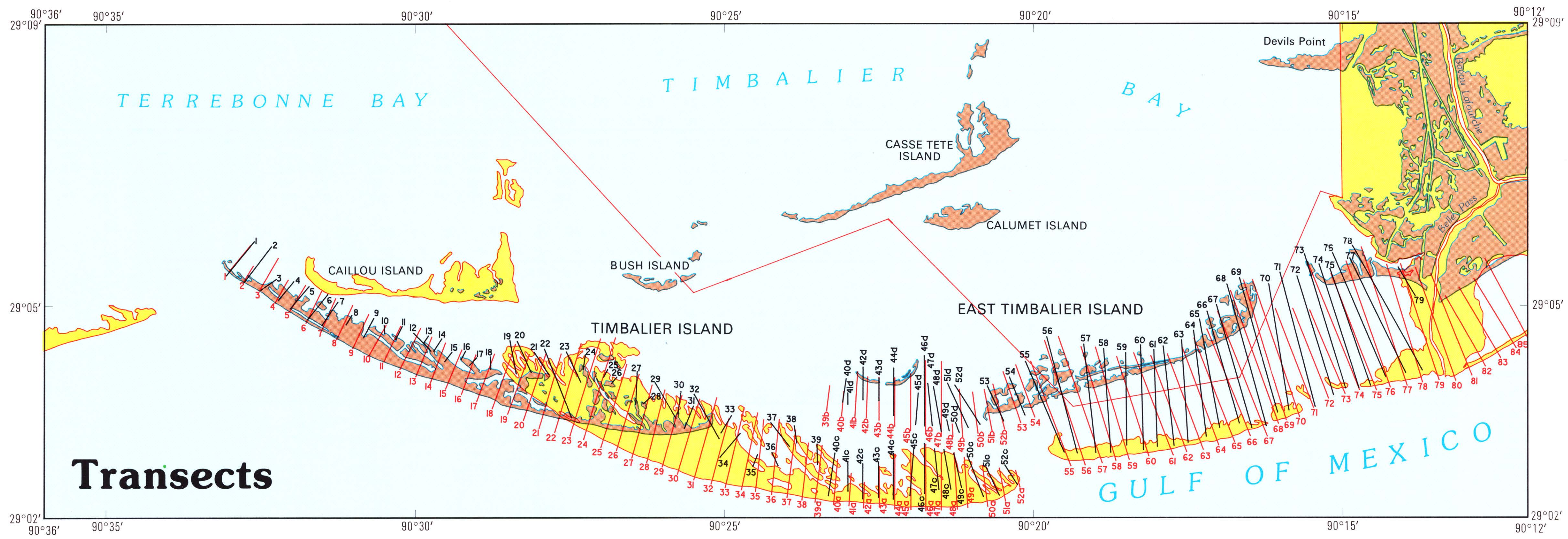
Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-2857	-136.0	85.7	24	-328	21
1934 - 1956	-1244	-46.1	66.5	62	-249	27
1956 - 1978	-894	-28.8	232.7	586	-547	31
1978 - 1988	-4216	-140.5	267.5	522	-1227	30
1887 - 1988	-7007	-500.5	316.7	-140	-1478	14

East Timbalier Island bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	19057	2117.4	93.7	2267	1981	9
1934 - 1956	4034	403.4	319.3	785	-41	10
1956 - 1978	10064	347.0	358.9	1012	-109	29
1978 - 1988	-293	-12.2	214.2	411	-613	24
1887 - 1988	41247	2426.3	429.9	3302	1768	17

Timbalier Islands bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	19289	584.5	1024.3	2267	-328	33
1934 - 1956	4910	122.8	332.6	1124	-249	40
1956 - 1978	9787	155.3	347.2	1012	-547	63
1978 - 1988	-4458	-78.2	247.7	522	-1227	57
1887 - 1988	40117	1179.9	1511.9	3302	-1478	34



Gulfside Transects

Bayside Transects

EXPLANATION
(Timbalier Islands only)
Description of shoreline change data

1439 Shoreline advance or island width as measured at points subject to the influence of entrances (e.g., tidal inlets, bayous, bays, etc.)

158 Shoreline advance or island width as measured at points not subject to the influence of entrances

0 Black zeroes, italicized or non-italicized, represent no shoreline movement

-345 Shoreline retreat as measured at points not subject to the influence of entrances

-942 Shoreline retreat as measured at points subject to the influence of entrances

* Portions of the same transect used to represent different islands as a result of rapid lateral island migration
- a—1887 through 1934 gulfside and width measurements only
- b—1956 through 1988 gulfside and width measurements only
- c—1887 through 1934 bayside measurements only
- d—1956 through 1988 bayside measurements only

Abbreviations in shoreline change data tables

n.a. No shoreline data exist because of entrance location
n.a. No bayside shoreline exists (e.g., headland areas)
n.d. No survey exists or maps unavailable

TABLE 10.—*Timbalier Islands gulfside magnitude of change (meters)*

Transect #	1	2	3	4	5	6	7	8	9	10	11	12
Transect coordinates	90° 33' 00"	45"	30"	15"	90° 32' 00"	45"	30"	15"	90° 31' 00"	45"	30"	15"
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	n.a.
1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	758	421
1956 - 1978	n.a.	n.a.	12	15	20	n.a.	18	78	73	76	58	40
1978 - 1988	n.a.	n.a.	276	134	109	115	97	112	120	83	60	28
1887 - 1988	n.a.	n.a	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinates	90° 30 00"	45"	30"	15"	90° 29' 00"	45"	30"	15"	90° 28' 00"	45"	30"	15"
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	853	685	615	517	381	284	192
1934 - 1956	322	266	210	139	105	107	69	-19	-84	-77	-94	-130
1956 - 1978	6	6	12	6	4	14	7	14	16	-31	-77	-85
1978 - 1988	1	-63	-110	-120	-145	-165	-157	-206	-227	-227	-188	-159
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	809	604	404	222	46	-75	-182

Transect #	25	26	27	28	29	30	31	32	33	34	35	36
Transect coordinates	90° 27' 00"	45"	30"	15"	90° 26' 00"	45"	30"	15"	90° 25' 00"	45"	30"	15"
Years 1887 - 1934	141	44	-71	-119	-202	-308	-395	-444	-494	-479	-426	-430
1934 - 1956	-212	-250	-280	-289	-272	-253	-321	-156	-90	-30	-183	-316
1956 - 1978	-105	-131	-155	-164	-221	-173	-52	-237	-352	-836	n.a.	n.a.
1978 - 1988	-140	-122	-72	-80	-129	-323	-540	n.a.	n.a.	n a.	n.a.	n.a.
1887 - 1988	-316	-459	-578	-652	-824	-1057	-1308	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #	37	38	39*	40*	41*	42*	43*	44*	45*	46*	47*	48*
Transect coordinates	90° 24' 00"	45"	30"	15"	90° 23' 00"	45"	30"	15"	90° 22' 00"	45"	30"	15"
Years 1887 - 1934	-389	-521	-866	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956 - 1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-531	n.a.	-623	-836	n.a.
1978 - 1988	n.a.	n.a.	n.a.	n.a.	-845	-663	-649	-480	n.a.	n.a.	n.a.	n.a.
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #	49*	50*	51*	52*	53	54	55	56	57	58	59	60
Transect coordinates	90° 21' 00"	45"	30"	15"	90° 20' 00"	45"	30"	15"	90° 19' 00"	45"	30"	15"
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	n.a.	n.a.	n.a.	n.a.	n.a.
1956 - 1978	-1014	-531	-133	-196	-220	-208	-200	-222	-250	-253	-256	-232
1978 - 1988	n.a.	n.a.	-272	-142	-98	-19	-65	-74	-1	25	38	46
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-1647	-1826	-1850	-1883	-1949	-2017

Transect #	61	62	63	64	65	66	67	68	69	70	71	72
Transect coordinates	90° 18' 00"	45"	30"	15"	90° 17' 00"	45"	30"	15"	90° 16' 00"	45"	30"	15"
Years 1887 - 1934	-2021	-1972	-2055	-2124	-2133	-2120	-2138	-2119	-2103	n.a.	n.a.	n.a.
1934 - 1956	57	-47	-43	-79	-123	-153	-139	-305	-243	n.a.	n.a.	n.a.
1956 - 1978	-221	-203	-118	-107	-123	-94	-198	-91	-197	-335	-463	-1148
1978 - 1988	26	15	-40	-44	-71	-17	35	-106	-336	-765	n.a.	n.a.
1887 - 1988	-2159	-2207	-2256	-2354	-2450	-2384	-2440	-2621	-2879	-3368	n.a.	n.a.

Transect #	73	74	75	76	77	78	79	80	81	82	83	84	85
Transect coordinates	90° 15' 00"	45"	30"	15"	90° 14' 00"	45"	30"	15"	90° 13' 00"	45"	30"	15"	90° 12' 00'
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	-2011	-1928	-1883	-1808	-1568	-1437	-1206	-1942	-2150
1934 - 1956	n.a.	-133	n.a.	n.a.	-368	-593	-446	-311	-291	-401	-616	158	362
1956 - 1978	-720	-513	-527	-280	-243	-107	-256	-320	-14	-36	-79	-125	-115
1978 - 1988	n.a.	-846	-106	-279	-243	-157	-80	-76	-12	-36	-28	-41	-61
1887 - 1988	n.a.	n.a.	-2876	-2826	-2865	-2785	-2665	-2515	-1885	-1910	-1929	-1950	-1964

Timbalier Island gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-1432	-65.1	455.0	853	-866	22
1934 - 1956	-659	-25.3	256.9	758	-321	26
1956 - 1978	-2144	-69.2	173.2	78	-836	31
1978 - 1988	-2038	-70.3	165.2	276	-540	29
1887 - 1988	-3366	-240.4	600.0	809	-1308	14

East Timbalier Island gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-18785	-2087.2	54.8	-1972	-2138	9
1934 - 1956	-1208	-120.8	97.6	57	-305	10
1956 - 1978	-11043	-356.2	268.6	-91	-1148	31
1978 - 1988	-5733	-212.3	287.5	46	-846	27
1887 - 1988	-41992	-2332.9	439.8	-1647	-3368	18

Timbalier Islands gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-36150	-903.8	1002.0	853	-2150	40
1934 - 1956	-4373	-97.2	263.0	758	-616	45
1956 - 1978	-14482	-204.0	253.7	78	-1148	71
1978 - 1988	-8505	-130.8	227.8	276	-846	65
1887 - 1988	-65826	-1605.5	1099.7	809	-3368	41

Timbalier Islands

TABLE 11.—*Timbalier Islands bayside rate of change (meters per year)*

Transect #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinates	90° 33′ 00″	45″	30″	15″	90° 32′ 00″	45″	30″	15″	90° 31′ 00″	45″	30″	15″	90° 30′ 00″	45″	30″	15″	90° 29′ 00″	45″	30″	15″	90° 28′ 00″	45″	30″	15″
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−5.7	−7.0	−1.8	−0.7	−3.5	−2.3
1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−5.8	−6.1	−2.6	−2.5	−4.8	−2.1	−2.2	−0.6	−2.5	−3.3	−0.7	−2.3	−1.5	−0.8
1956 - 1978	n.a.	n.a.	8.3	14.5	26.6	n.a.	15.6	1.4	12.2	2.6	2.0	−0.2	0.5	0.3	−0.3	−0.2	−0.5	−0.4	−8.8	−0.5	−9.5	−7.7	−6.2	−7.4
1978 - 1988	n.a.	n.a.	−7.6	−11.6	−40.2	−23.0	−17.0	3.4	−47.6	−13.0	−14.6	−36.8	−5.2	−0.7	−2.0	−1.5	−2.5	−23.8	−0.9	−19.0	−15.8	−122.7	−36.3	−8.1
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−5.2	−6.0	−4.6	−14.6	−6.9	−3.6

Transect #	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39*	40*	41*	42*	43*	44*	45*	46*	47*	48*
Transect coordinates	90° 27′ 00″	45″	30″	15″	90° 26′ 00″	45″	30″	15″	90° 25′ 00″	45″	30″	15″	90° 24′ 00″	45″	30″	15″	90° 23′ 00″	45″	30″	15″	90° 22′ 00″	45″	30″	15″
Years 1887 - 1934	−2.6	−2.1	−4.2	−0.9	0.5	−4.3	−1.1	−4.6	−0.2	−3.8	−3.6	−3.7	−2.9	−2.1	−4.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1934 - 1956	−0.5	0.5	2.5	0	−1.0	−0.3	−0.3	−11.3	0.3	−0.2	n.a.	2.8	−8.5	−2.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956 - 1978	−0.5	−0.6	−15.0	−0.6	−23.0	−7.5	−18.2	−24.9	0.9	6.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.3	26.0	19.7	35.0	44.0
1978 - 1988	−0.2	−3.9	−11.8	−14.3	−0.8	1.0	2.7	52.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	41.1	26.8	36.3	n.a.	n.a.	n.a.	n.a.
1887 - 1988	−1.4	−1.4	−5.9	−2.0	−5.1	−3.6	−4.3	−4.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #	49*	50*	51*	52*	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
Transect coordinates	90° 21′ 00″	45″	30″	15″	90° 20′ 00″	45″	30″	15″	90° 19′ 00″	45″	30″	15″	90° 18′ 00″	45″	30″	15″	90° 17′ 00″	45″	30″
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	45.4	45.1	44.4	46.6	43.1	42.1	43.0	48.2
1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.6	−1.9	0.5	7.7	17.3	20.6	35.6	34.7
1956 - 1978	n.a.	n.a.	n.a.	46.0	33.9	14.1	−3.5	22.5	−0.2	7.5	−2.8	11.0	−0.3	0.8	−5.0	−0.5	0.2	−1.9	0.3
1978 - 1988	n.a.	n.a.	n.a.	n.a.	−13.3	−4.2	−6.6	−61.3	−8.5	−11.7	−1.0	−3.1	−1.6	−1.6	−3.8	−23.1	−3.7	−1.2	−1.6
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	17.5	22.2	20.7	21.9	19.3	23.8	20.4	20.8	21.1	21.4	23.8	27.2	29.9

Transect #	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
Transect coordinates	15″	90° 16′ 00″	45″	30″	15″	90° 15′ 00″	45″	30″	15″	90° 14′ 00″	45″	30″	15″	90° 13′ 00″	45″	30″	15″	90° 12′ 00″
Years 1887 - 1934	47.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	35.3	31.4	−0.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1934 - 1956	35.7	n.a.	n.a.	n.a.	n.a.	n.a.	30.5	n.a.	n.a.	44.0	51.1	1.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956 - 1978	14.7	n.a.	29.6	37.5	32.5	40.8	5.3	32.3	14.6	7.8	17.6	2.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1978 - 1988	−34.7	−0.3	n.a.	n.a.	n.a.	23.2	28.1	−2.5	−1.0	0.8	2.0	2.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1887 - 1988	29.7	32.7	n.a.	n.a.	n.a.	n.a.	n.a.	28.8	27.3	27.8	29.8	0.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Timbalier Island bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	−60.8	−2.9	1.8	0.5	−7.0	21
1934 - 1956	−56.5	−2.1	3.0	2.8	−11.3	27
1956 - 1978	−40.6	−1.3	10.6	26.6	−24.9	31
1978 - 1988	−421.6	−14.1	26.7	52.2	−122.7	30
1887 - 1988	−69.4	−5.0	3.1	−1.4	−14.6	14

East Timbalier Island bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	405.5	45.1	2.0	48.2	42.1	9
1934 - 1956	183.4	18.3	14.5	35.7	−1.9	10
1956 - 1978	457.5	15.8	16.3	46.0	−5.0	29
1978 - 1988	−29.3	−1.2	21.4	41.1	−61.3	24
1887 - 1988	408.4	24.0	4.3	32.7	17.5	17

Timbalier Islands bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	410.4	12.4	21.8	48.2	−7.0	33
1934 - 1956	223.2	5.6	15.1	51.1	−11.3	40
1956 - 1978	444.9	7.1	15.8	46.0	−24.9	63
1978 - 1988	−445.8	−7.8	24.8	52.2	−122.7	57
1887 - 1988	397.2	11.7	15.0	32.7	−14.6	34

TABLE 12.—*Timbalier Islands width measurements (meters)*

Transect #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinates	90° 33′ 00″	45″	30″	15″	90° 32′ 00″	45″	30″	15″	90° 31′ 00″	45″	30″	15″	90° 30′ 00″	45″	30″	15″	90° 29′ 00″	45″	30″	15″	90° 28′ 00″	45″	30″	15″
Years 1887	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	652	914	977	949	1696	2217	2355
1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	122	567	615	664	671	803	1051	1187	1390	1562	1739	1906	1719	1682
1956	n.a.	n.a.	7	108	n.a.	n.a.	287	464	420	586	630	748	860	779	846	830	1073	1210	1365	1496	1478	1773	2246	2065
1978	n.a.	n.a.	578	428	604	653	671	704	354	733	722	777	874	788	852	876	1059	979	1363	1365	1546	1593	1435	1451
1988	63	78	196	444	338	377	440	663	632	657	726	713	781	716	491	730	714	560	811	237	94	60	92	476

Transect #	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39*	40*	41*	42*	43*	44*	45*	46*	47*	48*
Transect coordinates	90° 27′ 00″	45″	30″	15″	90° 26′ 00″	45″	30″	15″	90° 25′ 00″	45″	30″	15″	90° 24′ 00″	45″	30″	15″	90° 23′ 00″	45″	30″	15″	90° 22′ 00″	45″	30″	15″
Years 1887	1672	1859	1560	1579	1796	1844	1683	1464	2026	1807	1286	1826	1532	1190	1315	970	675	462	913	1297	1335	1519	1384	1334
1934	1729	1718	1445	1315	1398	1345	1145	1012	469	296	119	393	233	283	338	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	179	239	n.a.
1956	1456	1525	1160	1014	1116	943	795	588	404	845	52	139	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	617	232	250	118	184
1978	1146	1089	1000	574	707	434	366	456	674	356	n.a.	n.a.	n.a.	n.a.	102	81	152	685	423	170	n.a.	292	16	n.a.
1988	94	131	132	382	507	150	383	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	20	32	37	41	60	n.a.	n.a.	n.a.

Transect #	49*	50*	51*	52*	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
Transect coordinates	90° 21′ 00″	45″	30″	15″	90° 20′ 00″	45″	30″	15″	90° 19′ 00″	45″	30″	15″	90° 18′ 00″	45″	30″	15″	90° 17′ 00″	45″	30″
Years 1887	1150	866	664	163	n.a.	n.a.	649	269	329	243	379	239	399	241	126	362	363	400	179
1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	385	441	256	255	213	275	233	173
1956	180	241	217	1017	800	1161	1132	500	1240	702	506	464	364	314	328	476	197	928	813
1978	199	438	606	795	933	875	1431	1353	1001	793	331	198	125	134	261	351	341	699	1059
1988	n.a.	n.a.	120	606	619	106	788	706	1114	506	632	420	202	125	79	40	26	189	523

Transect #	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
Transect coordinates	15″	90° 16′ 00″	45″	30″	15″	90° 15′ 00″	45″	30″	15″	90° 14′ 00″	45″	30″	15″	90° 13′ 00″	45″	30″	15″	90° 12′ 00″
Years 1887	374	213	168	94	n.a.	80	n.a.	145	412	621	766	854	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1934	n.a.	94	n.a.	n.a.	n.a.	n.a.	159	n.a.	n.a.	194	306	924	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956	n.a.	257	286	470	504	344	269	480	605	663	388	489	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1978	1054	1133	965	544	58	321	705	331	734	844	309	315	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1988	766	819	326	n.a.	n.a.	24	75	202	461	724	248	251	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Timbalier Island width summary

Years	Sum	Avg	STD	Total	Range	Count
1887	46931	1340.9	495.8	2355	163	35
1934	29334	946.3	581.7	1906	119	31
1956	29308	915.9	555.6	2246	7	32
1978	27207	850.2	358.9	1593	354	32
1988	12868	415.1	251.3	811	60	31

East Timbalier Island width summary

Years	Sum	Avg	STD	Total	Range	Count
1887	5664	283.2	135.1	649	80	20
1934	2484	248.4	97.8	441	94	10
1956	16196	506.1	310.1	1240	118	32
1978	19689	546.9	386.7	1431	16	36
1988	9664	333.2	308.1	1114	20	29

Timbalier Islands width summary

Years	Sum	Avg	STD	Total	Range	Count
1887	54836	945.4	634.6	2355	80	58
1934	33242	755.5	580.6	1906	94	44
1956	47044	702.1	485.5	2246	7	67
1978	48364	681.2	400.1	1593	16	71
1988	23755	377.1	280.7	1114	20	63

TABLE 13.—*Timbalier Islands gulfside rate of change (meters per year)*

Transect #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinates	90° 33′ 00″	45″	30″	15″	90° 32′ 00″	45″	30″	15″	90° 31′ 00″	45″	30″	15″	90° 30′ 00″	45″	30″	15″	90° 29′ 00″	45″	30″	15″	90° 28′ 00″	45″	30″	15″
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	18.1	14.6	13.1	11.0	8.1	6.0	4.1
1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	34.5	19.1	14.6	12.1	9.5	6.3	4.8	4.9	3.1	−0.9	−3.8	−3.5	−4.3	−5.9
1956 - 1978	n.a.	n.a.	0.5	0.7	0.9	n.a.	0.8	3.5	3.3	3.5	2.6	1.8	0.3	0.3	0.5	0.3	0.2	0.6	0.3	0.6	0.7	−1.4	−3.5	−3.9
1978 - 1988	n.a.	n.a.	27.6	13.4	10.9	11.5	9.7	11.2	12.0	8.3	6.0	2.8	0.1	−6.3	−11.0	−12.0	−14.5	−16.5	−15.7	−20.6	−22.7	−22.7	−18.8	−15.9
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	8.0	6.0	4.0	2.2	0.5	−0.7	−1.8

Transect #	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39*	40*	41*	42*	43*	44*	45*	46*	47*	48*
Transect coordinates	90° 27′ 00″	45″	30″	15″	90° 26′ 00″	45″	30″	15″	90° 25′ 00″	45″	30″	15″	90° 24′ 00″	45″	30″	15″	90° 23′ 00″	45″	30″	15″	90° 22′ 00″	45″	30″	15″
Years 1887 - 1934	3.0	0.9	−1.5	−2.5	−4.3	−6.6	−8.4	−9.4	−10.5	−10.2	−9.1	−9.1	−8.3	−11.1	−18.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1934 - 1956	−9.6	−11.4	−12.7	−13.1	−12.4	−11.5	−14.6	−7.1	−4.1	−1.4	−8.3	−14.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
1956 - 1978	−4.8	−6.0	−7.0	−7.5	−10.0	−7.9	−2.4	−10.8	−16.0	−38.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−24.1	n.a.	−28.3	−38.0	n.a.
1978 - 1988	−14.0	−12.2	−7.2	−8.0	−12.9	−32.3	−54.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−84.5	−66.3	−64.9	−48.0	n.a.	n.a.	n.a.	n.a.
1887 - 1988	−3.1	−4.5	−5.7	−6.5	−8.2	−10.5	−13.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #	49*	50*	51*	52*	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
Transect coordinates	90° 21′ 00″	45″	30″	15″	90° 20′ 00″	45″	30″	15″	90° 19′ 00″	45″	30″	15″	90° 18′ 00″	45″	30″	15″	90° 17′ 00″	45″	30″
Years 1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−43.0	−42.0	−43.7	−45.2	−45.4	−45.1	−45.5
1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.6	−2.1	−2.0	−3.6	−5.6	−7.0	−6.3
1956 - 1978	−46.1	−24.1	−6.0	−8.9	−10.0	−9.5	−9.1	−10.1	−11.4	−11.5	−11.6	−10.5	−10.0	−9.2	−5.4	−4.9	−5.6	−4.3	−9.0
1978 - 1988	n.a.	n.a.	−27.2	−14.2	−9.8	−1.9	−6.5	−7.4	−0.1	2.5	3.8	4.6	2.6	1.5	−4.0	−4.4	−7.1	−1.7	3.5
1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−16.3	−18.1	−18.3	−18.6	−19.3	−20.0	−21.4	−21.9	−22.3	−23.3	−24.3	−23.6	−24.2

Transect #	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85
Transect coordinates	15″	90° 16′ 00″	45″	30″	15″	90° 15′ 00″	45″	30″	15″	90° 14′ 00″	45″	30″	15″	90° 13′ 00″	45″	30″	15″	90° 12′ 00″
Years 1887 - 1934	−45.1	−44.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−42.8	−41.0	−40.1	−38.5	−33.4	−30.6	−25.7	−41.3	−45.7
1934 - 1956	−13.9	−11.0	n.a.	n.a.	n.a.	n.a.	−6.0	n.a.	n.a.	−16.7	−27.0	−20.3	−14.1	−13.2	−18.2	−28.0	7.2	16.5
1956 - 1978	−4.1	−9.0	−15.2	−21.0	−52.2	−32.7	−23.3	−24.0	−12.7	−11.0	−4.9	−11.6	−14.5	−0.6	−1.6	−3.6	−5.7	−5.2
1978 - 1988	−10.6	−33.6	−76.5	n.a.	n.a.	n.a.	−84.6	−10.6	−27.9	−24.3	−15.7	−8.0	−7.6	−1.2	−3.6	−2.8	−4.1	−6.1
1887 - 1988	−26.0	−28.5	−33.3	n.a.	n.a.	n.a.	n.a.	−28.5	−28.0	−28.4	−27.6	−26.4	−24.9	−18.7	−18.9	−19.1	−19.3	−19.4

Timbalier Island gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	−30.5	−1.4	9.7	18.1	−18.4	22
1934 - 1956	−30.0	−1.2	11.7	34.5	−14.6	26
1956 - 1978	−97.5	−3.1	7.9	3.5	−38.0	31
1978 - 1988	−203.8	−7.0	16.5	27.6	−54.0	29
1887 - 1988	−33.3	−2.4	5.9	8.0	−13.0	14

East Timbalier Island gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	−399.7	−44.4	1.2	−42.0	−45.5	9
1934 - 1956	−54.9	−5.5	4.4	2.6	−13.9	10
1956 - 1978	−502.0	−16.2	12.2	−4.1	−52.2	31
1978 - 1988	−573.3	−21.2	28.7	4.6	−84.6	27
1887 - 1988	−415.8	−23.1	4.4	−16.3	−33.3	18

Timbalier Islands gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	−769.1	−16.3	21.7	18.1	−45.7	40
1934 - 1956	−198.8	−3.8	11.2	34.5	−28.0	45
1956 - 1978	−658.3	−9.6	11.9	3.5	−52.2	71
1978 - 1988	−850.5	−14.0	23.7	27.6	−84.6	65
1887 - 1988	−651.7	−15.2	11.6	8.0	−33.3	41

See page 55 for explanation of numbers.

Timbalier Islands

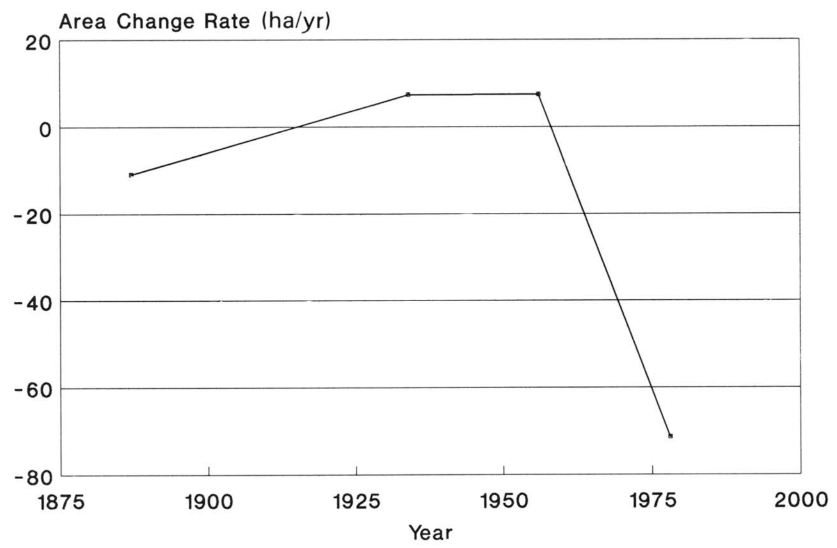


FIGURE 23.—Rate of area change between 1887 and 1988 for the Timbalier Islands.

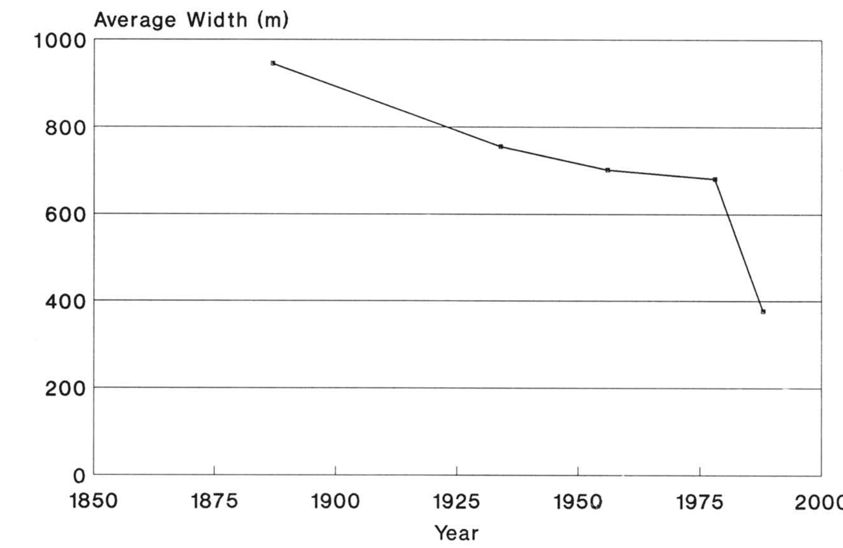


FIGURE 24.—Average barrier width between 1887 and 1988 for the Timbalier Islands shoreline.

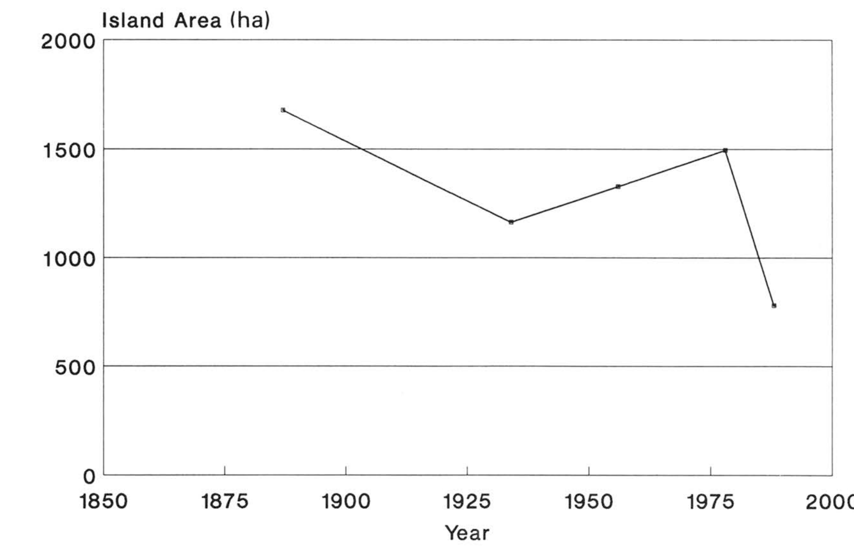


FIGURE 25.—Area changes between 1887 and 1988 for the Timbalier Islands.

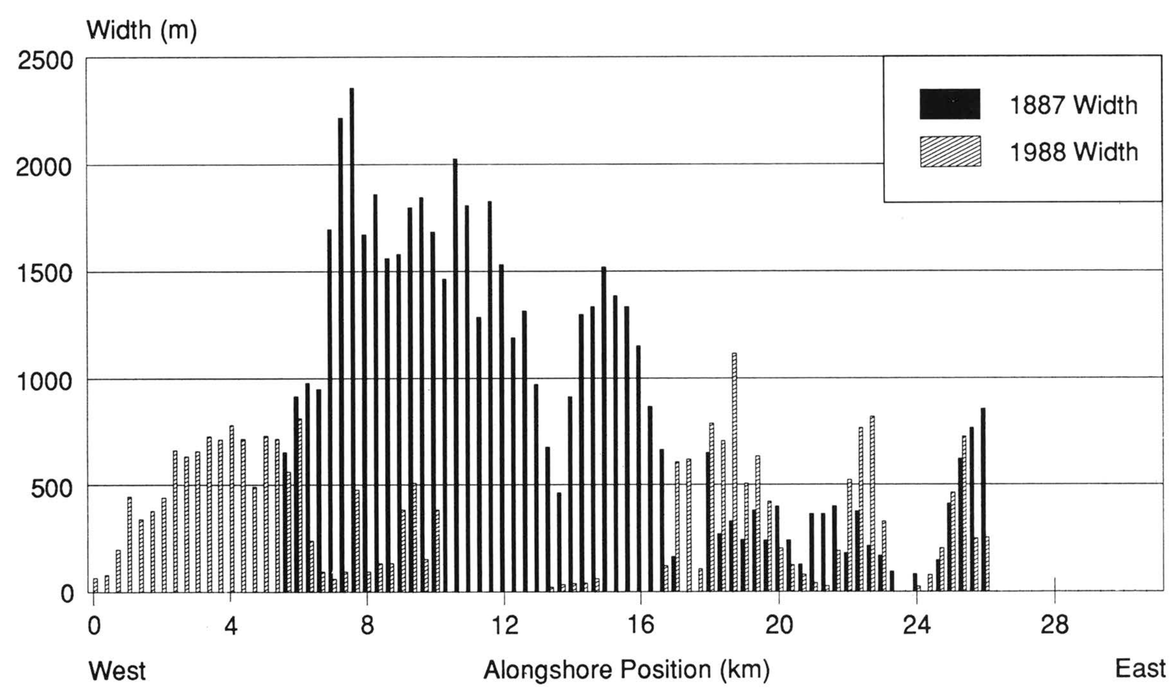


FIGURE 26.—Comparison of barrier widths between 1887 and 1988 for the Timbalier Islands shoreline.

TABLE 14.—*Lateral and length change of Timbalier Island*

Lateral Migration

Dates (Number of Years)	West End(m)	Rate(m/yr)	East End(m)	Rate(m/yr)
1887-1934 (47)	2,843	60.5	5,207	110.8
1934-1956 (22)	3,715	168.9	743	33.8
1956-1978 (22)	83	3.8	1,232	56.0
1978-1988 (10)	1,154	115.4	1,063	106.3
1887-1988 (101)	7,795	77.2	8,245	81.6

Length of Island

Date	Length(m)	Change(m)	Rate of Change(m/yr)
1887	13,952	N.A.	N.A.
1934	11,651	-2,301	-49.0
1956	14,646	2,995	136.1
1978	13,477	-1,169	-53.1
1988	13,569	-92	-9.2
1887-1988		-383	-3.8

TABLE 15.—*Area changes for Timbalier Island from 1887 to 1988*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1887	1,485				
1934	1,071	-414	-28%	-8.8	2056
1934	1,071				
1956	915	-156	-15%	-7.1	2085
1956	915				
1978	999	84	9%	3.8	N.A.
1978	999				
1988	542	-457	-46%	-45.7	2000
1887	1,485				
1988	542	-943	-64%	-9.3	2046

TABLE 16.—*Area changes for East Timbalier Island from 1887 to 1988*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1887	193				
1934	93	-100	-52%	-2.1	1978
1934	93				
1956	413	320	344%	14.5	N.A.
1956	413				
1978	495	82	20%	3.7	N.A.
1978	495				
1988	238	-257	-52%	-25.7	1997
1887	193				
1988	238	45	23%	0.4	N.A.

TABLE 17.—*Area changes for the Timbalier Islands from 1887 to 1988*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1887	1,677				
1934	1,164	-513	-31%	-10.9	2041
1934	1,164				
1956	1,328	16	14%	7.5	N.A.
1956	1,328				
1978	1,495	167	13%	7.6	N.A.
1978	1,495				
1988	780	-715	-48%	-71.5	1999
1887	1,677				
1988	780	-897	-53%	-8.9	2076

Caminada-Moreau Headland and Grand Isle—1887 to 1988

CAMINADA-MOREAU HEADLAND AND GRAND ISLE

Morphology

In 1887, several tidal inlets and former distributaries segmented Caminada-Moreau Headland and Grand Isle. Raccoon Pass formed the western boundary and has been open continuously from pre-1887 to present (1887 map). No major changes in morphology had occurred by 1934, except for the barriers fronting Bay Marchand, which were mapped as intertidal features and therefore do not appear on the 1934 map.

Belle Pass, Pass Fourchon, and Bayou Moreau segment the central headland area. Caminada Pass lies between the large, well-developed Caminada spit (locally known as Elmer's Island) to the west and Grand Isle to the east. Grand Isle is a classic drumstick-shaped barrier island with a narrow western end that widens to the east and becomes bulbous on the eastern end. It is the only barrier island in Louisiana commercially and residentially developed (Meyer-Arendt, 1987). Barataria Pass, the deepest tidal inlet along the Louisiana coastline (>40 m in 1989), forms the eastern boundary and is the primary tidal inlet that connects Barataria Bay to the Gulf of Mexico.

By 1956, the land area fronting Lake Champagne was breached as the shoreline retreated (1956 map). Bay Marchand decreased over 70 percent in response to shoreline retreat. Moreover, the downdrift offset west of Belle Pass began to develop. The 1978 shoreline depicts the widening of Bayou Lafourche and Pass Fourchon, while the downdrift offset is more acute (1978 map). Shoreline retreat has reduced Bay Marchand to a small pond and intercepted Bayou Moreau to segment the distributary. By 1988, shoreline retreat had removed large quantities of sediment from the central headland area. This sediment was transported downdrift to Grand Isle but blocked from reaching the Timbalier Islands by the Belle Pass jetties, causing the magnitude of downdrift offset to increase west of Belle Pass. Bay Champagne experienced extensive size reductions, while Bay Marchand is close to complete disappearance. Bayou Moreau now intersects the shoreline in three different locations, and numerous dredge canals dissect the coastal landscape.

Shoreline Movement

Shoreline change was measured at 91 shore-normal transects along the gulf and bay shorelines (transects map; tables 18, 19, 20, 21, and 22). Shoreline change measurements were taken along the gulf shoreline, but bayside measurements were possible only along Caminada spit because no bay shoreline exists to the west.

Caminada-Moreau Headland

The Caminada-Moreau Headland has experienced some of the highest rates of shoreline movement along the Louisiana coastline. Between 1887 and 1934, the average gulfside rate of change was -15.8 m/yr, but this rate gradually decreased to -11.5 m/yr and -9.5 m/yr for the periods 1934 to 1956 and 1956 to 1978, respectively (fig. 27, table 22). The average rate of coastal retreat increased to -13.6 m/yr between 1978 and 1988. The rapid landward movement of the shoreline along the Caminada-Moreau Headland has caused large quantities of sediment to be eroded from this segment. Most of the sediment is transported laterally or offshore, and a smaller percentage has moved landward by overwash processes. In contrast to barrier island shorelines, the Caminada-Moreau Headland consists predominately of cohesive deltaic sediment and a large, sandy beach ridge plain with no back-barrier lagoon or bay, except for a small water body behind Caminada spit. The average rate of bayside movement slowed along Caminada spit from shoreline advance to more stable conditions (fig. 28, table 20).

Grand Isle

Grand Isle is characterized by shoreline retreat and advance along the gulf side, which balances migration directions. The average rate of gulfside change was -0.9 m/yr between 1887 and 1934, with stable or slightly increasing shoreline advance rates of 0.0 m/yr, 2.5 m/yr, and 5.2 m/yr for the periods 1934 to 1956, 1956 to 1978, and 1978 to 1988, respectively (fig. 29, table 22). For 101 years, the gulf shoreline has experienced retreat along its western end while remaining relatively stationary at its midsection and accreting seaward on its eastern end. These trends show that Grand Isle is slowly rotating clockwise around a stable midpoint, a result of net longshore sediment transport that becomes captured by Barataria Pass. The Barataria Pass tidal inlet system is a large sediment sink storing most of its sand as a large ebb-tidal delta. Shoreline advance at the eastern end of Grand Isle is directly related to this ebb-tidal delta (Shamban, 1982). Average bayside rates of change showed slowly increasing rates of shoreline retreat between 1887 and 1988 (fig. 30, table 20). The bay shoreline experienced the greatest erosion to the west and slowly decreased to the east with stable conditions at the eastern end.

Caminada-Moreau Headland and Grand Isle Summary

The average rate of gulfside change between 1887 and 1934 was -10.1 m/yr (table 22). The average rate decreased to -7.2 m/yr between 1934 and 1956 and to -4.9 m/yr between 1956 and 1978. This trend was interrupted when the average gulfside rate increased to -6.5 m/yr between 1978 and 1988 (fig. 31). These rates reveal shoreline retreat of the gulf side except on the eastern end of Grand Isle, which exhibits seaward progradation. The average bayside rate of change for the periods 1887 vs. 1934, 1934 vs. 1956, and 1956 vs. 1978 indicates that only migration direction has changed (fig. 32, table 20). Between 1934 and 1956, average shoreline movement along the bay reversed direction from landward to seaward. The rate of change slowly increased seaward to -3.0 m/yr between 1978 and 1988.

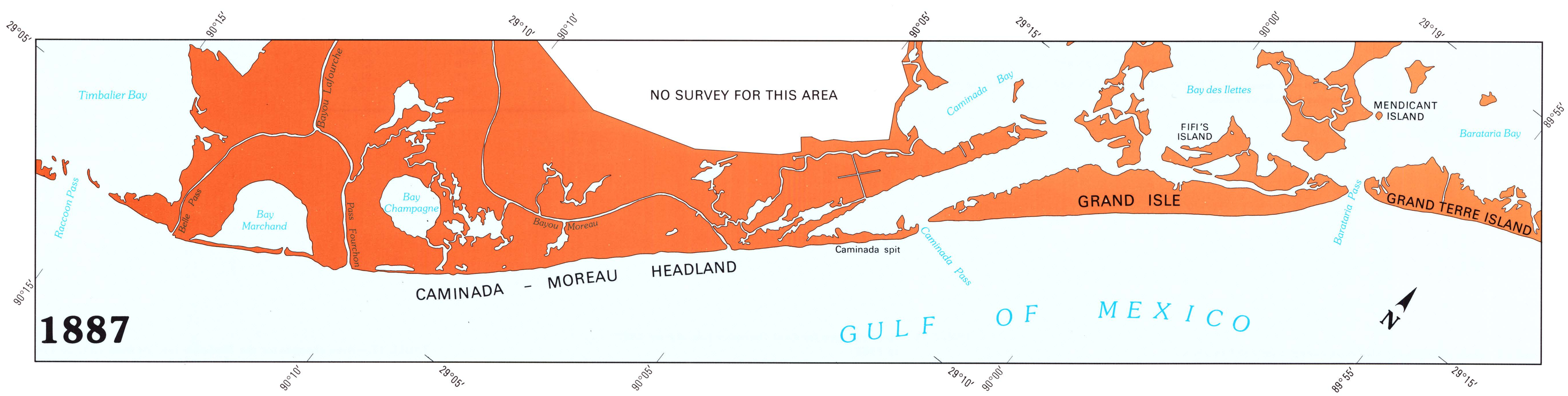
The 1887 vs. 1988 map illustrates land loss and summarizes the cumulative measured changes along the gulf and bay shorelines. The rate of change between 1887 and 1988 along the gulf side of the Caminada-Moreau Headland and Grand Isle ranged from 6.2 to -20 m/yr, with an average change rate of -7.9 m/yr (table 22). The rate of change along the bay between 1887 and 1988 ranged from 7.0 to -13.0 m/yr with an average change rate of 0.1 m/yr (table 20).

Area and Width Change at Grand Isle

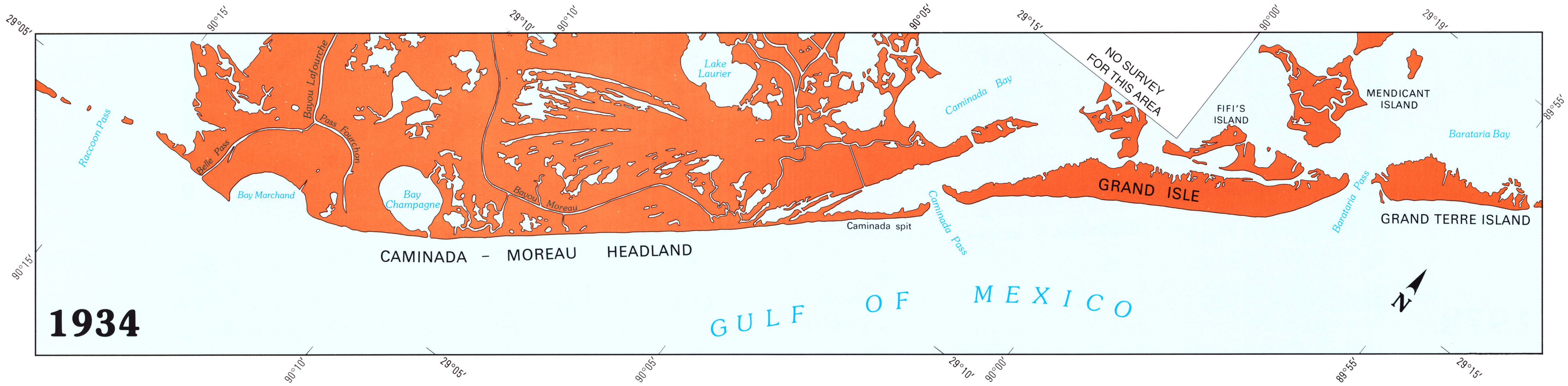
In 1887, Grand Isle ranged from 301 to 1,451 m wide, with an average width of 882 m (table 21). The average rate of land loss between 1887 and 1934 was 2.3 ha/yr (table 23). By 1934, the island had narrowed to an average width of 841 m; widths ranged between 302 and 1,186 m. Between 1934 and 1956, the average rate of area change underwent land loss but slowed slightly to 1.6 ha/yr. Similarly, the average width continued to decrease to 821 m by 1956. Between 1956 and 1978, land loss reversed at an average rate of 1.0 ha/yr, and by 1978, the average width increased to 851 m. Land gain continued at a rate of 1.1 ha/yr between 1978 and 1988 (fig. 33). Numerous coastal engineering activities (beach restoration and replenishment projects) began along Grand Isle in the mid-1950's, and changes in island area and width possibly reflect these human alterations, especially the extensive 1984 dune restoration project conducted by the U.S. Army Corps of Engineers (Adams and others, 1976; Combe and Soileau, 1987).

Overall, Grand Isle experienced only a slight decrease in area from 1,059 to 960 ha between 1887 and 1988 (fig. 34). Compared with other barrier islands along the Louisiana coast, the area of Grand Isle has remained relatively stable. For the period 1887 to 1988, the average width of Grand Isle is essentially stable, ranging between 821 and 882 m (fig. 35, table 21). Barrier widths for the Grand Isle area between 1887 and 1988 are shown in figure 36.

• Historic Shorelines •



Caminada - Moreau Headland and Grand Isle



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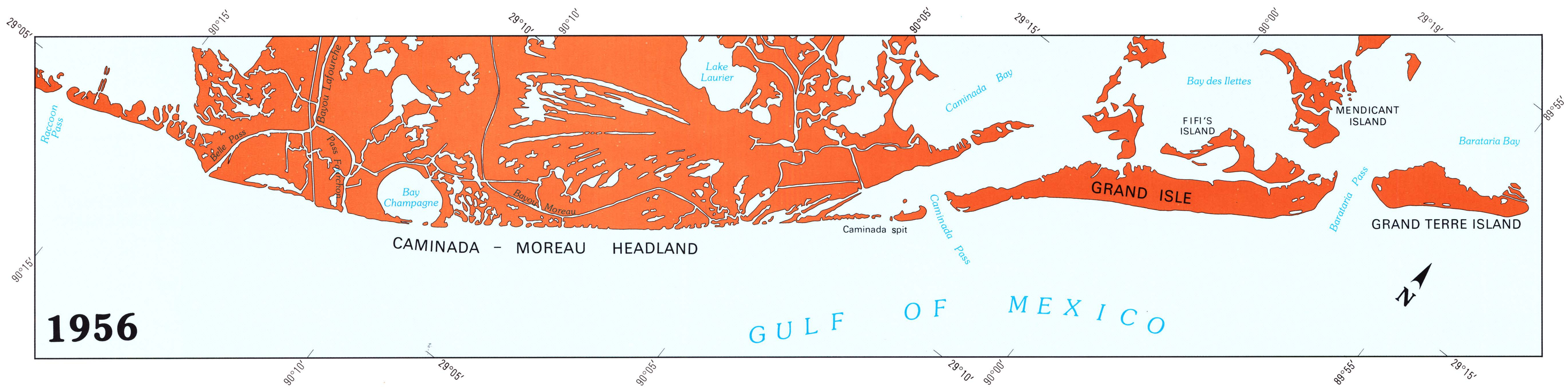
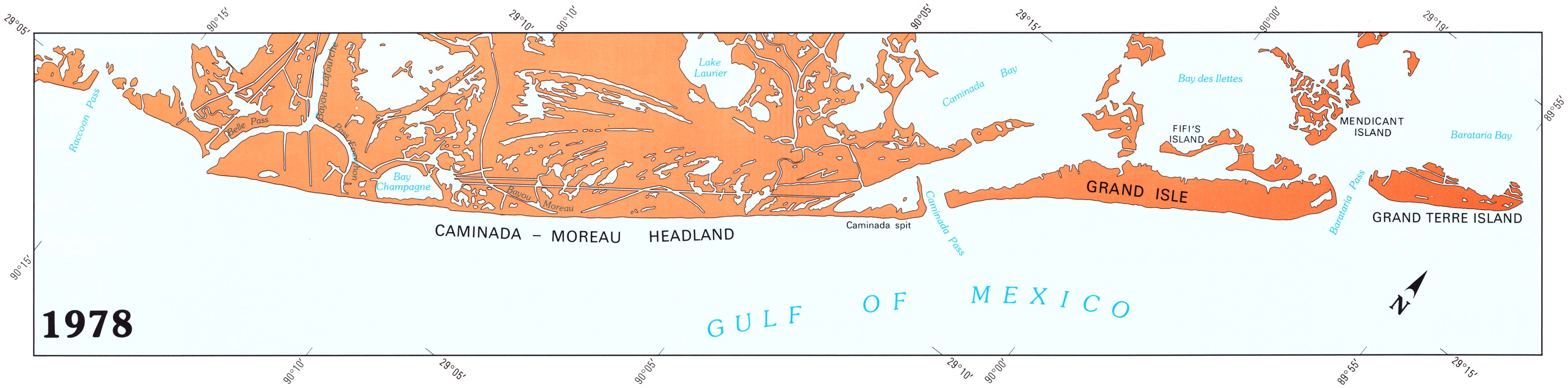
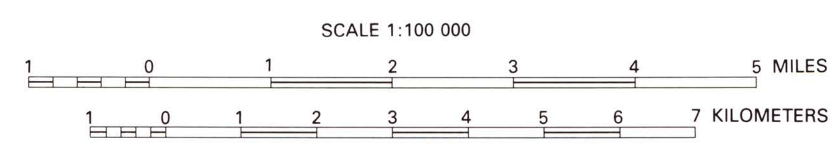
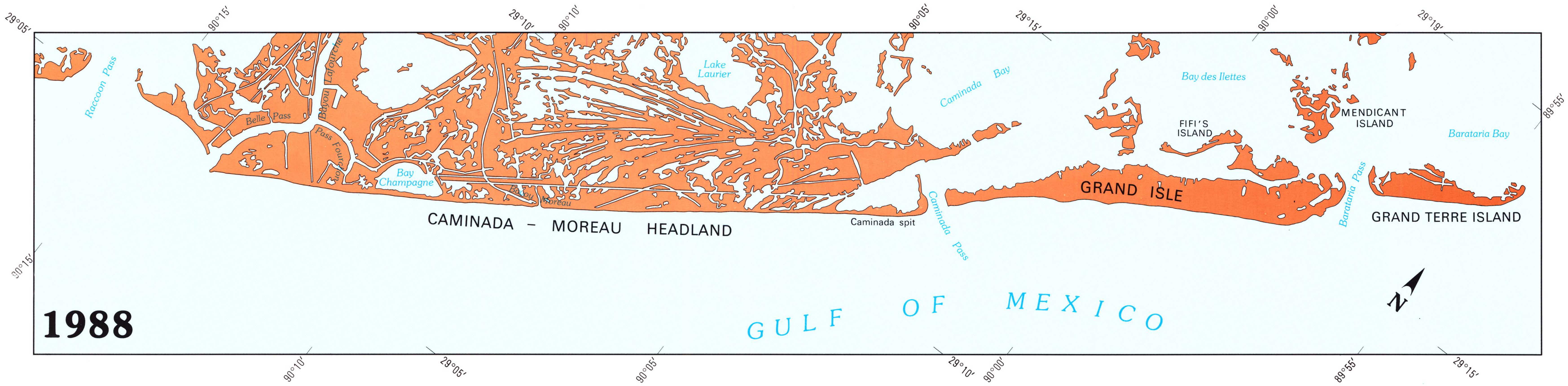
1 0 1 2 3 4 5 6 7 KILOMETERS



Caminada - Moreau Headland and Grand Isle







Caminada - Moreau Headland and Grand Isle

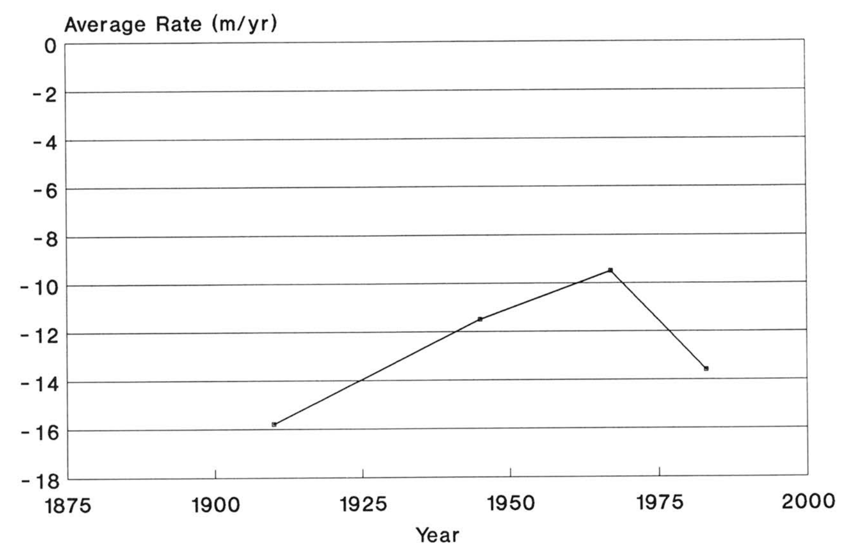


FIGURE 27.—Average gulfside rate of change along the Caminada-Moreau Headland between 1887 and 1988.

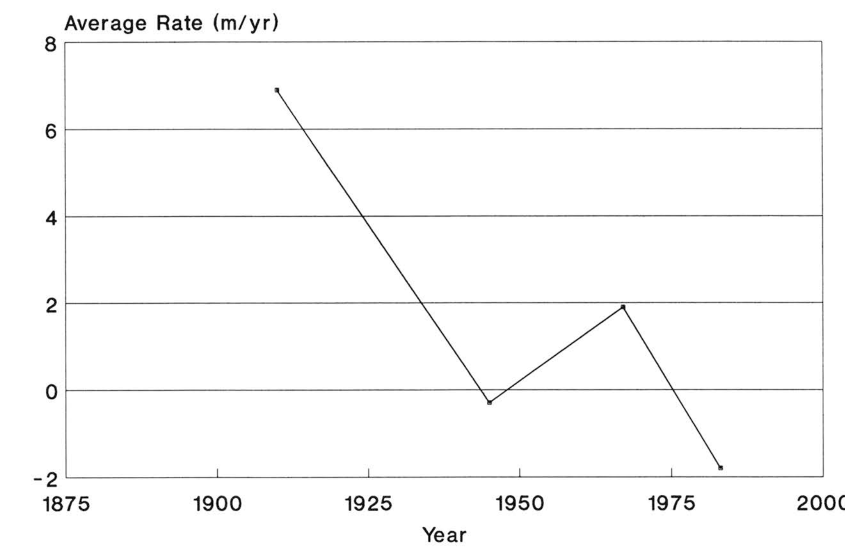


FIGURE 28.—Average bayside rate of change along the Caminada-Moreau Headland between 1887 and 1988.

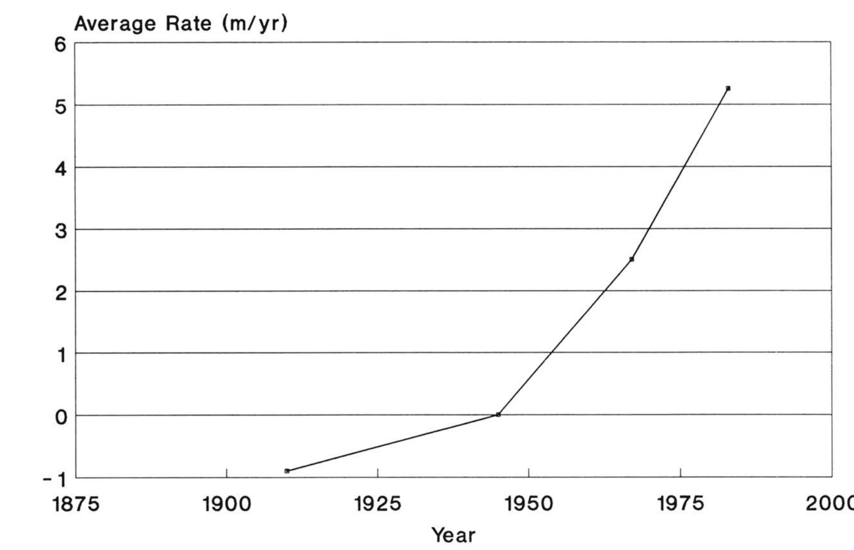


FIGURE 29.—Average gulfside rate of change along Grand Isle between 1887 and 1988.

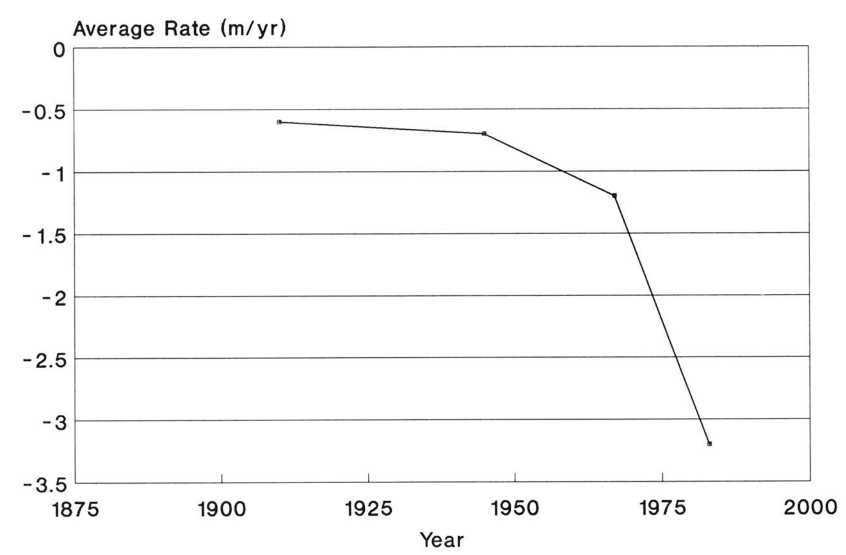


FIGURE 30.—Average bayside rate of change along Grand Isle between 1887 and 1988.

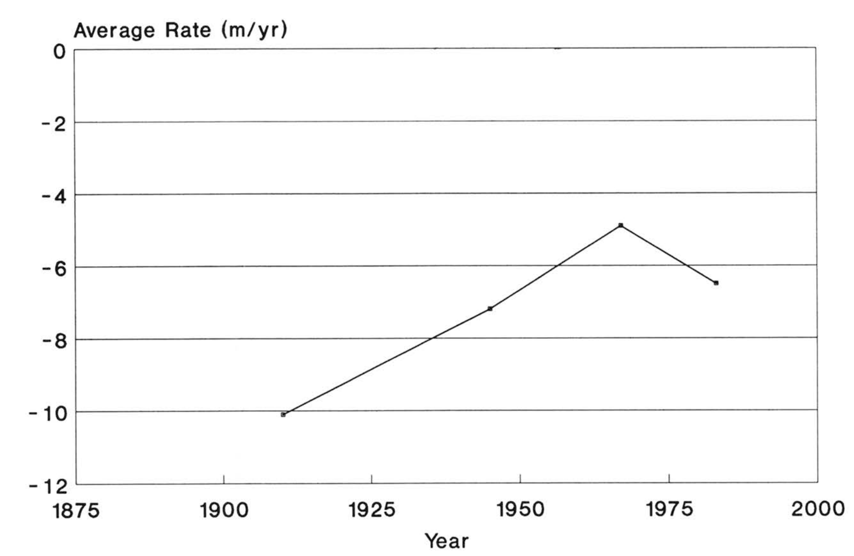


FIGURE 31.—Average gulfside rate of change between 1887 and 1988 for the Caminada-Moreau Headland and Grand Isle shoreline.

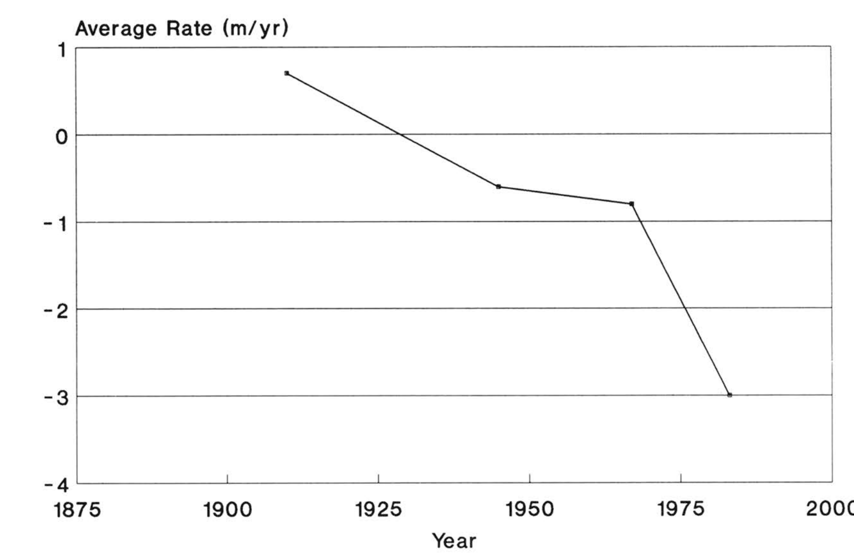


FIGURE 32.—Average bayside rate of change between 1887 and 1988 for the Caminada-Moreau Headland and Grand Isle shoreline.

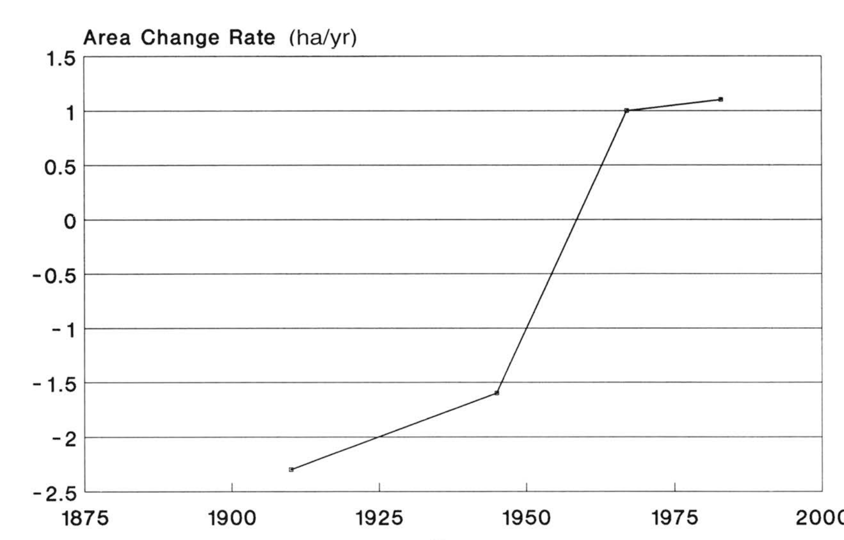
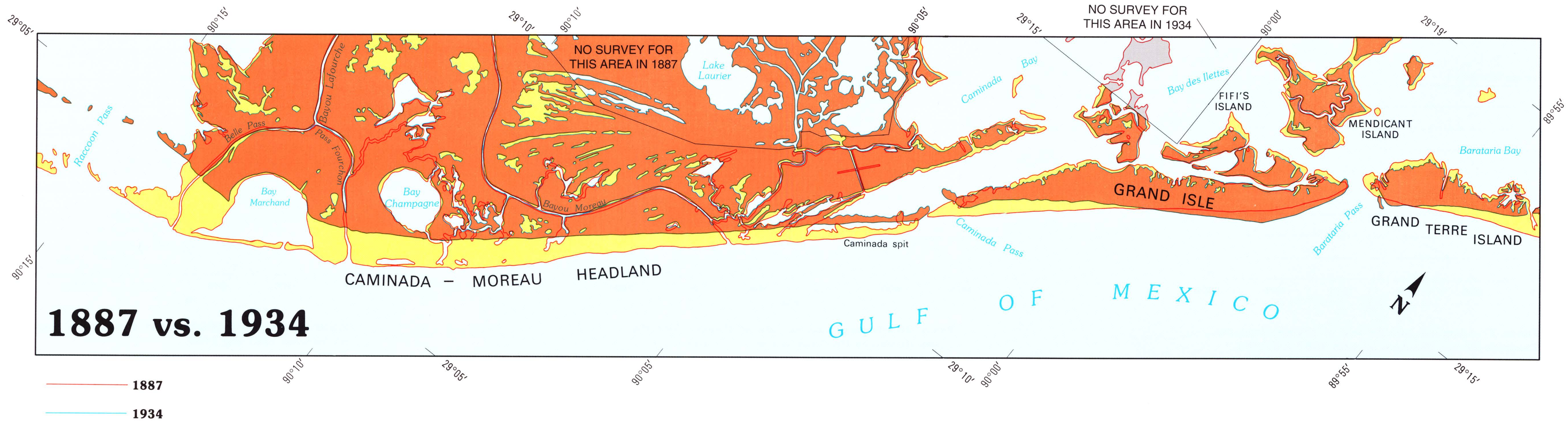


FIGURE 33.—Rate of area change between 1887 and 1988 of Grand Isle.

Caminada - Moreau Headland and Grand Isle

• Shoreline Change and Land Loss •



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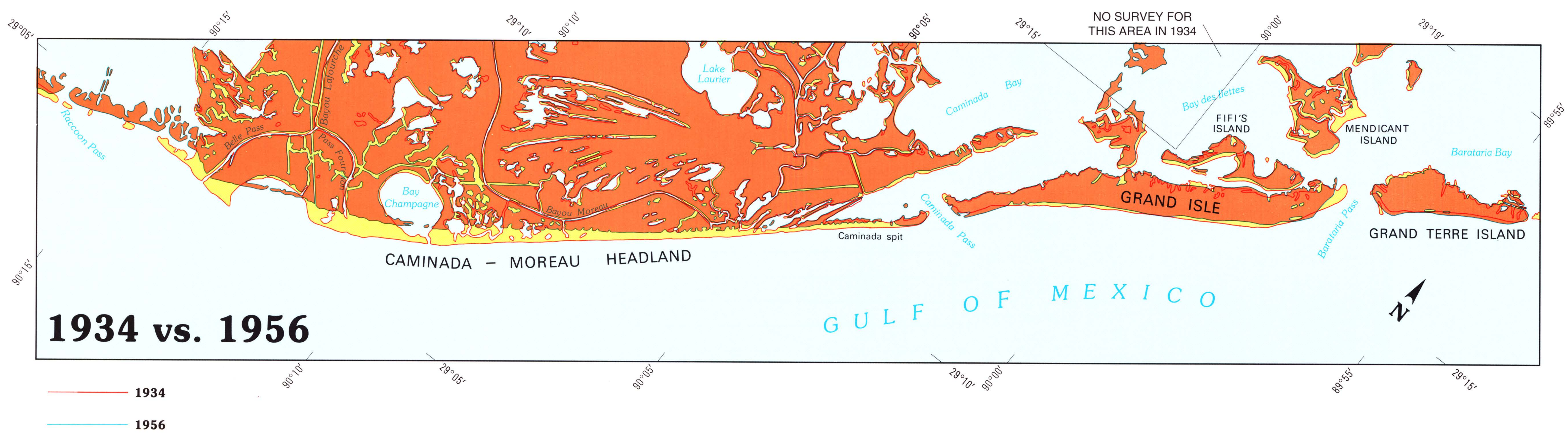
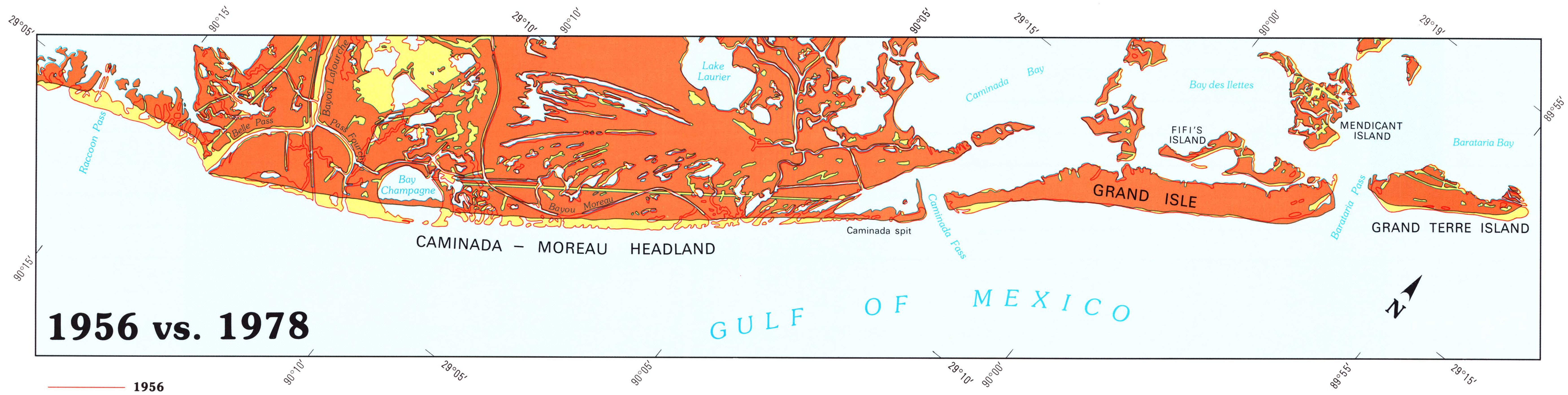
1 0 1 2 3 4 5 6 7 KILOMETERS



Caminada - Moreau Headland and Grand Isle

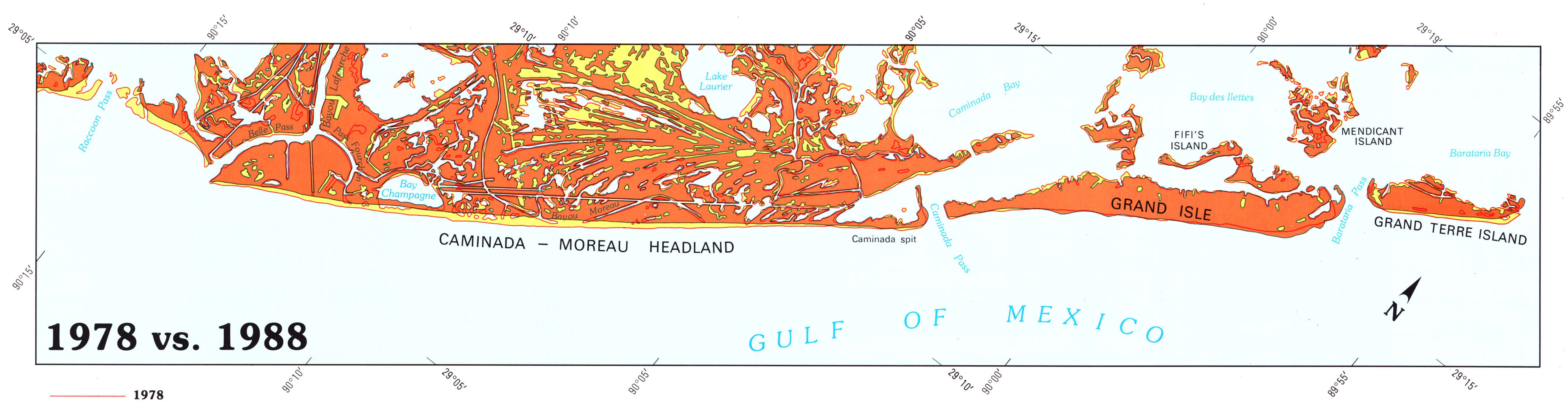


1956

1978

Land

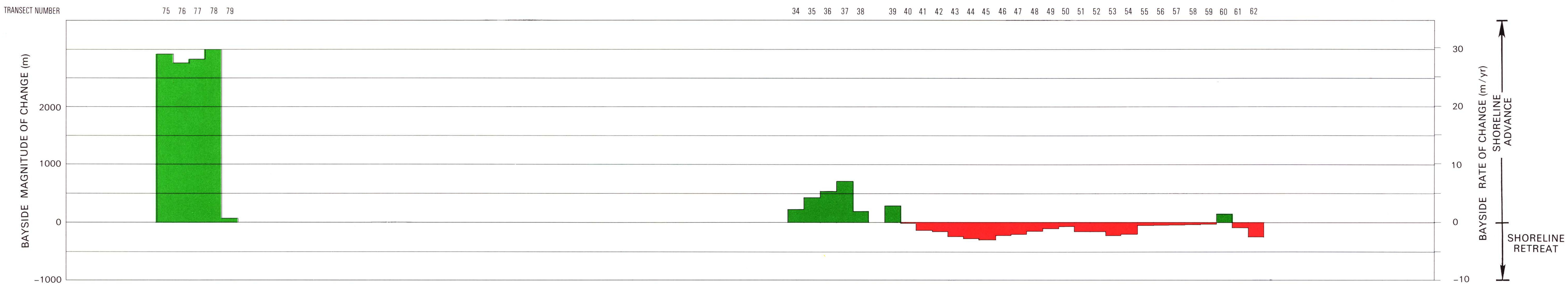
Land Loss

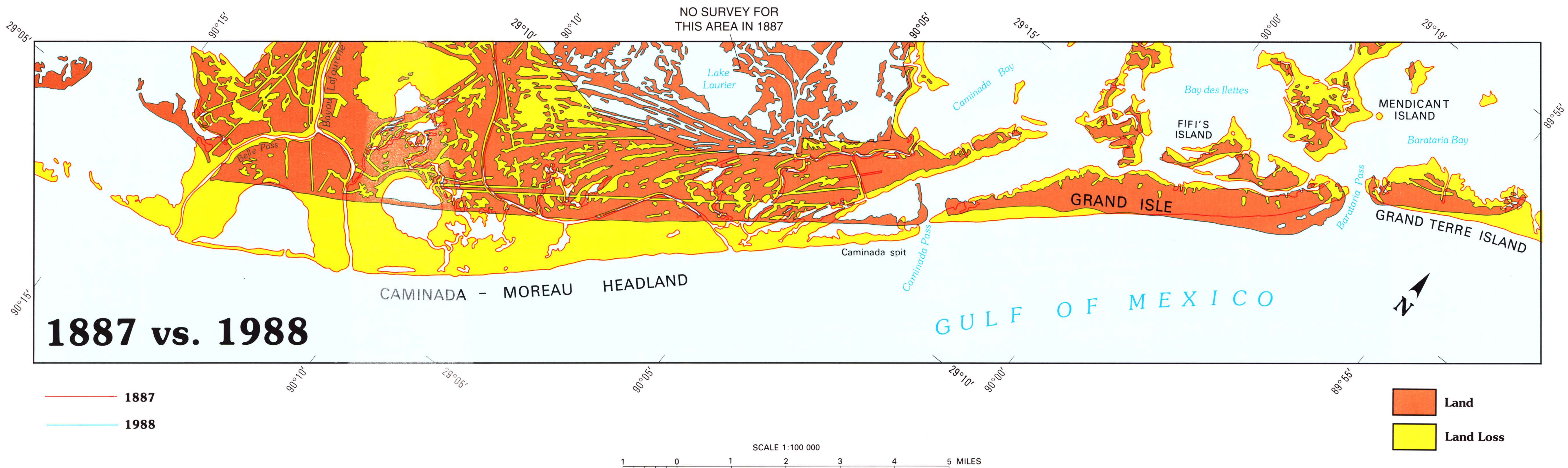


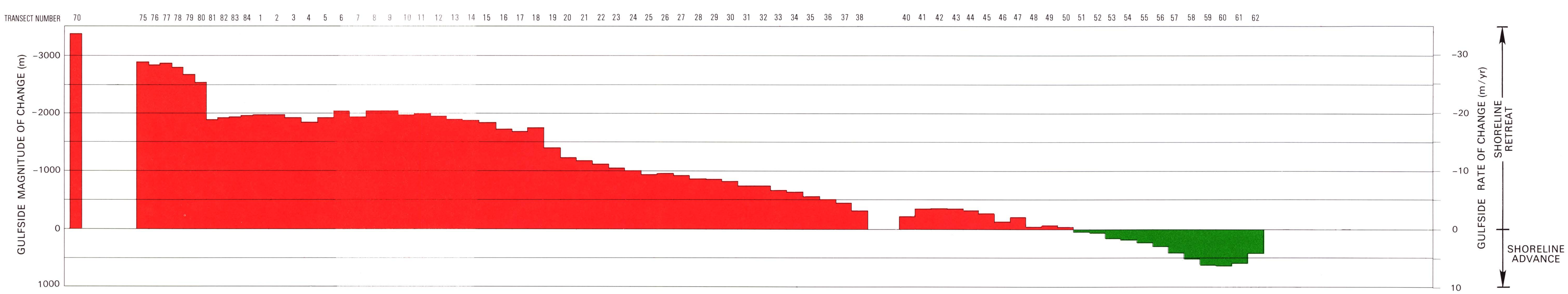
1978

1988

Caminada - Moreau Headland and Grand Isle







Caminada - Moreau Headland and Grand Isle

TABLE 18.—*Caminada-Moreau headland and Grand Isle bayside magnitude of change (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Transect coordinate		90° 12' 00"	45"	30"	15"	90° 11' 00"	45"	30"	15"	90° 10' 00"	45"	30"	15"	90° 09' 00"	45"	30"	15"	90° 08' 00"	45"	30"	15"	90° 07' 00"	45"
Y	1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1956 - 1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1978 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Transect coordinate		30"	15"	90° 06' 00"	45"	30"	15"	90° 05' 00"	45"	30"	15"	90° 04' 00"	45"	30"	15"	90° 03' 00"	45"	30"	15"	90° 02' 00"	45"	30"
Y	1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	208	420	399	353	247	490	38	-41	35	-115
e	1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a	n.a.	-20	5	-2	n.a.	-8	-190	-97	19	-56	-35
a	1956 - 1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	26	0	153	n.a.	-9	-72	64	-76	-92	-11
r	1978 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4	-8	-19	-28	-37	55	-9	-26	-39	-69
s	1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	218	417	531	707	193	283	-4	-124	-152	-230

Transect #		44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Transect coordinate		15"	90° 01' 00"	45"	30"	15"	90° 00' 00"	45"	30"	15"	89° 59' 00"	45"	30"	15"	89° 58' 00"	45"	30"	15"	89° 57' 00"	45"
Y	1887 - 1934	-134	-229	-45	-123	-79	-9	-79	-127	-54	-33	-24	-19	12	-11	-11	3	1	-8	-170
e	1934 - 1956	-31	63	-10	29	-4	24	34	70	-74	-157	-28	14	-16	10	16	22	174	-20	-107
a	1956 - 1978	-17	-9	-26	-5	-13	3	-14	-80	-18	14	-145	-17	-21	-14	-39	-30	-23	-30	14
r	1978 - 1988	-92	-112	-130	-95	-46	-115	-10	-8	-7	-38	-8	-13	2	-6	8	0	-5	-32	24
s	1887 - 1988	-274	-287	-211	-194	-142	-97	-59	-145	-153	-214	-205	-35	-23	-21	-26	-5	147	-90	-239

Caminada-Moreau headland bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	1627	325.4	83.7	420	208	5
1934 - 1956	-25	-6.3	9.2	5	-20	4
1956 - 1978	170	42.5	65.1	153	-9	4
1978 - 1988	-88	-17.6	14.5	4	-37	5
1887 - 1988	2066	413.2	193.3	707	193	5

Grand Isle bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-732	-30.5	126.8	490	-229	24
1934 - 1956	-350	-14.6	74.2	174	-190	24
1956 - 1978	-657	-27.4	40.8	64	-145	24
1978 - 1988	-771	-32.1	46.2	55	-130	24
1887 - 1988	-2500	-104.2	130.0	283	-287	24

Caminada-Moreau headland and Grand Isle bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	895	30.9	180.5	490	-229	29
1934 - 1956	-375	-13.4	68.8	174	-190	28
1956 - 1978	-487	-17.4	51.3	153	-145	28
1978 - 1988	-859	-29.6	42.8	55	-130	29
1887 - 1988	-434	-15.0	242.1	707	-287	29

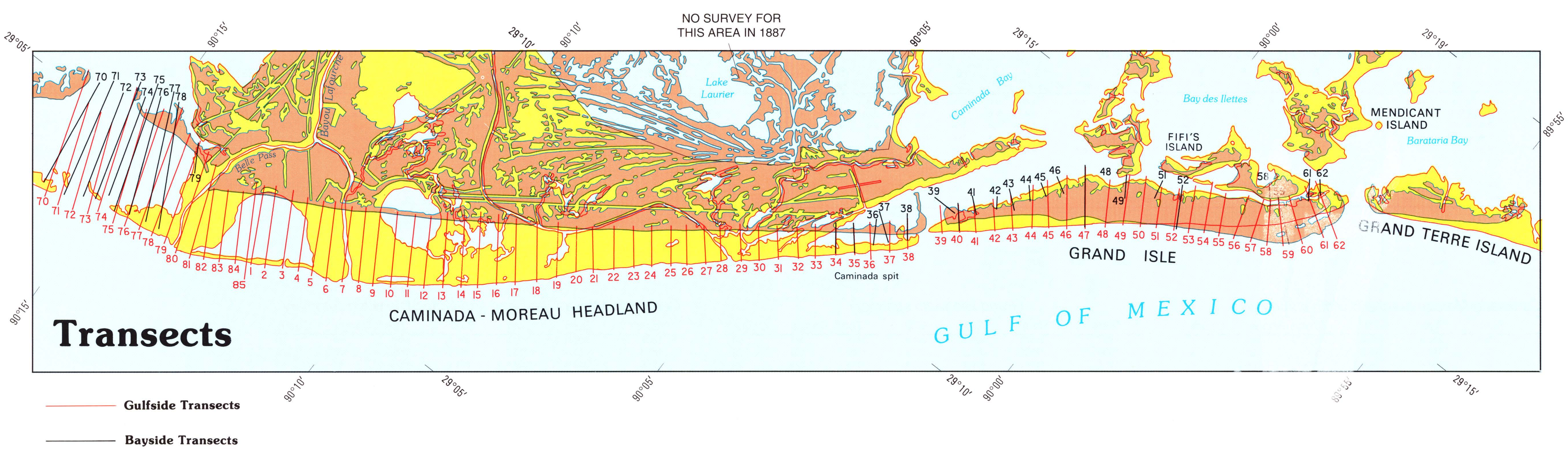


TABLE 19.—*Caminada-Moreau headland and Grand Isle gulfside magnitude of change (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Transect coordinate		90° 12' 00"	45"	30"	15"	90° 11' 00"	45"	30"	15"	90° 10' 00"	45"	30"	15"	90° 09' 00"	45"	30"	15"	90° 08' 00"	45"	30"	15"	90° 07' 00"	45"
Y	1887 - 1934	-2119	-2128	-1866	-1203	-1014	-1047	-912	-929	-936	-889	-896	-861	-815	-848	-855	-818	-806	-748	-659	-538	-528	-490
e	1934 - 1956	350	380	200	-334	-441	-521	-501	-495	-444	-423	-497	-418	-727	-546	-582	-373	-367	-332	-287	-278	-243	-201
a	1956 - 1978	-138	-117	-154	-170	-349	-339	-385	-444	-452	-471	-436	-528	-194	-254	-167	-272	-249	-234	-237	-213	-212	-253
r	1978 - 1988	-62	-97	-92	-130	-102	-114	-132	-157	-188	-186	-151	-128	-151	-215	-233	-254	-253	-420	-213	-190	-189	-167
s	1887 - 1988	-1969	-1962	-1912	-1837	-1906	-2021	-1930	-2025	-2020	-1969	-1980	-1935	-1887	-1863	-1837	-1717	-1675	-1734	-1396	-1219	-1172	-1111

Transect #		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Transect coordinate		30"	15"	90° 06' 00"	45"	30"	15"	90° 05' 00"	45"	30"	15"	90° 04' 00"	45"	30"	15"	90° 03' 00"	45"	30"	15"	90° 02' 00"	45"	30"
Y	1887 - 1934	-433	-423	-386	-405	-386	-352	-379	-410	-395	-461	-433	-423	-439	-398	-378	-265	-682	-287	-288	-415	-396
e	1934 - 1956	-187	-165	-292	-246	-228	-175	-306	-293	-125	-94	-85	-111	-87	-82	-62	0	n.a.	169	155	137	39
a	1956 - 1978	-250	-263	-122	-164	-187	-212	-77	-30	-169	-133	-96	-28	35	15	40	4	n.a.	-99	-196	-61	40
r	1978 - 1988	-164	-150	-139	-144	-120	-117	-79	-81	-52	-52	-50	-63	-52	-28	-28	-35	n.a.	11	31	-2	-12
s	1887 - 1988	-1034	-1001	-939	-959	-921	-856	-841	-814	-741	-740	-664	-625	-543	-493	-428	-296	n.a.	-206	-328	-341	-329

Transect #		44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Transect coordinate		15"	90° 01' 00"	45"	30"	15"	90° 00 00"	45"	30"	15"	89° 59' 00"	45"	30"	15"	89° 58' 00"	45"	30"	15"	89° 57' 00"	45"
Y	1887 - 1934	-320	-304	-270	-247	-138	-67	-12	55	90	152	193	212	253	321	326	287	228	163	91
e	1934 - 1956	-22	-57	-52	1	-34	-20	35	35	-21	-36	-31	-51	-93	-61	-3	-5	91	-18	-158
a	1956 - 1978	33	70	64	65	75	46	-4	-9	-6	2	-10	-1	7	65	74	189	138	332	475
r	1978 - 1988	3	49	141	2	77	-5	-18	-25	30	40	42	76	117	88	113	145	167	107	10
s	1887 - 1988	-306	-242	-117	-179	-20	-46	1	56	63	158	194	237	284	413	510	616	624	584	418

Caminada-Moreau headland gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-28271	-744.0	451.4	-265	-2128	38
1934 - 1956	-9618	-253.1	234.2	380	-727	38
1956 - 1978	-7905	-208.0	142.2	40	-528	38
1978 - 1988	-5178	-136.3	77.6	-28	-420	38
1887 - 1988	-50972	-1341.4	569.4	-296	-2025	38

Grand Isle gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-1055	-44.0	275.7	326	-682	24
1934 - 1956	0	0.0	76.5	169	-158	23
1956 - 1978	1289	56.0	132.5	475	-196	23
1978 - 1988	1187	51.6	56.7	167	-25	23
1887 - 1988	2044	88.9	317.3	624	-341	23

Caminada-Moreau headland and Grand Isle gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-29326	-473.0	520.2	326	-2128	62
1934 - 1956	-9618	-157.7	226.8	380	-727	61
1956 - 1978	-6616	-108.5	188.7	475	-528	61
1978 - 1988	-3991	-65.4	115.1	167	-420	61
1887 - 1988	-98479	-321.8	544.6	624	-2128	61

See page 46 for explanation of numbers.

Caminada - Moreau Headland and Grand Isle

TABLE 20.—*Caminada-Moreau headland and Grand Isle bayside rate of change (meters per year)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Transect coordinate		90° 12′ 00″	45″	30″	15″	90° 11′ 00″	45″	30″	15″	90° 10′ 00″	45″	30″	15″	90° 09′ 00″	45″	30″	15″	90° 08′ 00″	45″	30″	15″	90° 07′ 00″	45″
Y	1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1956 - 1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1978 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Transect coordinate		30″	15″	90° 06′ 00″	45″	30″	15″	90° 05′ 00″	45″	30″	15″	90° 04′ 00″	45″	30″	15″	90° 03′ 00″	45″	30″	15″	90° 02′ 00″	45″	30″
Y	1887 - 1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4.4	8.9	8.5	7.5	5.3	10.4	0.8	-0.9	0.7	-2.4
e	1934 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-0.9	0.2	-0.1	n.a.	-0.4	-8.6	-4.4	0.9	-2.5	-1.6
a	1956 - 1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1.2	0	7.0	n.a.	-0.4	-3.3	2.9	-3.5	-4.2	-0.5
r	1978 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.4	-0.8	-1.9	-2.8	-3.7	5.5	-0.9	-2.6	-3.9	-6.9
s	1887 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.2	4.1	5.3	7.0	1.9	2.8	0	-1.2	-1.5	-2.3

Transect #		44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Transect coordinate		15″	90° 01′ 00″	45″	30″	15″	90° 00′ 00″	45″	30″	15″	89° 59′ 00″	45″	30″	15″	89° 58′ 00″	45″	30″	15″	89° 57′ 00″	45″
Y	1887 - 1934	-2.9	-4.9	-1.0	-2.6	-1.7	-0.2	-1.7	-2.7	-1.1	-0.7	-0.5	-0.4	0.3	-0.2	-0.2	0.1	0	-0.2	-3.6
e	1934 - 1956	-1.4	2.9	-0.5	1.3	-0.2	1.1	1.5	3.2	-3.4	-7.1	-1.3	0.6	-0.7	0.5	0.7	1.0	7.9	-0.9	-4.9
a	1956 - 1978	-0.8	-0.4	-1.2	-0.2	-0.6	0.1	-0.6	-3.6	-0.8	0.6	-6.6	-0.8	-1.0	-0.6	-1.8	-1.4	-1.0	-1.4	0.6
r	1978 - 1988	-9.2	-11.2	-13.0	-9.5	-4.6	-11.5	-1.0	-0.8	-0.7	-3.8	-0.8	-1.3	0.2	-0.6	0.8	0	-0.5	-3.2	2.4
s	1887 - 1988	-2.7	-2.8	-2.1	-1.9	-1.4	-1.0	-0.6	-1.4	-1.5	-2.1	-2.0	-0.3	-0.2	-0.2	-0.3	0	1.5	-0.9	-2.4

Caminada-Moreau headland bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	34.6	6.9	1.8	8.9	4.4	5
1934 - 1956	-1.1	-0.3	0.4	0.2	-0.9	4
1956 - 1978	7.7	1.9	3.0	7.0	-0.4	4
1978 - 1988	-8.8	-1.8	1.4	0.4	-3.7	5
1887 - 1988	20.5	4.1	1.9	7.0	1.9	5

Grand Isle bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-15.6	-0.6	2.7	10.4	-4.9	24
1934 - 1956	-15.9	-0.7	3.4	7.9	-8.6	24
1956 - 1978	-29.9	-1.2	1.9	2.9	-6.6	24
1978 - 1988	-77.1	-3.2	4.6	5.5	-13.0	24
1887 - 1988	-24.8	-1.0	1.3	2.8	-2.8	24

Caminada-Moreau headland and Grand Isle bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	19.0	0.7	3.8	10.4	-4.9	29
1934 - 1956	-17.0	-0.6	3.1	7.9	-8.6	28
1956 - 1978	-22.1	-0.8	2.3	7.0	-6.6	28
1978 - 1988	-85.9	-3.0	4.3	5.5	-13.0	29
1887 - 1988	-4.3	-0.1	2.4	7.0	-13.0	29

TABLE 21.—*Caminada-Moreau headland and Grand Isle width measurements (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Transect coordinate		90° 12′ 00″	45″	30″	15″	90° 11′ 00″	45″	30″	15″	90° 10′ 00″	45″	30″	15″	90° 09′ 00″	45″	30″	15″	90° 08′ 00″	45″	30″	15″	90° 07′ 00″	45″
Y	1887	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Transect coordinate		30″	15″	90° 06′ 00″	45″	30″	15″	90° 05′ 00″	45″	30″	15″	90° 04′ 00″	45″	30″	15″	90° 03′ 00″	45″	30″	15″	90° 02′ 00″	45″	30″
Y	1887	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	461	260	174	145	224	301	553	698	686	870
e	1934	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	248	242	161	122	201	n.a.	302	358	378	343
a	1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	120	159	64	101	193	n.a.	315	537	420	358
r	1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	118	170	212	380	189	n.a.	342	283	278	328
s	1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	59	110	201	314	117	n.a.	344	272	238	306

Transect #		44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Transect coordinate		15″	90° 01′ 00″	45″	30″	15″	90° 00′ 00″	45″	30″	15″	89° 59′ 00″	45″	30″	15″	89° 58′ 00″	45″	30″	15″	89° 57′ 00″	45″
Y	1887	1080	1171	1323	1451	1160	1301	1244	1011	895	1006	938	826	855	642	563	550	416	771	866
e	1934	550	724	980	1088	941	1186	1149	1013	982	1126	1105	1021	1125	950	876	843	643	896	772
a	1956	545	650	911	1116	900	1094	1223	1033	928	933	1046	983	1011	901	892	856	910	828	491
r	1978	549	701	967	1176	967	1166	1204	953	911	949	890	964	1001	951	926	992	1024	1115	939
s	1988	428	643	971	1085	998	1141	1172	917	928	956	926	1027	1118	1030	1050	1145	1185	1209	982

Caminada-Moreau headland width summary

Years	Sum	Avg	STD	Total	Range	Count
1887	1264	252.8	111.4	461	145	5
1934	974	194.8	48.0	248	122	5
1956	637	127.4	44.9	193	64	5
1978	1069	213.8	88.7	380	118	5
1988	801	160.2	89.4	314	59	5

Grand Isle width summary

Years	Sum	Avg	STD	Total	Range	Count
1887	21177	882.4	294.5	1451	301	24
1934	19351	841.3	276.8	1186	302	23
1956	18881	820.9	252.5	1223	315	23
1978	19576	851.1	284.1	1204	278	23
1988	20071	872.7	316.1	1209	238	23

Caminada-Moreau headland and Grand Isle width summary

Years	Sum	Avg	STD	Total	Range	Count
1887	22441	773.8	361.2	1451	145	29
1934	20325	725.9	353.1	1186	122	28
1956	19518	697.1	351.1	1223	64	28
1978	20645	737.3	356.8	1204	118	28
1988	20872	745.4	397.5	1451	59	28

TABLE 22.—*Caminada-Moreau headland and Grand Isle gulfside rate of change (meters per year)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Transect coordinate		90° 12′ 00″	45″	30″	15″	90° 11′ 00″	45″	30″	15″	90° 10′ 00″	45″	30″	15″	90° 09′ 00″	45″	30″	15″	90° 08′ 00″	45″	30″	15″	90° 07′ 00″	45″
Y	1887 - 1934	-45.1	-45.3	-39.7	-25.6	-21.6	-22.3	-19.4	-19.8	-19.9	-18.9	-19.1	-18.3	-17.3	-18.0	-18.2	-17.4	-17.1	-15.9	-14.0	-11.4	-11.2	-10.4
e	1934 - 1956	15.9	17.3	9.1	-15.2	-20.0	-23.7	-22.8	-22.5	-20.2	-19.2	-22.6	-19.0	-33.0	-24.8	-26.5	-17.0	-16.7	-15.1	-13.0	-12.6	-11.0	-9.1
a	1956 - 1978	-6.3	-5.3	-7.0	-7.7	-15.9	-15.4	-17.5	-20.2	-20.5	-21.4	-19.8	-24.0	-8.8	-11.5	-7.6	-12.4	-11.3	-10.6	-10.8	-9.7	-9.6	-11.5
r	1978 - 1988	-6.2	-9.7	-9.2	-13.0	-10.2	-11.4	-13.2	-15.7	-18.8	-18.6	-15.1	-12.8	-15.1	-21.5	-23.3	-25.4	-25.3	-42.0	-21.3	-19.0	-18.9	-16.7
s	1887 - 1988	-19.5	-19.4	-18.9	-18.2	-18.9	-20.0	-19.1	-20.0	-20.0	-19.5	-19.6	-19.2	-18.7	-18.4	-18.2	-17.0	-16.6	-17.2	-13.8	-12.1	-11.6	-11.0

Transect #		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Transect coordinate		30″	15″	90° 06′ 00″	45″	30″	15″	90° 05′ 00″	45″	30″	15″	90° 04′ 00″	45″	30″	15″	90° 03′ 00″	45″	30″	15″	90° 02′ 00″	45″	30″
Y	1887 - 1934	-9.2	-9.0	-8.2	-8.6	-8.2	-7.5	-8.1	-8.7	-8.4	-9.8	-9.2	-9.0	-9.3	-8.5	-8.0	-5.6	-14.5	-6.1	-6.1	-8.8	-8.4
e	1934 - 1956	-8.5	-7.5	-13.3	-11.2	-10.4	-8.0	-13.9	-13.3	-5.7	-4.3	-3.9	-5.0	-4.0	-3.7	-2.8	0	n.a.	7.7	7.0	6.2	1.8
a	1956 - 1978	-11.4	-12.0	-5.5	-7.5	-8.5	-9.6	-3.5	-1.4	-7.7	-6.0	-4.4	-1.3	1.6	0.7	1.8	0.2	n.a.	-4.5	-8.9	-2.8	1.8
r	1978 - 1988	-16.4	-15.0	-13.9	-14.4	-12.0	-11.7	-7.9	-8.1	-5.2	-5.2	-5.0	-6.3	-5.2	-2.8	-2.8	-3.5	n.a.	1.1	3.1	-0.2	-1.2
s	1887 - 1988	-10.2	-9.9	-9.3	-9.5	-9.1	-8.5	-8.3	-8.1	-7.3	-7.3	-6.6	-6.2	-5.4	-4.9	-4.2	-2.9	n.a.	-2.0	-3.2	-3.4	-3.3

Transect #		44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Transect coordinate		15″	90° 01′ 00″	45″	30″	15″	90° 00′ 00″	45″	30″	15″	89° 59′ 00″	45″	30″	15″	89° 58′ 00″	45″	30″	15″	89° 57′ 00″	45″
Y	1887 - 1934	-6.8	-6.5	-5.7	-5.3	-2.9	-1.4	-0.3	1.2	1.9	3.2	4.1	4.5	5.4	6.8	6.9	6.1	4.9	3.5	1.9
e	1934 - 1956	-1.0	-2.6	-2.4	0	-1.5	-0.9	1.6	1.6	-1.0	-1.6	-1.4	-2.3	-4.2	-2.8	-0.1	-0.2	4.1	-0.8	-7.2
a	1956 - 1978	1.5	3.2	2.9	3.0	3.4	2.1	-0.2	-0.4	-0.3	0.1	-0.5	0	0.3	3.0	3.4	8.6	6.3	15.1	21.6
r	1978 - 1988	0.3	4.9	14.1	0.2	7.7	-0.5	-1.8	-2.5	3.0	4.0	4.2	7.6	11.7	8.8	11.3	14.5	16.7	10.7	1.0
s	1887 - 1988	-3.0	-2.4	-1.2	-1.8	-0.2	-0.5	0	0.6	0.6	1.6	1.9	2.3	2.8	4.1	5.0	6.1	6.2	5.8	4.1

Caminada-Moreau headland gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-601.5	-15.8	9.6	-5.6	-45.3	38
1934 - 1956	-437.2	-11.5	10.6	17.3	-33.0	38
1956 - 1978	-359.3	-9.5	6.5	1.8	-24.0	38
1978 - 1988	-517.8	-13.6	7.8	-2.8	-42.0	38
1887 - 1988	-504.7	-13.3	5.6	-2.9	-20.0	38

Grand Isle gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-22.4	-0.9	5.9	6.9	-14.5	24
1934 - 1956	0.0	0.0	3.5	7.7	-7.2	23
1956 - 1978	58.6	2.5	6.0	21.6	-8.9	23
1978 - 1988	118.7	5.2	5.7	16.7	-2.5	23
1887 - 1988	20.2	0.9	3.1	6.2	-3.4	23

Caminada-Moreau headland and Grand Isle gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1887 - 1934	-624.0	-10.1	11.1	6.9	-45.3	62
1934 - 1956	-437.2	-7.2	10.3	17.3	-33.0	61
1956 - 1978	-300.7	-4.9	8.6	21.6	-24.0	61
1978 - 1988	-399.1	-6.5	11.5	16.7	-42.0	61
1887 - 1988	-484.4	-7.9	8.4	6.2	-20.0	61

See page 46 for explanation of numbers.

Caminada - Moreau Headland and Grand Isle

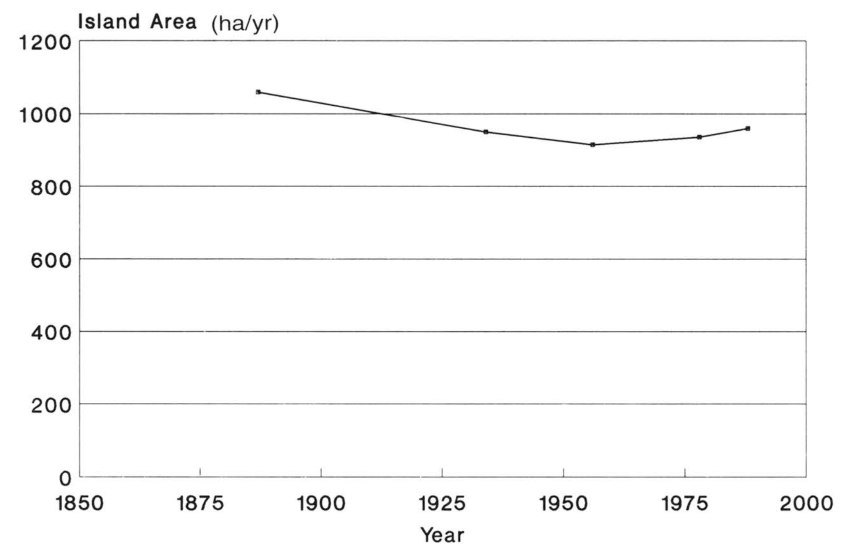


FIGURE 34.—Area changes between 1887 and 1988 of Grand Isle.

FIGURE 35.—Average barrier width of Grand Isle between 1887 and 1988.

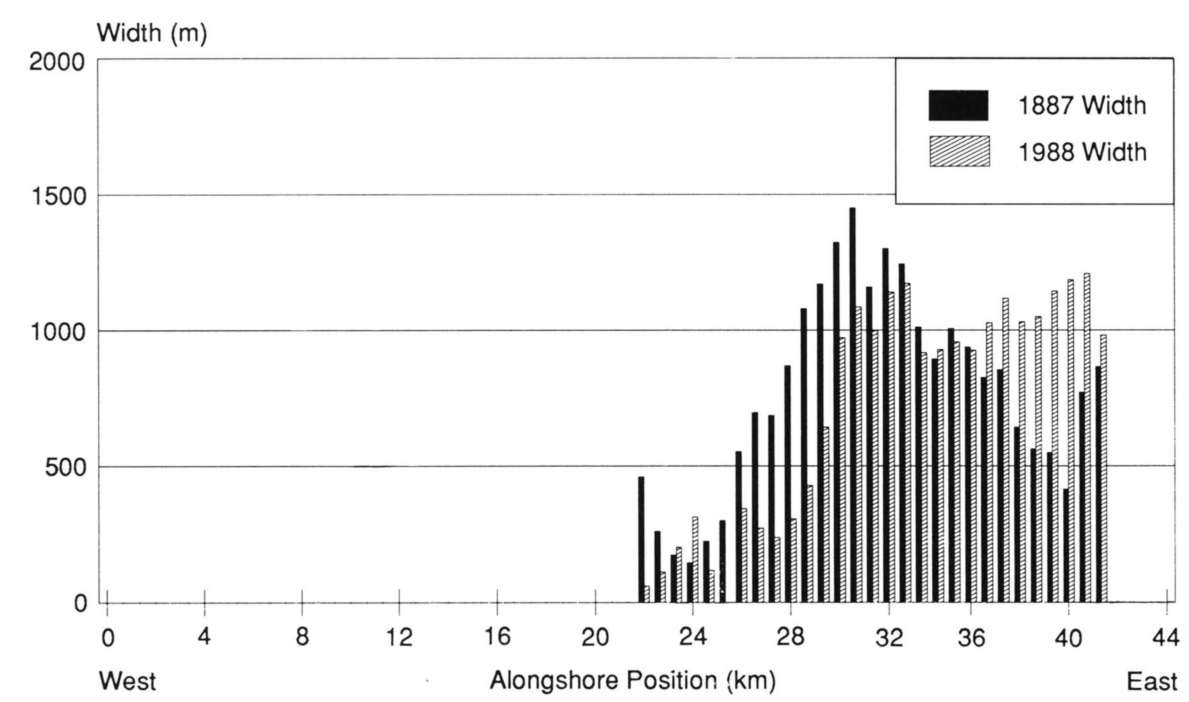


FIGURE 36.—Comparison of barrier widths for 1887 and 1988 for the Caminada-Moreau Headland and Grand Isle shoreline.

TABLE 23.—*Area changes for Grand Isle from 1887 to 1988*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1887	1,059				
1934	950	-109	-10%	-2.3	2347
1934	950				
1956	915	-35	-4%	-1.6	2528
1956	915				
1978	936	21	2%	1.0	N.A.
1978	936				
1988	960	24	3%	1.1	N.A.
1887	1,059				
1988	960	-99	-9%	-1.0	2948

Plaquemines Barrier System—1884 to 1988

The Plaquemines barrier shoreline lies about 45 km northwest of the mouth of the Mississippi River and about 80 km south-southeast of New Orleans (fig. 1). The arcuate barrier system is approximately 48 km long, forms the eastern flank of Barataria Bight, and extends from Grand Terre Islands to Sandy Point (chapter 1, fig. 14). The Plaquemines barrier shoreline consists of the Grand Terre Islands (west, central, and east), Cheniere Ronquille, the Bay La Mer area, Bay Joe Wise spit, Bastian Island, Shell Island, Pelican Island, and Sandy Point. These islands and spits range from 0.02 to 0.9 km wide. Barataria Pass, Pass Abel, Quatre Bayoux Pass, Pass Ronquille, Pass La Mer, Chaland Pass, Grand Bayou Pass, Coupe Bob, Fontanelle Pass, Scofield Bayou, and Dry Cypress Bayou Pass are some of the numerous tidal inlets and bayous that segment the shoreline. In addition, an extensive network of pipeline canals fragment the shoreline's landscape. The Plaquemines shoreline has undergone severe coastal erosion and land loss, primarily from a lack of sediment supply, rapid subsidence, and storm and human impacts (Adams, 1970; Adams and others, 1976; Howard, 1982; Mossa and others, 1985; Penland and Suter, 1988; Levin, 1990; Ritchie and others, 1990). Maps presented depict changes along the shoreline during the years 1884, 1932, 1956, 1973, and 1988. From these maps, linear, area, and width measurements were obtained, and rates of change were calculated to determine the amount and rapidity of change that has occurred.

MORPHOLOGY

In 1884, Plaquemines' morphology was influenced by several tidal inlets and passes, such as Barataria Pass, Quatre Bayoux Pass, Pass La Mer, Chaland Pass, Grand Bayou Pass, and two unnamed passes at both ends of Lanaux Island (1884 map). Grand Terre Island was a large and continuous barrier island that extended from Barataria Pass to Quatre Bayoux Pass. The remainder of the shoreline was dominated by deltaic headlands associated with Robinson Bayou, Grand Bayou, and Dry Cypress Bayou and flanking barrier islands and spits. Lanaux Island was a long and narrow barrier island with bulbous ends, which suggests longshore sediment transport at both ends and an erosional center portion. By 1932, Grand Terre Island was breached, and Pass Ronquille opened east of Quatre Bayoux Pass (1932 map). Chaland Pass had widened substantially, and Lanaux Island was breached by an unnamed tidal inlet as its eastern end welded to the mainland shoreline. Moreover, an opening developed west of Sandy Point to form Sandy Point Island. By 1956, the Grand Terre area had deteriorated and separated into three smaller barriers (1956 map). Lanaux Island, currently known as Shell Island, welded onto the mainland shoreline and evolved into a long, narrow spit. Fontanelle Pass was dredged, and Scofield Bayou developed naturally, forming two new entrances along the shoreline.

By 1973, Grand Terre Island was reduced to less than half its original size with only fragmentary island remnants remaining between Pass Abel and Quatre Bayoux Pass (1973 map). This fragmentary nature of the shoreline had developed between Pass Abel and Chaland Pass. Jetties at Fontanelle Pass (known as Empire jetties) blocked longshore sediment transport to the west-northwest, and a downdrift offset occurred. Large volumes of sand deposited against the updrift jetty to the east caused seaward advance, while the area to the west experienced inadequate sediment supply and shoreline recession. The Plaquemines shoreline appears to be reaching a complete breakdown in the coastal system (1988 map). The Grand Terre Islands no longer form a protective barrier for Barataria Bay. Submergence, a decreasing sediment supply, and human impacts have caused large areas of back-barrier marsh to be converted to open water (Britsch and Kemp, 1990). In 1979, Hurricane Bob breached Shell Island (Coupe Bob), and the island further deteriorated (see Neumann and others, 1985).

SHORELINE MOVEMENT

Magnitude and rate of change, as well as island width for the Plaquemines coast, were derived from 149 shore-normal transects along the gulf and bay shorelines (transects map; tables 24, 25, 26, 27, and 28). Comparisons of shoreline position are made for the periods 1884 vs. 1932, 1932 vs. 1956, 1956 vs. 1973, 1973 vs. 1988, and 1884 vs. 1988. Proximity of the shore-normal transects to entrances (tidal inlets) is also provided.

The average rate of change between 1884 and 1932 along the gulf shoreline was -5.5 m/yr. This average rate decreased to -4.1 and -3.2 m/yr for the periods 1932 and 1956, and 1956 and 1973, respectively. However, the rate increased threefold to -9.9 m/yr between 1973 and 1988 (fig. 37, table 28). This period coincides with the occurrence of Hurricanes Bob (1979) and Juan (1985). The impacts of these hurricanes on the fragile Plaquemines shoreline probably contributed to the increased rate of retreat of the gulf shoreline over the last 15 years.

The bayside rate of change between 1884 and 1932 averaged 2.2 m/yr (table 26). From 1932 to 1956, the shoreline continued to migrate landward at a slower rate of 0.2 m/yr and reversed directions to increase to -2.3 m/yr between 1956 and 1973. Bayside movement reversed again to migrate landward at 3.7 m/yr between 1973 and 1988 (fig. 38). A sudden reverse of the bay shoreline landward suggests storm impacts (hurricanes or cold fronts). Elevated water levels associated with storms carry sediment across islands and deposit it as washover along the bay shoreline to result in shoreline progradation. Hurricanes Bob and Juan directly impacted the Plaquemines shoreline and produced washover deposits (Neumann and others, 1985; Case, 1986; Penland and others, 1987, 1989c; Ritchie and others, 1990).

The 1884 vs. 1988 map illustrates land loss and quantitative changes for the Plaquemines barrier system. The rate of gulfside change along individual transects ranged from 1.9 to -15.6 m/yr (table 28). Three locations exhibited stable or accretionary trends: west Grand Terre Island, west Shell Island, and the land east of Fontanelle Pass. Grand Terre and Shell islands experienced accretion from spit processes, but the land east of Fontanelle Pass is on the updrift side of the Empire jetties, which capture sediment in the longshore transport system. The average gulfside rate of change was -5.5 m/yr (table 28), and the bayside rate of change ranged from 12.5 to -4.7 m/yr, with an average rate of 0.4 m/yr (table 26). The average width narrowed from 487 to 263 m between 1884 and 1988 (fig. 39, table 27) because the gulf shoreline migrated landward about five times faster than the bay shoreline (-5.5 m/yr vs. 0.4 m/yr, respectively). Barrier widths for 1884 and 1988 are shown in figure 40.

AREA AND WIDTH CHANGE

Coalescing deltaic headlands with numerous spits dominate the Plaquemines shoreline. Therefore Grand Terre and Shell islands are the only locations along the Plaquemines coast where true area calculations could be obtained.

Grand Terre

In 1884, the area of Grand Terre was 1,699 ha with an average width of 909 m (tables 27 and 29). By 1932, both area and width decreased to 1,058 ha and 701 m, respectively. The average rate of land loss between 1884 and 1932 was 13.4 ha/yr, a 38 percent decrease in island area. By 1956, the area of Grand Terre was 901 ha and the average width 670 m. As width decreases in response to gulf and bayside erosion, area decreases. Between 1932 and 1956, the average rate of change decreased 15 percent to -6.5 ha/yr. By 1973, area had contracted further to 675 ha, while island width decreased to 608 m. Between 1956 and 1973, area decreased by 25 percent, or an average rate of 13.3 ha/yr. Between 1973 and 1988, the rate of land loss slowed slightly to -10.8 ha/yr (fig. 41).

Overall, the area of Grand Terre Island decreased 1,186 ha at a rate of 11.4 ha/yr between 1884 and 1988 (fig. 42, table 29). Island width decreased from 909 to 530 m, an average island narrowing rate of 3.6 m/yr (fig. 43).

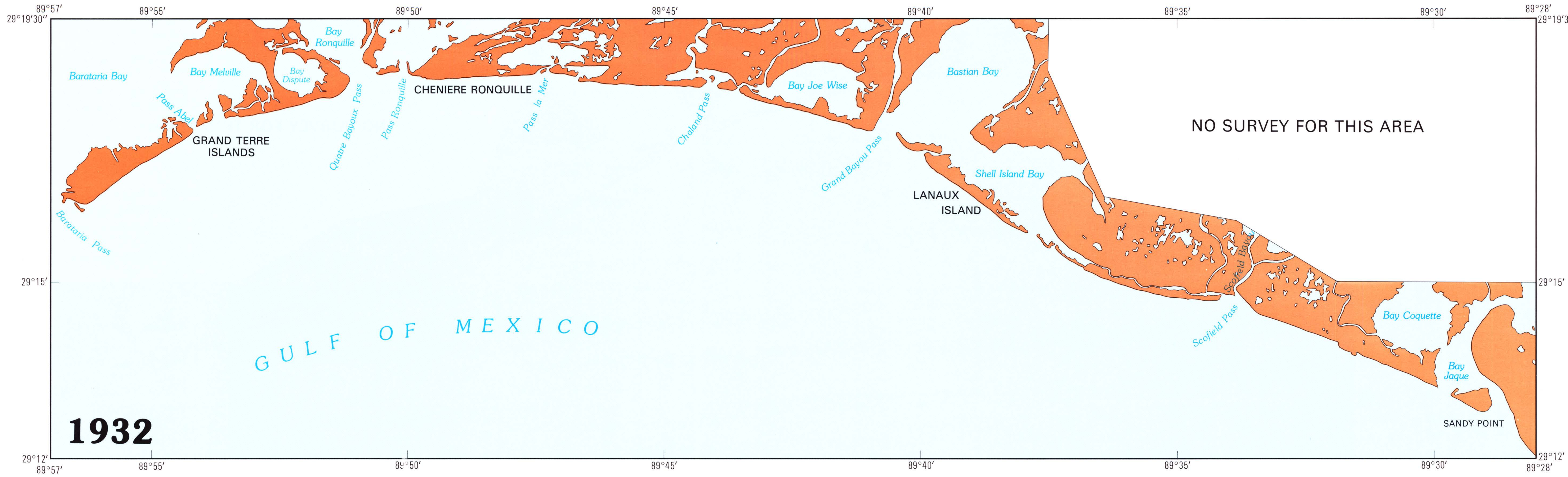
Shell Island

In 1884, the area of Shell Island was 127 ha with an average width of 136 m (tables 27 and 30). By 1932, area and width increased to 175 ha and 247 m as the island grew in size at a rate of 1.0 ha/yr (fig. 44). Between 1932 and 1956, the rate of change slowed to 0.1 ha/yr. Area remained relatively stable at 178 ha, while the width showed an increase to 269 m. By 1973, the size of the island decreased to 144 ha at a rate of 2.0 ha/yr. Similarly, island width narrowed to 207 m. The land loss rate further increased to -5.0 ha/yr between 1973 and 1988 as both area and width experienced nearly a 50 percent decrease to 69 ha and 105 m, respectively.

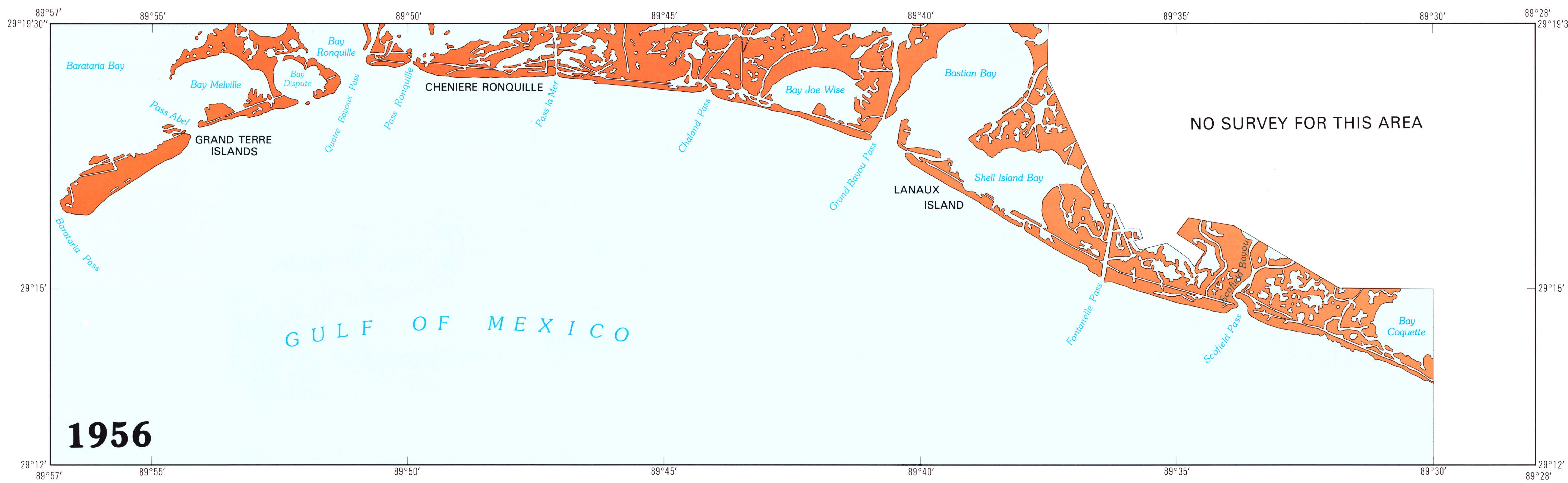
Shell Island decreased 46 percent between 1884 and 1988 (fig. 45, table 30). Its width decreased 55 m to represent an average narrowing rate of 0.5 m/yr for the last 104 years (fig. 46).

• Historic Shorelines •

Plaquemines



SCALE 1:100 000
1 0 1 2 3 4 5 MILES
1 0 1 2 3 4 5 6 7 KILOMETERS



Plaquemines

SCALE 1:100 000

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1 0 1 2 3 4 5 6 7 KILOMETERS

Plaquemines

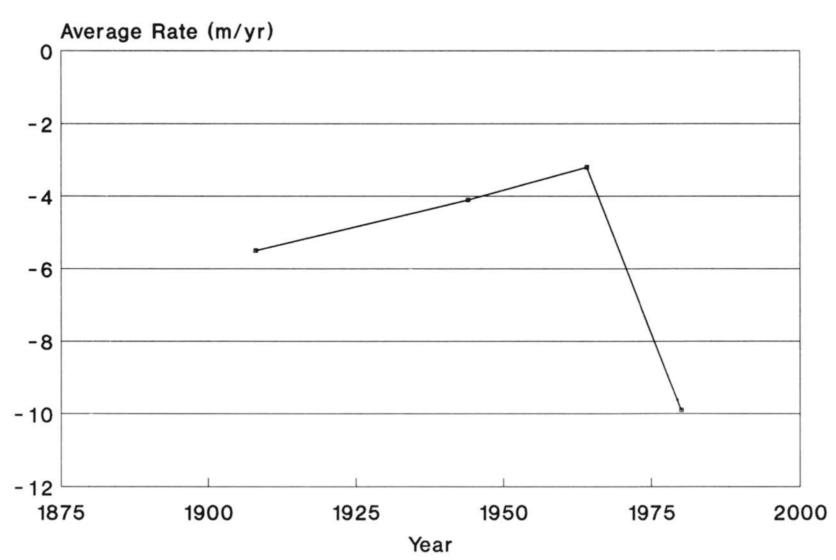


FIGURE 37.—Average gulfside rate of change along the Plaquemines shoreline between 1884 and 1988.

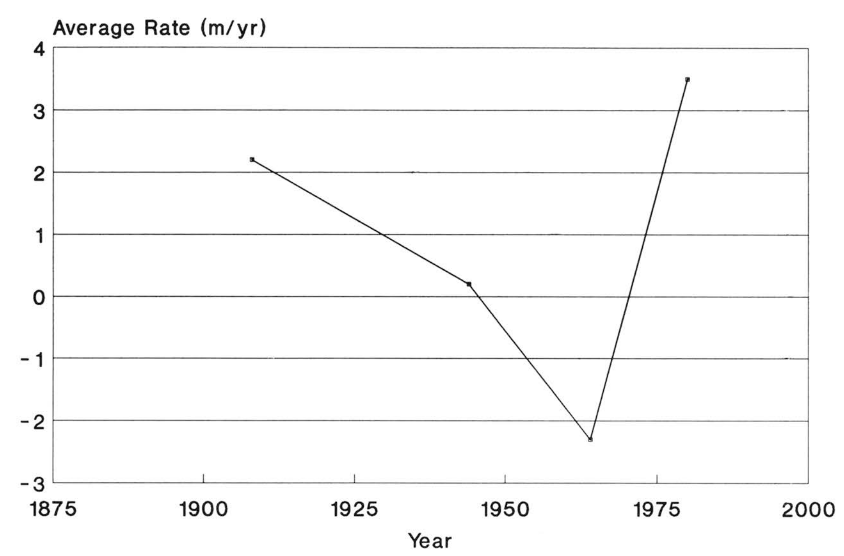


FIGURE 38.—Average bayside rate of change along the Plaquemines shoreline between 1884 and 1988

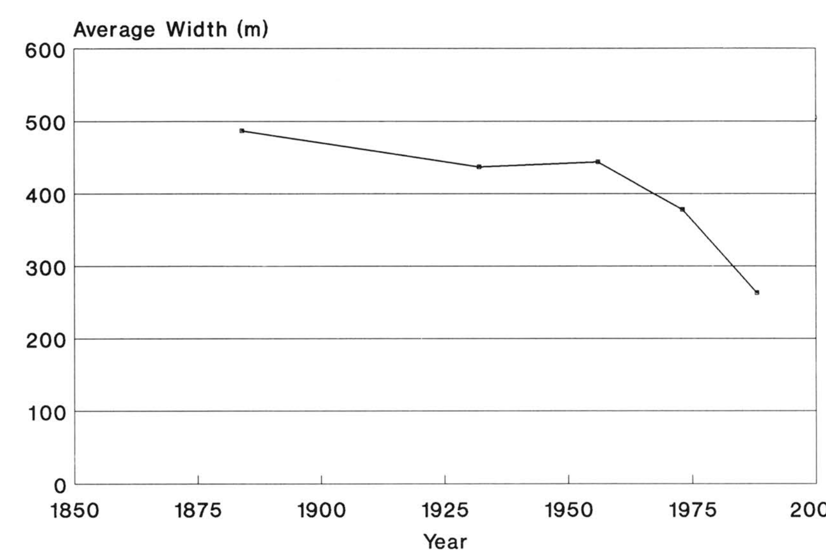


FIGURE 39.—Average barrier width of the Plaquemines shoreline between 1884 and 1988.

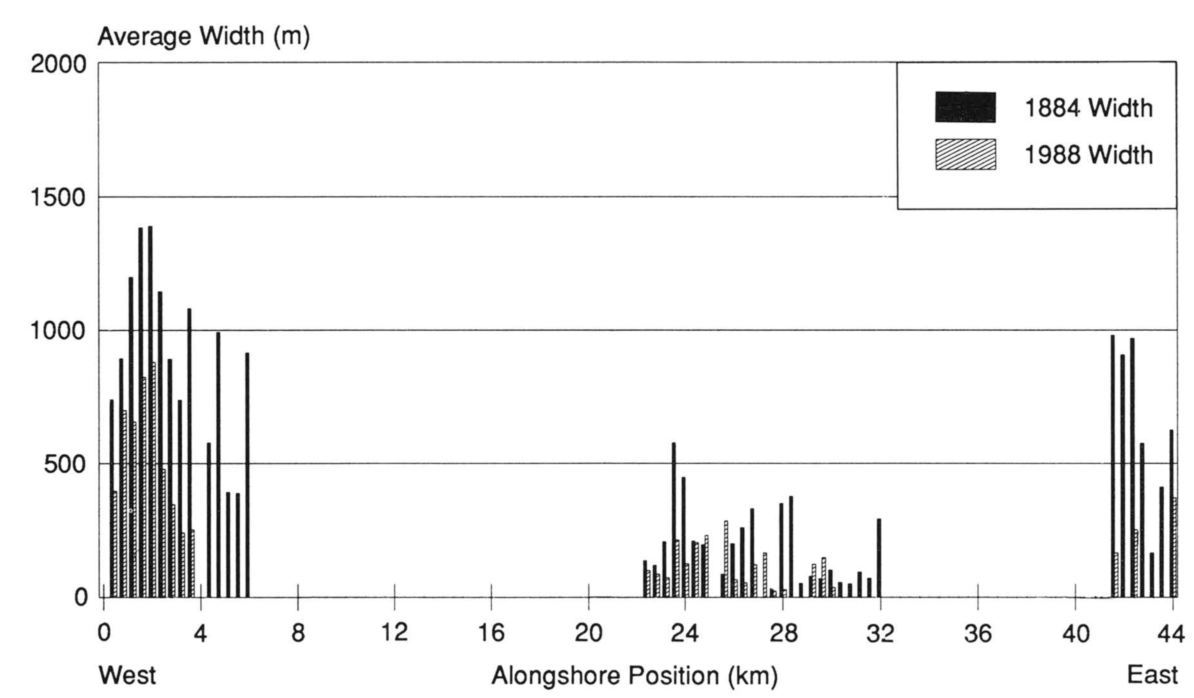


FIGURE 40.—Comparison of the 1884 and 1988 barrier widths along the Plaquemines shoreline.

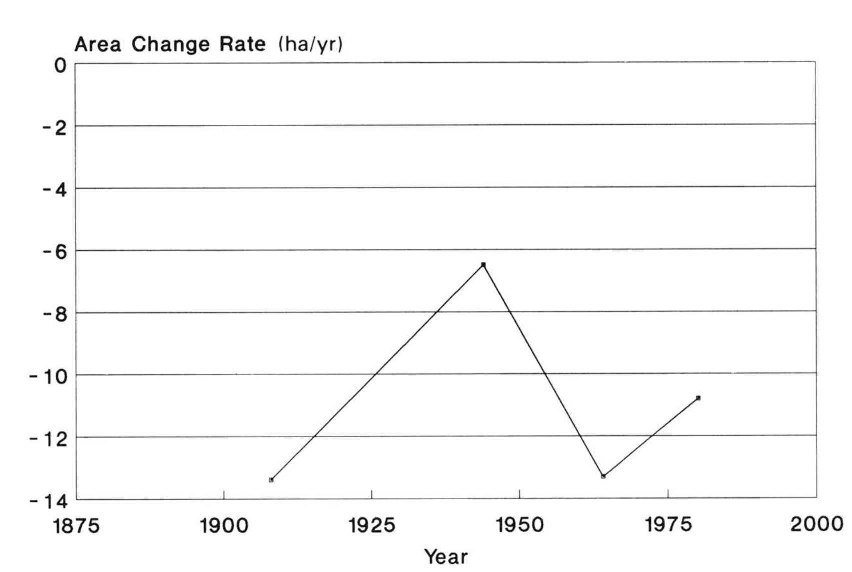


FIGURE 41.—Rate of area change for the Grand Terre Islands between 1884 and 1988.

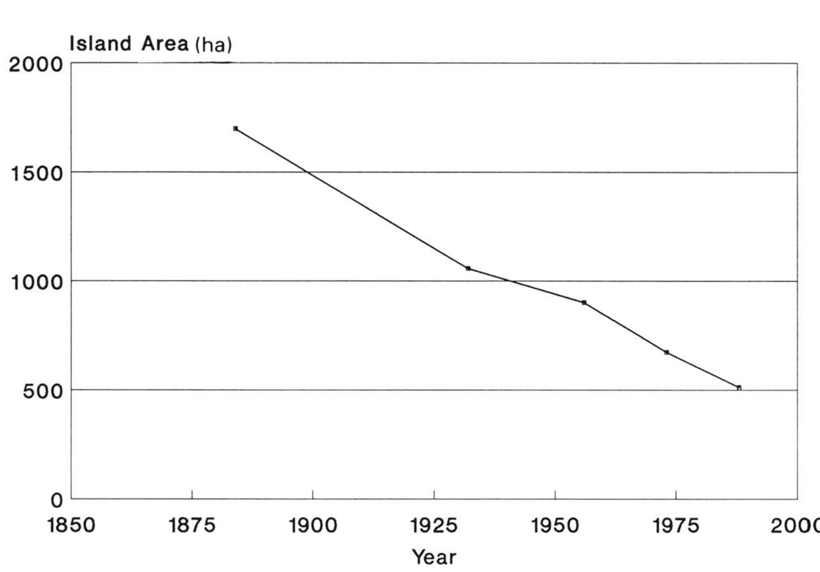
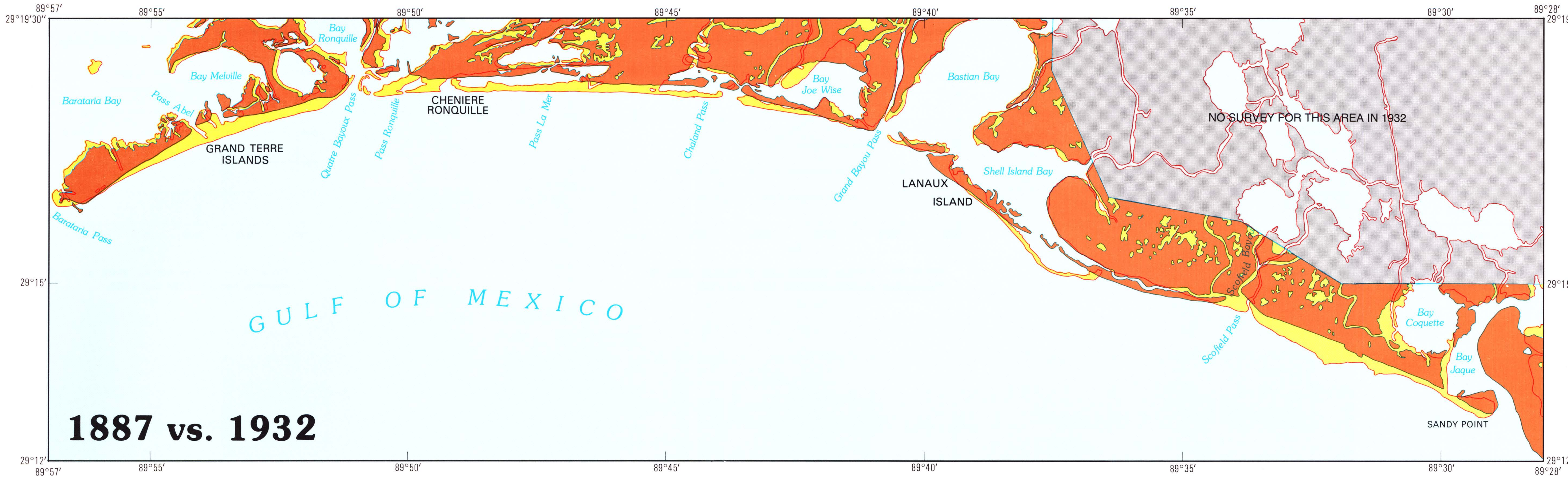


FIGURE 42.—Area changes for the Grand Terre Islands between 1884 and 1988.

Plaquemines

• Shoreline Change and Land Loss •



1887
1932

SCALE 1:100 000
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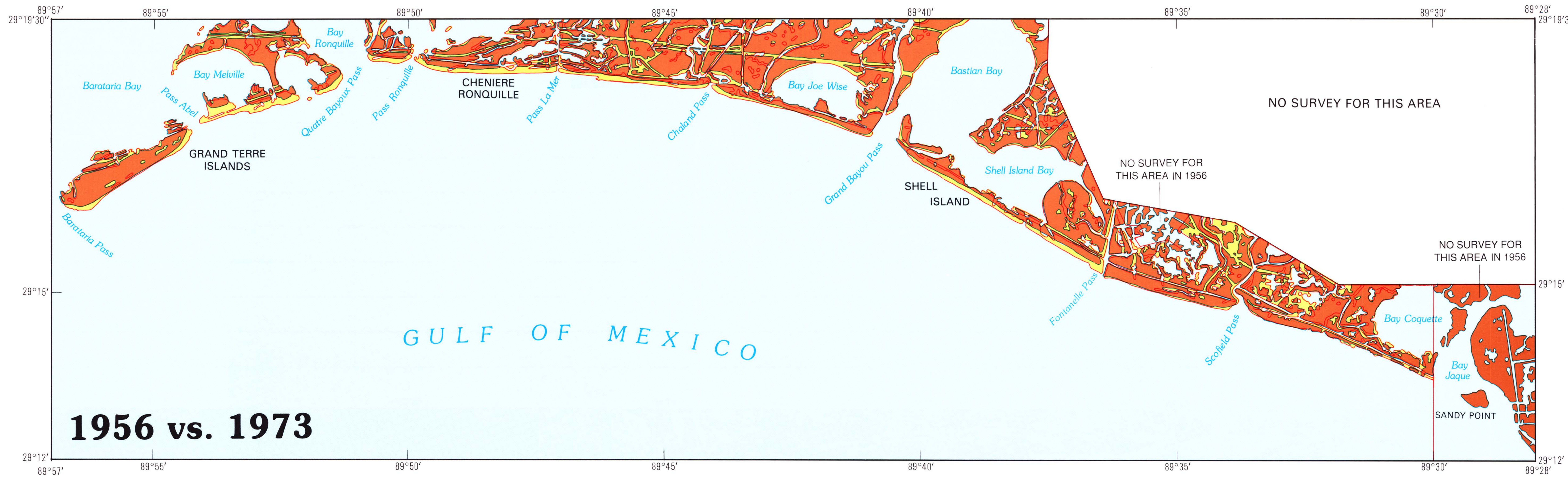
1 0 1 2 3 4 5 6 7 KILOMETERS

1932
1956

Plaquemines

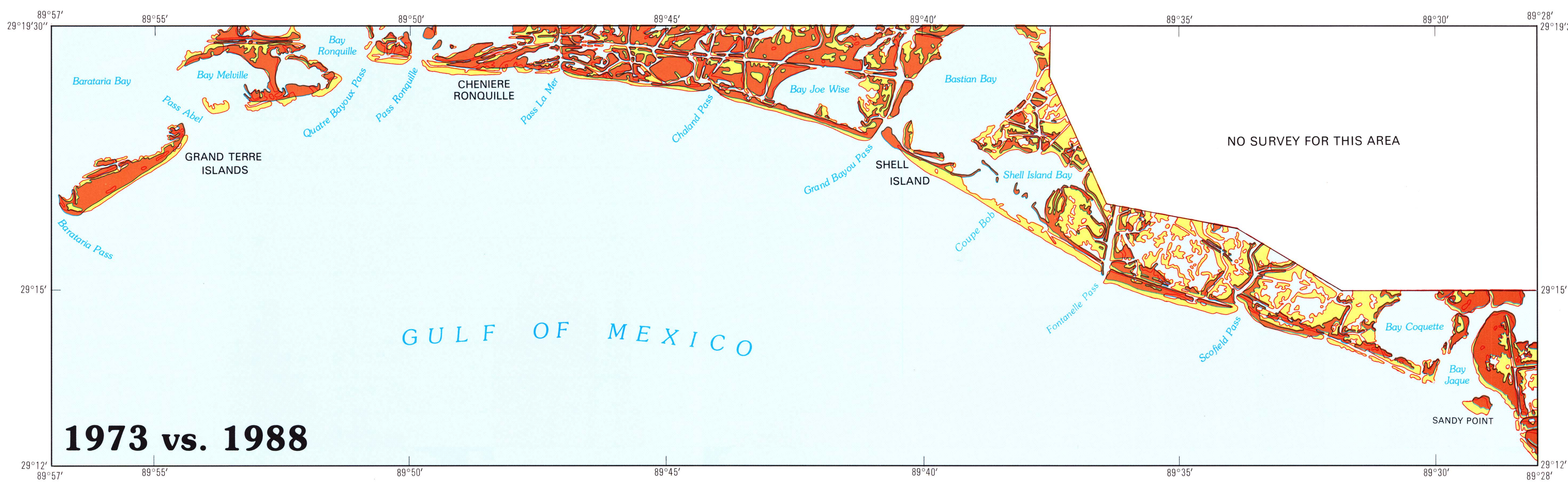


1956

1973

Land

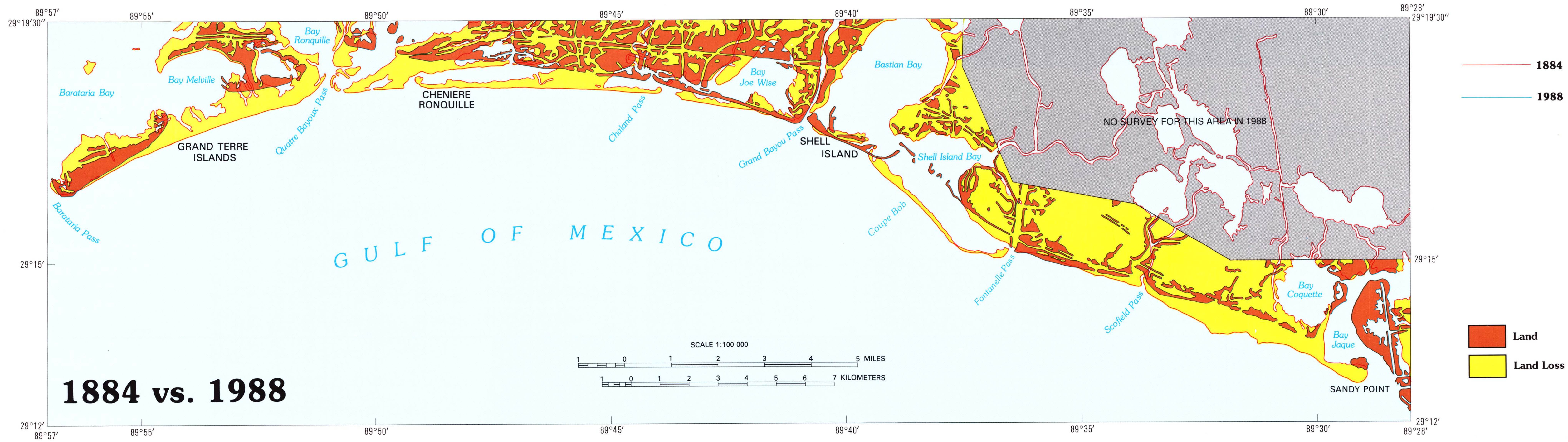
Land Loss

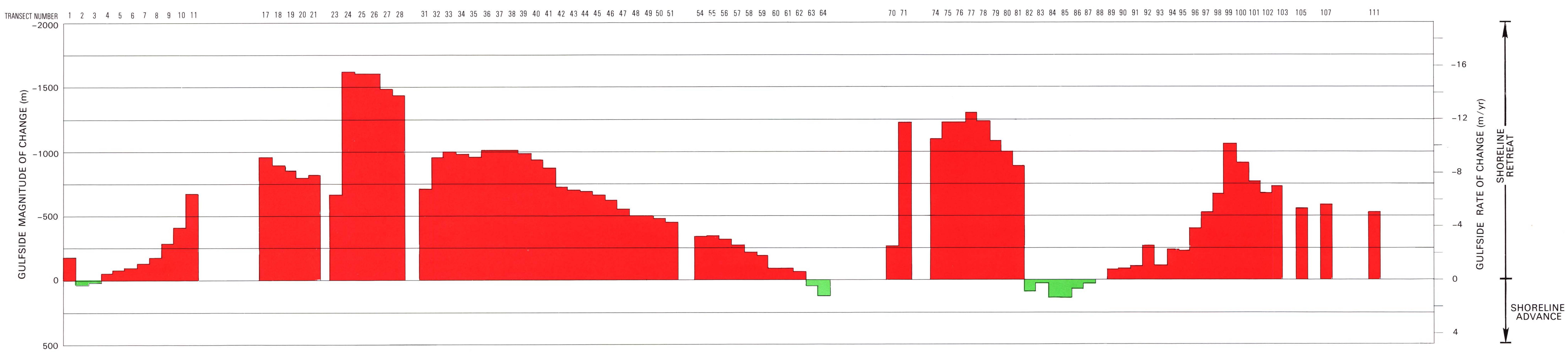


1973

1988

Plaquemines





Plaquemines

TABLE 24 —*Plaquemines bayside magnitude of change (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Transect coordinate		89° 56' 45"	30"	15"	89° 56' 00"	45"	30"	15"	89° 55' 00"	45"	30"	15"	89° 54' 00"	45"	30"	15"	89° 53' 00"
Y	1884 - 1932	-77	-218	-140	-171	-213	-34	-82	-131	-33	-17	n.a.	-43	n.a.	926	0	-55
e	1932 - 1956	-16	-54	-74	-37	-26	-59	-75	-45	-68	-45	n.a.	-53	n.a.	-45	-84	-115
a	1956 - 1973	120	-75	-52	-61	-124	-97	-75	-37	-28	-48	n.a.	n.a.	n.a.	16	n.a.	36
r	1973 - 1988	76	-31	-63	-78	-113	-102	-72	-64	-45	258	n.a.	n.a.	n.a.	n.a.	n.a.	33
s	1884 - 1988	103	-378	-329	-347	-476	-292	-304	-277	-174	148	n.a.	n.a.	n.a.	n.a.	n.a.	-101

Transect #		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Transect coordinate		45"	30"	15"	89° 52' 00"	45"	30"	15"	89° 51' 00"	45"	30"	15"	89° 50' 00"	45"	30"	15"	89° 49' 00"
Y	1884 - 1932	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1932 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1956 - 1973	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1973 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1884 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Transect coordinate		45"	30"	15"	89° 48' 00"	45"	30"	15"	89° 47' 00"	45"	30"	15"	89° 46' 00"	45"	30"	15"	89° 45' 00"	45"
Y	1884 - 1932	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1932 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1956 - 1973	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1973 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1884 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
Transect coordinate		30"	15"	89° 44' 00"	45"	30"	15"	89° 43' 00"	45"	30"	15"	89° 42' 00"	45"	30"	15"	89° 41' 00"	45"
Y	1884 - 1932	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	257	219	83	59	-165	139	96	n.a.	n.a.
e	1932 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-14	-27	25	3	2	-27	12	n.a.	n.a.
a	1956 - 1973	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-15	9	-10	-31	-12	-5	-33	n.a.	n.a.
r	1973 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	4	-17	-39	-297	-57	-48	-83	n.a.	n.a.
s	1884 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	232	184	59	-266	-232	59	-8	n.a.	n.a.

Transect #		66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81
Transect coordinate		30"	15"	89° 40' 00"	45"	30"	15"	89° 39' 00"	45"	30"	15"	89° 38' 00"	45"	30"	15"	89° 37' 00"	45"
Y	1884 - 1932	n.a.	n.a.	n.a.	n.a.	294	-80	25	533	428	228	n.a.	618	683	453	346	n.a.
e	1932 - 1956	n.a.	n.a.	25	-13	21	38	4	18	-56	564	n.a.	408	n.a.	n.a.	n.a.	n.a.
a	1956 - 1973	n.a.	-49	-43	-65	-46	-41	-27	-43	16	-46	-36	n.a.	n.a.	n.a.	n.a.	n.a.
r	1973 - 1988	n.a.	30	-2	-11	-17	991	n.a.	n.a.	757	551	172	n.a.	n.a.	n.a.	n.a.	n.a.
s	1884 - 1988	n.a.	n.a.	n.a.	n.a.	252	908	n.a.	508	1145	1297	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
Transect coordinate		30"	15"	89° 36' 00"	45"	30"	15"	89° 35' 00"	45"	30"	15"	89° 34' 00"	45"	30"	15"	89° 33' 00"	45"	30"
Y	1884 - 1932	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1932 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1956 - 1973	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1973 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1884 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		99	100	101	102	103	104	105	106	107	108	109	110	111	112
Transect coordinate		15"	89° 32' 00"	45"	30"	15"	89° 31' 00"	45"	30"	15"	89° 30' 00"	45"	30"	15"	89° 29' 00"
Y	1884 - 1932	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-219	-113	98	-283	n.a.	112	297	n.a.
e	1932 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	73	38	-126	n.d.	n.d.	n.d.	n.d.	n.d.
a	1956 - 1973	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-145	-130	-100	n.d.	n.d.	n.d.	n.d.	n.d.
r	1973 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-27	n.a.	-188	n.a.	n.a.	n.a.	-15	n.a.
s	1884 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-318	n.a.	-316	n.a.	n.a.	n.a.	n.a.	n.a.

Grand Terre Islands bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	-288	-20.6	271.3	926	-218	14
1932 - 1956	-796	-56.9	24.4	-16	-115	14
1956 - 1973	-425	-35.4	63.1	120	-124	12
1973 - 1988	-201	-18.3	102.4	258	-113	11
1884 - 1988	-2427	-220.6	188.3	148	-476	11

Shell Island bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	3528	352.8	232.7	683	-80	10
1932 - 1956	601	75.1	147.7	564	-56	8
1956 - 1973	-380	-38.0	136.8	16	-65	10
1973 - 1988	2471	308.9	213.1	991	-17	8
1884 - 1988	4110	822.0	310.3	1297	252	5

Plaquemines bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	3820	103.2	278.0	926	-283	37
1932 - 1956	172	5.2	131.3	564	-126	33
1956 - 1973	-1277	-39.9	50.3	120	-145	32
1973 - 1988	1503	51.8	267.1	991	-297	29
1884 - 1988	1077	43.1	466.4	1297	-476	25

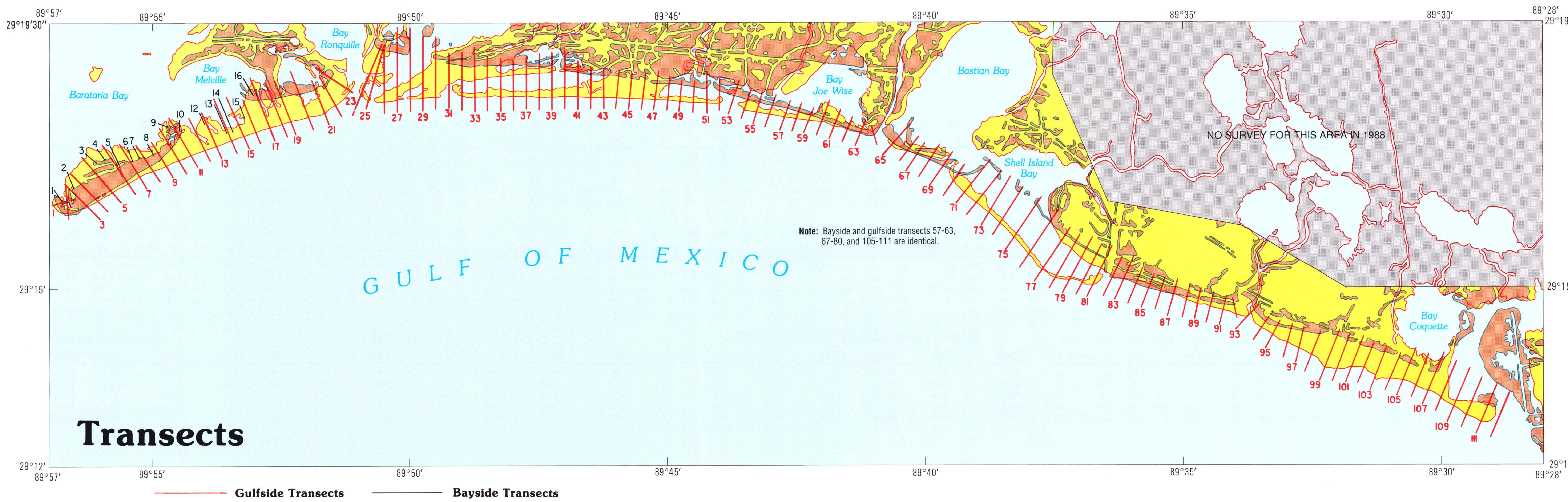


TABLE 25 —*Plaquemines gulfside magnitude of change (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Transect coordinate		89° 56' 45"	30"	15"	89° 56' 00"	45"	30"	15"	89° 55' 00"	45"	30"	15"	89° 54' 00"	45"	30"	15"	89° 53' 00"
Y	1884 - 1932	-356	-213	135	51	-48	-106	-160	-191	-263	-304	-354	n.a.	-630	n.a.	-474	-390
e	1932 - 1956	55	169	174	108	95	119	134	117	110	148	105	n.a.	-79	n.a.	-163	-213
a	1956 - 1973	82	-1	-168	-62	-12	23	14	34	10	-82	-214	n.a.	n.a.	-287	-459	n.a.
r	1973 - 1988	44	75	-128	-153	-111	-134	-118	-140	-141	-169	-207	n.a.	n.a.	n.a.	n.a.	n.a.
s	1884 - 1988	-175	30	13	-56	-76	-98	-130	-180	-284	-407	-670	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Transect coordinate		45"	30"	15"	89° 52' 00"	45"	30"	15"	89° 51' 00"	45"	30"	15"	89° 50' 00"	45"	30"	15"	89° 49' 00"
Y	1884 - 1932	-367	-314	-280	-282	-330	-93	-28	-907	-917	-712	-747	-933	-520	-443	-48	-388
e	1932 - 1956	-135	-214	-202	-257	n.a.	-292	-277	-208	-238	-465	-312	-213	-498	-386	-278	-234
a	1956 - 1973	-218	-452	-155	n.a.	n.a.	-102	-139	-98	-120	-118	-116	-114	n.a.	-120	-127	-103
r	1973 - 1988	-234	88	-218	n.a.	-138	n.a.	-221	-407	-332	-310	-315	-177	n.a.	n.a.	-252	-226
s	1884 - 1988	-954	-892	-855	-795	-817	n.a.	-665	-1620	-1607	-1605	-1490	-1437	n.a.	n.a.	-705	-951

Transect #		33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Transect coordinate		45"	30"	15"	89° 48' 00"	45"	30"	15"	89° 47' 00"	45"	30"	15"	89° 46' 00"	45"	30"	15"	89° 45' 00"	45"
Y	1884 - 1932	-489	-488	-514	-518	-549	-623	-812	-572	-524	-360	-319	-292	-288	-283	-307	-298	-304
e	1932 - 1956	-177	-166	-129	-154	-134	-103	105	-148	-97	-250	-171	-184	-119	-136	-84	-44	-43
a	1956 - 1973	-77	-93	-134	-561	-138	-187	-58	-195	-125	-27	-136	-113	-111	-73	-81	-81	-55
r	1973 - 1988	-251	-234	-181	224	-185	-92	-223	-24	-128	-90	-76	-100	-147	-133	-79	-81	-102
s	1884 - 1988	-994	-981	-958	-1009	-1006	-1005	-988	-939	-874	-727	-702	-689	-665	-625	-551	-504	-504

Transect #		50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
Transect coordinate		30"	15"	89° 44' 00"	45"	30"	15"	89° 43' 00"	45"	30"	15"	89° 42' 00"	45"	30"	15"	89° 41' 00"	45"
Y	1884 - 1932	-344	-354	n.a.	n.a.	-342	-272	-240	-200	-171	-152	-72	-81	-90	-7	121	n.a.
e	1932 - 1956	-14	-20	n.a.	518	93	15	16	11	29	37	38	60	82	86	95	n.a.
a	1956 - 1973	-24	-64	-290	-73	-14	-7	-14	-19	-10	-17	-12	-17	-26	4	-5	-30
r	1973 - 1988	-97	-13	185	-61	-80	-82	-81	-64	-64	-63	-49	-52	-32	-38	-93	n.a.
s	1884 - 1988	-479	-451	n.a.	n.a.	-343	-346	-319	-272	-216	-195	-95	-90	-66	45	118	n.a.

Transect #		66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81
Transect coordinate		30"	15"	89° 40' 00"	45"	30"	15"	89° 39' 00"	45"	30"	15"	89° 38' 00"	45"	30"	15"	89° 37' 00"	45"
Y	1884 - 1932	-53	26	118	n.a.	114	-20	-73	-32	-46	-194	n.a.	-637	-680	-508	-361	-234
e	1932 - 1956	-93	134	233	21	-60	-85	-141	-217	-258	-317	n.a.	-278	-251	-288	-302	-240
a	1956 - 1973	188	27	-7	-35	-57	-71	-56	-52	-63	-27	-53	-84	-82	-97	-57	-142
r	1973 - 1988	-54	-156	-209	-232	-257	-1051	n.a.	n.a.	-731	-691	-433	-301	-228	-192	-274	-275
s	1884 - 1988	n.a.	n.a.	n.a.	n.a.	-260	-1227	n.a.	n.a.	-1098	-1229	-1229	-1300	-1241	-1085	-994	-891

Transect #		82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
Transect coordinate		30"	15"	89° 36' 00"	45"	30"	15"	89° 35' 00"	45"	30"	15"	89° 34' 00"	45"	30"	15"	89° 33' 00"	45"	30"
Y	1884 - 1932	261	278	371	342	282	265	158	63	-10	-109	-471	-165	-306	-353	-464	-539	-594
e	1932 - 1956	-282	-151	-183	-168	-141	-132	-54	-7	50	123	357	-94	-28	-9	-13	-80	-131
a	1956 - 1973	192	7	35	8	-6	4	-23	0	14	17	10	137	47	105	76	88	-7
r	1973 - 1988	-87	-115	-96	-52	-73	-115	-95	-145	-150	-144	-163	3	47	24	-6	0	57
s	1884 - 1988	84	19	127	130	62	22	-14	-89	-96	-113	-267	-119	-240	-233	-407	-531	-675

Transect #		99	100	101	102	103	104	105	106	107	108	109	110	111	112
Transect coordinate		15"	89° 32' 00"	45"	30"	15"	89° 31' 00"	45"	30"	15"	89° 30' 00"	45"	30"	15"	89° 29' 00"
Y	1884 - 1932	-765	-687	-343	-268	-358	-289	-167	-181	-158	-171	n.a.	-250	-216	n.a.
e	1932 - 1956	-253	-208	-306	-332	-325	-287	-277	-240	-236	n.d.	n.d.	n.d.	n.d.	n.d.
a	1956 - 1973	95	71	27	65	119	1	44	47	33	n.d.	n.d.	n.d.	n.d.	n.d.
r	1973 - 1988	-141	-94	-147	-147	-171	n.a.	-160	n.a.	-226	n.a.	n.a.	n.a.	-165	n.a.
s	1884 - 1988	-1064	-918	-769	-682	-735	n.a.	-560	n.a.	-587	n.a.	n.a.	n.a.	-526	n.a.

Grand Terre Islands gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	-4817	-229.4	197.0	315	-630	21
1932 - 1956	-498	-24.9	169.1	174	-292	20
1956 - 1973	-2188	-121.6	153.9	82	-459	18
1973 - 1988	-1905	-119.1	98.0	88	-234	16
1884 - 1988	-6831	-401.8	365.1	193	-954	17

Shell Island gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	-2580	-184.3	255.3	118	-680	14
1932 - 1956	-2142	-142.8	161.7	233	-317	15
1956 - 1973	-698	-41.1	67.7	188	-142	17
1973 - 1988	-5084	-363.1	264.4	-54	-1051	14
1884 - 1988	-10554	-1055.4	291.6	-260	-1300	10

Plaquemines gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	-27600	-265.4	279.7	371	-933	104
1932 - 1956	-9867	-97.7	173.1	518	-498	101
1956 - 1973	-5429	-53.8	115.9	192	-561	101
1973 - 1988	-13955	-148.5	166.5	224	-1051	94
1884 - 1988	-51411	-571.2	464.5	193	-1620	90

See page 46 for explanation of numbers.

Plaquemines

TABLE 26.—*Plaquemines bayside rate of change (meters per year)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Transect coordinate		89° 56′ 45″	30″	15″	89° 56′ 00″	45″	30″	15″	89° 55′ 00″	45″	30″	15″	89° 54′ 00″	45″	30″	15″	89° 53′ 00″	45″	30″	15″	89° 52′ 00″	45″	30″	15″	89° 51′ 00″	45″	30″	15″	89° 50′ 00″	45″	30″	15″	89° 49′ 00″	45″	30″	15″	89° 48′ 00″	45″	30″	15″	89° 47′ 00″	45″	30″	15″	89° 46′ 00″	45″	30″	15″	89° 45′ 00″	45″
Y	1884 - 1932	-1.6	-4.5	-2.9	-3.6	-4.4	-0.7	-1.7	-2.7	-0.7	-0.4	n.a.	-0.9	n.a.	19.3	0	-1.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1932 - 1956	-0.7	-2.3	-3.1	-1.5	-1.1	-2.5	-3.1	-1.9	-2.8	-1.9	n.a.	-2.2	n.a.	-1.9	-3.5	-4.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1956 - 1973	7.1	-4.4	-3.1	-3.6	-7.3	-5.7	-4.4	-2.2	-1.6	-2.8	n.a.	n.a.	n.a.	0.9	n.a.	2.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1973 - 1988	5.1	-2.1	-4.2	-5.2	-7.5	-6.8	-4.8	-4.3	-3.0	17.2	n.a.	n.a.	n.a.	n.a.	n.a.	2.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1884 - 1988	1.0	-3.7	-3.3	-3.4	-4.7	-2.9	-3.0	-2.7	-1.7	1.5	n.a.	n.a.	n.a.	n.a.	n.a.	-1.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
Transect coordinate		30″	15″	89° 44′ 00″	45″	30″	15″	89° 43′ 00″	45″	30″	15″	89° 42′ 00″	45″	30″	15″	89° 41′ 00″	45″	30″	15″	89° 40′ 00″	45″	30″	15″	89° 39′ 00″	45″	30″	15″	89° 38′ 00″	45″	30″	15″	89° 37′ 00″	45″	30″	15″	89° 36′ 00″	45″	30″	15″	89° 35′ 00″	45″	30″	15″	89° 34′ 00″	45″	30″	15″	89° 33′ 00″	45″	30″
Y	1884 - 1932	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	5.4	4.6	1.7	1.2	-3.4	2.9	2.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.1	-1.7	0.5	11.1	8.9	4.8	n.a.	12.9	14.2	9.4	7.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1932 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-0.6	-1.1	1.0	0.1	0.1	-1.1	0.5	n.a.	n.a.	n.a.	n.a.	1.0	-0.5	0.9	1.6	0.2	0.8	-2.3	23.5	n.a.	17.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1956 - 1973	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-0.9	0.5	-0.6	-1.8	-0.7	-0.3	-1.9	n.a.	n.a.	n.a.	-2.9	-2.5	-3.8	-2.7	-2.4	-1.6	-2.5	0.9	-2.7	-2.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1973 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0.3	-1.1	-2.6	-19.8	-3.8	-3.2	-5.5	n.a.	n.a.	n.a.	2.0	-0.1	-0.7	-1.1	66.1	n.a.	n.a.	50.5	36.7	11.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1884 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.2	1.8	0.6	-2.6	-2.2	0.6	-0.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.4	8.7	n.a.	4.9	11.0	12.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		99	100	101	102	103	104	105	106	107	108	109	110	111	112
Transect coordinate		15″	89° 32′ 00″	45″	30″	15″	89° 31′ 00″	45″	30″	15″	89° 30′ 00″	45″	30″	15″	89° 29′ 00″
Y	1884 - 1932	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-4.6	-2.4	2.0	-5.9	n.a.	2.3	6.2	n.a.
e	1932 - 1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.0	1.6	-5.3	n.d.	n.d.	n.d.	n.d.	n.d.
a	1956 - 1973	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-8.5	-7.6	-5.9	n.d.	n.d.	n.d.	n.d.	n.d.
r	1973 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-1.8	n.a.	-12.5	n.a.	n.a.	n.a.	-1.0	n.a.
s	1884 - 1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-3.1	n.a.	-3.0	n.a.	n.a.	n.a.	n.a.	n.a.

Grand Terre Islands bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	-6.0	-0.4	5.7	19.3	-4.5	14
1932 - 1956	-33.2	-2.4	1.0	-0.7	-4.8	14
1956 - 1973	-25.0	-2.1	3.7	7.1	-7.3	12
1973 - 1988	-13.4	-1.2	6.8	17.2	-7.5	11
1884 - 1988	-24.0	-2.2	1.9	1.5	-4.7	11

Shell Island bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	73.5	7.4	4.8	14.2	-1.7	10
1932 - 1956	25.0	3.1	3.9	23.5	-2.3	8
1956 - 1973	-22.4	-2.2	4.3	0.9	-3.8	10
1973 - 1988	164.7	20.6	12.4	66.1	-1.1	8
1884 - 1988	39.5	7.9	12.0	12.5	2.4	5

Plaquemines bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	79.6	2.2	5.8	19.3	-5.9	37
1932 - 1956	7.2	0.2	5.5	23.5	-5.3	33
1956 - 1973	-75.1	-2.3	3.0	7.1	-8.5	32
1973 - 1988	100.2	3.5	17.8	66.1	-19.8	29
1884 - 1988	9.7	0.4	4.5	12.5	-4.7	25

TABLE 27.—*Plaquemines width measurements (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Transect coordinate		89° 56′ 45″	30″	15″	89° 56′ 00″	45″	30″	15″	89° 55′ 00″	45″	30″	15″	89° 54′ 00″	45″	30″	15″	89° 53′ 00″	45″	30″	15″	89° 52′ 00″	45″	30″	15″	89° 51′ 00″	45″	30″	15″	89° 50′ 00″	45″	30″	15″	89° 49′ 00″	45″	30″	15″	89° 48′ 00″	45″	30″	15″	89° 47′ 00″	45″	30″	15″	89° 46′ 00″	45″	30″	15″	89° 45′ 00″	45″
Y	1884	n.a.	740	893	1199	1383	1390	1145	891	738	1080	n.a.	578	993	393	389	915	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1932	n.a.	329	964	1058	1168	1109	752	487	371	686	n.a.	n.a.	321	n.a.	678	494	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1956	n.a.	345	908	1081	1171	1146	870	586	454	617	n.a.	n.a.	268	591	478	195	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1973	n.a.	342	660	934	1094	1012	803	555	424	461	n.a.	n.a.	n.a.	319	83	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1988	n.a.	397	700	656	824	880	479	346	241	251	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
Transect coordinate		30″	15″	89° 44′ 00″	45″	30″	15″	89° 43′ 00″	45″	30″	15″	89° 42′ 00″	45″	30″	15″	89° 41′ 00″	45″	30″	15″	89° 40′ 00″	45″	30″	15″	89° 39′ 00″	45″	30″	15″	89° 38′ 00″	45″	30″	15″	89° 37′ 00″	45″	30″	15″	89° 36′ 00″	45″	30″	15″	89° 35′ 00″	45″	30″	15″	89° 34′ 00″	45″	30″	15″	89° 33′ 00″	45″	30″
Y	1884	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	136	119	208	577	449	210	195	n.a.	86	200	259	331	n.a.	34	351	377	52	79	69	102	55	49	93	70	293	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1932	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	193	167	139	565	202	261	285	n.a.	n.a.	118	257	251	505	442	251	331	552	462	100	n.a.	36	58	39	56	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	192	169	201	605	264	314	380	n.a.	n.a.	34	199	175	510	402	204	195	355	157	348	384	168	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1973	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	160	170	138	560	234	285	351	n.a.	n.a.	111	178	146	410	297	91	110	261	101	275	296	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	99	87	72	214	125	204	230	n.a.	284	64	53	120	166	23	29	n.a.	n.a.	123	147	36	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		99	100	101	102	103	104	105	106	107	108	109	110	111	112
Transect coordinate		15″	89° 32′ 00″	45″	30″	15″	89° 31′ 00″	45″	30″	15″	89° 30′ 00″	45″	30″	15″	89° 29′ 00″
Y	1884	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	980	908	968	575	166	412	626	n.a.
e	1932	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	667	648	945	124	n.a.	274	708	n.a.
a	1956	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	430	419	736	n.d.	n.d.	n.d.	n.d.	n.d.
r	1973	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	353	359	663	n.a.	n.a.	80	551	n.a.
s	1988	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	166	n.a.	251	n.a.	n.a.	n.a.	372	n.a.

Grand Terre Islands width summary

Years	Sum	Avg	STD	Total	Range	Count
1884	12727	909.1	309.0	1390	389	14
1932	8417	701.4	297.9	1168	321	12
1956	8710	670.0	320.5	1171	195	13
1973	6687	607.9	306.7	1094	83	11
1988	4774	530.4	228.3	880	241	9

Shell Island width summary

Years	Sum	Avg	STD	Total	Range	Count
1884	2183	136.4	111.7	377	34	16
1932	3458	247.0	179.1	552	36	14
1956	2963	269.4	132.7	510	34	11
1973	2276	206.9	101.2	410	91	11
1988	1045	104.5	77.3	284	23	10

Plaquemines width summary

Years	Sum	Avg	STD	Total	Range	Count
1884	21439	487.3	407.1	1390	34	44
1932	17053	437.3	310.5	1168	36	39
1956	15551	444.3	291.2	1171	34	35
1973	12867	378.4	269.2	1094	80	34
1988	7639	263.4	232.4	880	23	29

TABLE 28.—*Plaquemines gulfside rate of change (meters per year)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Transect coordinate		89° 56′ 45″	30″	15″	89° 56′ 00″	45″	30″	15″	89° 55′ 00″	45″	30″	15″	89° 54′ 00″	45″	30″	15″	89° 53′ 00″	45″	30″	15″	89° 52′ 00″	45″	30″	15″	89° 51′ 00″	45″	30″	15″	89° 50′ 00″	45″	30″	15″	89° 49′ 00″	45″	30″	15″	89° 48′ 00″	45″	30″	15″	89° 47′ 00″	45″	30″	15″	89° 46′ 00″	45″	30″	15″	89° 45′ 00″	45″
Y	1884 - 1932	-7.4	-4.4	2.8	1.1	-1.0	-2.2	-3.3	-4.0	-5.5	-6.3	-7.4	n.a.	-13.1	n.a.	-9.9	-8.1	-7.6	-6.5	-5.8	-5.9	-6.9	-1.9	-0.6	-18.9	-19.1	-14.8	-15.6	-19.4	-10.8	-9.2	-1.0	-8.1	-10.2	-10.2	-10.7	-10.8	-11.4	-13.0	-16.9	-11.9	-10.9	-7.5	-6.6	-6.1	-6.0	-5.9	-6.4	-6.2	-6.3
e	1932 - 1956	2.3	7.0	7.3	4.5	4.0	5.0	5.6	4.9	4.6	6.2	4.4	n.a.	-3.3	n.a.	-6.8	-8.9	-5.6	-8.9	-8.4	-10.7	n.a.	-12.2	-11.5	-8.7	-9.9	-19.4	-13.0	-8.9	-20.8	-16.1	-11.6	-9.8	-7.4	-6.9	-5.4	-6.4	-5.6	-4.3	4.4	-6.2	-4.0	-10.4	-7.1	-7.7	-5.0	-5.7	-3.5	-1.8	-1.8
a	1956 - 1973	4.8	-0.1	-9.9	-3.6	-0.7	1.4	0.8	2.0	0.6	-4.8	-12.6	n.a.	n.a.	-16.9	-27.0	n.a.	-12.8	-26.6	-9.1	n.a.	n.a.	-6.0	-8.2	-5.8	-7.1	-6.9	-6.8	-6.7	n.a.	-7.1	-7.5	-6.1	-4.5	-5.5	-7.9	-33.0	-8.1	-11.0	-3.4	-11.5	-7.4	-1.6	-8.0	-6.6	-6.5	-4.3	-4.8	-4.8	-3.2
r	1973 - 1988	2.9	5.0	-8.5	-10.2	-7.4	-8.9	-7.9	-9.3	-9.4	-11.3	-13.8	n.a.	n.a.	n.a.	n.a.	n.a.	-15.6	5.9	-14.5	n.a.	-9.2	n.a.	-14.7	-27.1	-22.1	-20.7	-21.0	-11.8	n.a.	n.a.	-16.8	-15.1	-16.7	-15.6	-12.1	14.9	-12.3	-6.1	-14.9	-1.6	-8.5	-6.0	-5.1	-6.7	-9.8	-8.9	-5.3	-5.4	-6.8
s	1884 - 1988	-1.7	0.3	0.1	-0.5	-0.7	-0.9	-1.3	-1.7	-2.7	-3.9	-6.4	n.a.	n.a.	n.a.	n.a.	n.a.	-9.2	-8.6	-8.2	-7.6	-7.9	n.a.	-6.4	-15.6	-15.5	-15.4	-14.3	-13.8	n.a.	n.a.	-6.8	-9.1	-9.6	-9.4	-9.2	-9.7	-9.7	-9.7	-9.5	-9.0	-8.4	-7.0	-6.8	-6.6	-6.4	-6.0	-5.3	-4.8	-4.8

Transect #		50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
Transect coordinate		30″	15″	89° 44′ 00″	45″	30″	15″	89° 43′ 00″	45″	30″	15″	89° 42′ 00″	45″	30″	15″	89° 41′ 00″	45″	30″	15″	89° 40′ 00″	45″	30″	15″	89° 39′ 00″	45″	30″	15″	89° 38′ 00″	45″	30″	15″	89° 37′ 00″	45″	30″	15″	89° 36′ 00″	45″	30″	15″	89° 35′ 00″	45″	30″	15″	89° 34′ 00″	45″	30″	15″	89° 33′ 00″	45″	30″
Y	1884 - 1932	-7.2	-7.4	n.a.	0	-7.1	-5.7	-5.0	-4.2	-3.6	-3.2	-1.5	-1.7	-1.9	-0.1	2.5	n.a.	-1.1	0.5	2.5	n.a.	2.4	-0.4	-1.5	-0.7	-1.0	-4.0	n.a.	-13.3	-14.2	-10.6	-7.5	-4.9	5.4	5.8	7.7	7.1	5.9	5.5	3.3	1.3	-0.2	-2.3	-9.8	-3.4	-6.4	-7.4	-9.7	-11.2	-12.4
e	1932 - 1956	-0.6	-0.8	n.a.	21.6	3.9	0.6	0.7	0.5	1.2	1.5	1.6	2.5	3.4	3.6	4.0	n.a.	-3.9	5.6	9.7	0.9	-2.5	-3.5	-5.9	-9.0	-10.8	-13.2	n.a.	-11.6	-10.5	-12.0	-12.6	-10.0	-11.8	-6.3	-7.6	-7.0	-5.9	-5.5	-2.3	-0.3	2.1	5.1	14.9	-3.9	-1.2	-0.4	-0.5	-3.3	-5.5
a	1956 - 1973	-1.4	-3.8	-17.1	-4.3	-0.8	-0.4	-0.8	-1.1	-0.6	-1.0	-0.7	-1.0	-1.5	0.2	-0.3	-1.8	11.1	1.6	-0.4	-2.1	-3.4	-4.2	-3.3	-3.1	-3.7	-1.6	-3.1	-4.9	-4.8	-5.7	-3.4	-8.4	11.3	0.4	2.1	0.5	-0.4	0.2	-1.4	0	0.8	1.0	0.6	8.1	2.8	6.2	4.5	5.2	-0.4
r	1973 - 1988	-6.5	-0.9	12.3	-4.1	-5.3	-5.5	-5.4	-4.3	-4.3	-4.2	-3.3	-3.5	-2.1	-2.5	-6.2	n.a.	-3.6	-10.4	-13.9	-15.5	-17.1	-70.1	n.a.	n.a.	-48.7	-46.1	-28.9	-20.1	-15.2	-12.8	-18.3	-18.3	-5.8	-7.7	-6.4	-3.5	-4.9	-7.7	-6.3	-9.7	-10.0	-9.6	-10.9	0.2	3.1	1.6	-0.4	0	3.8
s	1884 - 1988	-4.6	-4.3	n.a.	0	-3.3	-3.3	-3.1	-2.6	-2.1	-1.9	-0.9	-0.9	-0.6	0.4	1.1	n.a.	n.a.	n.a.	n.a.	n.a.	-2.5	-11.8	n.a.	n.a.	-10.6	-11.8	-11.8	-12.5	-11.9	-10.4	-9.6	-8.6	0.8	0.2	1.2	1.3	0.6	0.2	-0.1	-0.9	-0.9	-1.1	-2.6	-1.1	-2.3	-2.2	-3.9	-5.1	-6.5

Transect #		99	100	101	102	103	104	105	106	107	108	109	110	111	112
Transect coordinate		15″	89° 32′ 00″	45″	30″	15″	89° 31′ 00″	45″	30″	15″	89° 30′ 00″	45″	30″	15″	89° 29′ 00″
Y	1884 - 1932	-15.9	-14.3	-7.1	-5.6	-7.5	-6.0	-3.5	-3.8	-3.3	-3.6	n.a.	-5.2	-4.5	n.a.
e	1932 - 1956	-10.5	-8.7	-12.8	-13.8	-13.5	-12.0	-11.5	-10.0	-9.8	n.d.	n.d.	n.d.	n.d.	n.d.
a	1956 - 1973	5.6	4.2	1.6	3.8	7.0	0.1	2.6	2.8	1.9	n.d.	n.d.	n.d.	n.d.	n.d.
r	1973 - 1988	-9.4	-6.3	-9.8	-9.8	-11.4	n.a.	-10.7	n.a.	-15.1	n.a.	n.a.	n.a.	-11.0	n.a.
s	1884 - 1988	-10.2	-8.8	-7.4	-6.6	-7.1	n.a.	-5.4	n.a.	-5.6	n.a.	n.a.	n.a.	-5.1	n.a.

Grand Terre Islands gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	-100.4	-4.8	4.1	6.6	-13.1	21
1932 - 1956	-20.8	-1.0	7.0	7.3	-12.2	20
1956 - 1973	-128.7	-7.2	9.1	4.8	-27.0	18
1973 - 1988	-127.0	-7.9	6.5	5.9	-15.6	16
1884 - 1988	-65.7	-3.9	3.5	1.9	-9.2	17

Shell Island gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	-53.8	-3.8	5.3	2.5	-14.2	14
1932 - 1956	-89.3	-6.0	6.7	9.7	-13.2	15
1956 - 1973	-41.1	-2.4	4.0	11.1	-8.4	17
1973 - 1988	-338.9	-24.2	17.6	-3.6	-70.1	14
1884 - 1988	-101.5	-10.1	2.8	-2.5	-12.5	10

Plaquemines gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1884 - 1932	-575.0	-5.5	5.8	7.7	-19.4	104
1932 - 1956	-411.1	-4.1	7.2	21.6	-20.8	101
1956 - 1973	-319.4	-3.2	6.8	11.3	-33.0	101
1973 - 1988	-930.3	-9.9	11.1	14.9	-70.1	94
1884 - 1988	-494.3	-5.5	4.5	1.9	-15.6	90

See page 46 for explanation of numbers.

Plaquemines

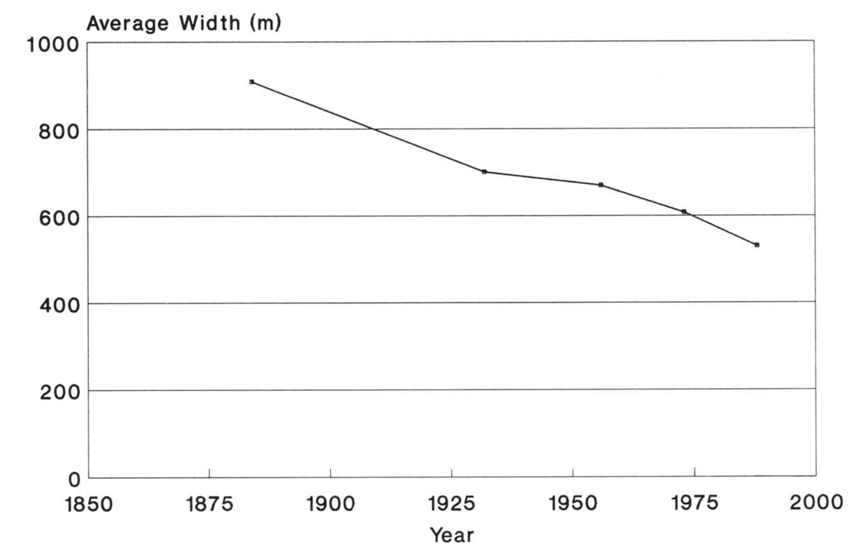


FIGURE 43.—Average barrier width of the Grand Terre Islands between 1884 and 1988.

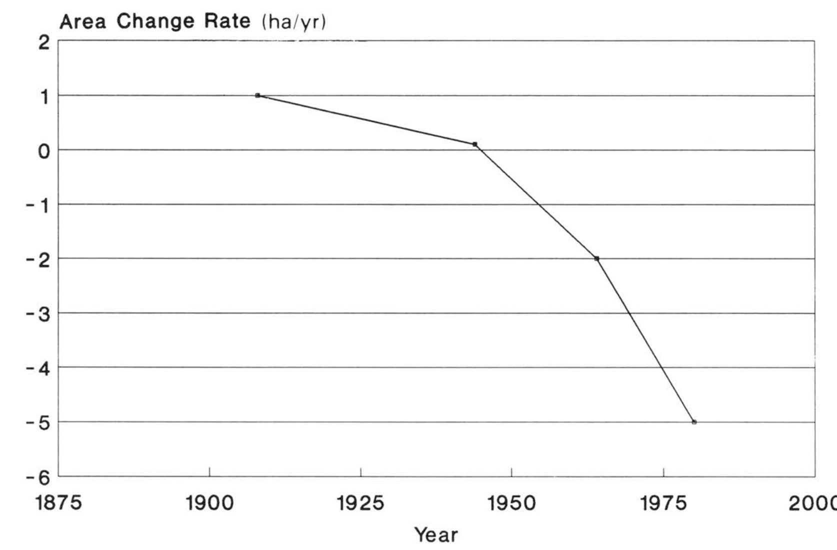


FIGURE 44.—Rate of area change of Shell Island between 1884 and 1988.

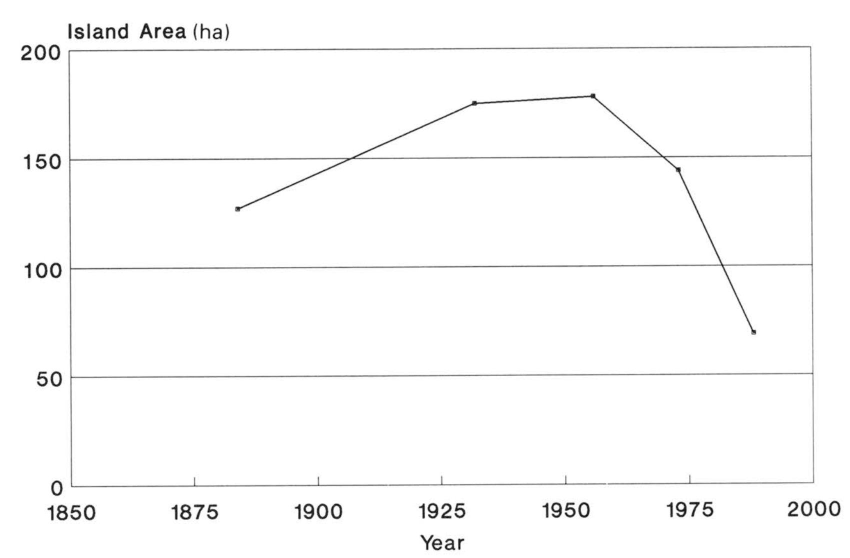


FIGURE 45.—Area changes of Shell Island between 1884 and 1988.

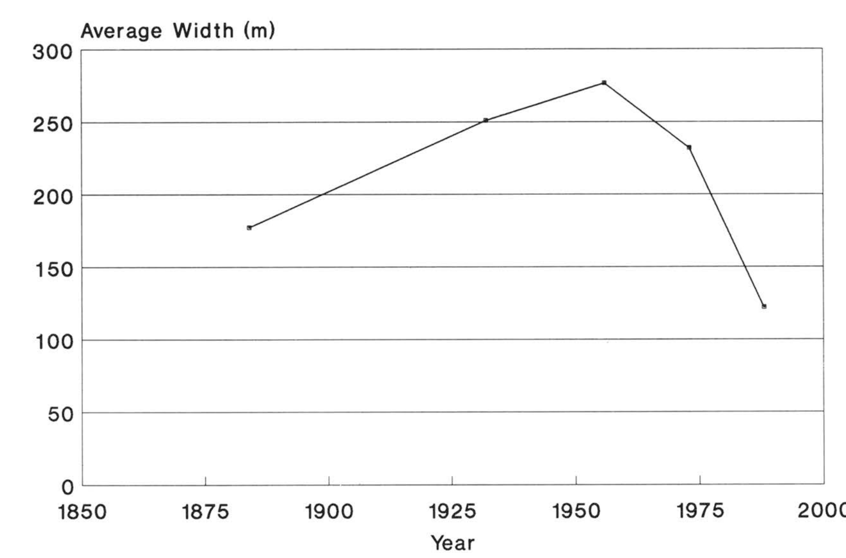


FIGURE 46.—Average barrier width of Shell Island between 1884 and 1988.

TABLE 29.—*Area changes for Grand Terre Island from 1884 to 1988*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1884	1,699				
1932	1,058	-641	-38%	-13.4	2011
1932	1,058				
1956	901	-157	-15%	-6.5	2095
1956	901				
1973	675	-226	-25%	-13.3	2024
1973	675				
1988	513	-162	-24%	-10.8	2036
1884	1,699				
1988	513	-1,186	-70%	-11.4	2033

TABLE 30.—*Area Changes for the Shell Island from 1884 to 1988*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1884	127				
1932	175	48	38%	1.0	N.A.
1932	175				
1956	178	3	0%	0.1	N.A.
1956	178				
1973	144	-34	-19%	-2.0	2045
1973	114				
1988	69	-75	-52%	-5.0	2002
1884	127				
1988	69	-58	-46%	-0.6	2103

Chandeleur Islands Barrier System

The Chandeleur Islands barrier system lies about 25 km north-northeast of the mouth of the Mississippi River and about 120 km east of New Orleans (fig. 1). This system extends south to north from Breton Island to Hewes Point (chapter 1, fig. 18). The Chandeleur Islands are the largest barrier island system along the Mississippi River delta plain and provide the seaward protective boundary for St. Bernard Parish (Kwon, 1969; Kahn, 1980; Nummedal and others, 1980; Kahn and Roberts, 1982; Penland and others, 1985; Suter and others, 1988; Ritchie and others, 1991). Three tidal inlets, Breton Island Pass, Grand Gosier Pass, and Curlew Island Pass, connect the Gulf of Mexico to Breton and Chandeleur sounds. For the purposes of this atlas, the Chandeleur Islands barrier system is divided into two sections: South Chandeleur Islands (Breton, Grand Gosier, and Curlew islands) and North Chandeleur Islands (New Harbor, North, and Freemason islands, and Chandeleur Island). The South Chandeleur Islands extend north from Breton Island to Curlew Island, and the North Chandeleur Islands extend from Curlew Island Pass to Hewes Point. Shoreline position, island width, and rate of change data were compiled for the South Chandeleur Islands from the years 1869, 1922, 1951, 1978, and 1989; the North Chandeleur Islands include the years 1855, 1922, 1951, 1978, and 1989.

South Chandeleur Islands—1869 to 1989

Morphology

The South Chandeleur Islands are fragmented into three groups of small ephemeral islands and shallow shoals that are separated by wide tidal inlets. In 1869, the barrier islands included Breton Island, Errol Island, and Curlew Island (1869 map). Grand Gosier, which currently lies between Breton Island and Curlew Island, was not mapped on the NOS T-sheet for this area. Either field surveyors accidently missed the island, or the island did not exist at that time. Breton Island displayed a typical horseshoe shape that characterizes the island today, which suggests antecedent topographic control that anchors both ends. By 1922, all of the islands except Breton were reduced to small islands and shoals (1922 map). Additionally, Breton Island was breached, and two small shoals appeared between Breton and Errol islands. These features later corresponded to the north and south ends of Grand Gosier Island.

By 1951, Grand Gosier had evolved into a substantial barrier island apparently from two much smaller shoals (1951 map). Also, Errol Island was not present, leaving Curlew Island and the southern half of Stake Island to the north. The 1978 map depicts Breton and Grand Gosier islands as breached. The resistant ends of Breton Island are evident and tend to anchor the island. Grand Gosier Island evolved into two smaller islands known as north and south Grand Gosier islands, and Curlew Island was the single remaining barrier island to the north. By 1989, these three groups of islands had remained relatively intact (1989 map). The central portion of Breton Island remained susceptible to breaching, and the northern end of south Grand Gosier formed a unique recurved spit directed offshore. A large fetch is available across Breton and Chandeleur sounds capable of producing enough wave energy to form well-developed, barred beaches along the bay shorelines of south and north Grand Gosier islands and Curlew Island. On the northern end of south Grand Gosier, bayside wave energy may be more dominant than gulfside wave energy, thus producing the recurved spit.

Shoreline Movement

Shoreline change maps were constructed for the South Chandeleur Islands area. Shoreline movement and island width were derived from 120 shore-normal transects along the gulf and bay shorelines (transects map, tables 31, 32, 33, 34, and 35). Comparisons of shoreline position are made for the periods 1869 vs. 1922, 1922 vs. 1951, 1951 vs. 1978, 1978 vs. 1989, and 1869 vs. 1989.

The average rate of gulfside change for the South Chandeleur Islands between 1869 and 1922 was -11.3 m/yr (fig. 47, table 35). This rate decreased twofold to -5.7 m/yr between 1922 and 1951. Between 1951 and 1978, the rate increased to -16.6 m/yr and increased further to -19.7 m/yr between 1978 and 1989. Along the bay shoreline, the average rate of change was 8.8 m/yr between 1869 and 1922 and decreased to 5.9 m/yr between 1922 and 1951 (fig. 48, table 33). The rate increased to 9.8 and 19.8 m/yr for the periods 1951 to 1978 and 1978 to 1989, respectively. The South Chandeleur Islands are migrating landward along the gulf and bay shorelines because a good sediment supply exists, and the islands are narrow and low enough for this sediment to be transported across the island by washover processes.

The 1869 vs. 1989 map illustrates land loss and summarizes changes along the gulf and bay shorelines. Between 1869 and 1989, the average rate of change along the gulf shoreline ranged from 5.9 to -21.1 m/yr with an average rate of -11.6 m/yr (table 35). The gulf shoreline of the South Chandeleur Islands has undergone retreat over the last 120 years, except for the southern end of Breton Island, which experienced accretion. The bay-side rate of change ranged from 22.6 to -7.7 m/yr, with an average rate of 10.7 m/yr (table 33). The gulf shoreline is migrating landward about 1.0 m/yr faster than the bay shoreline (-11.6 m/yr vs. 10.7 m/yr), causing the barrier width to narrow as the islands retreat (fig. 49, table 34).

Area and Width Change

Breton Island

In 1869, the average width of Breton Island was 396 m, and the area was 332 ha (tables 34, and 36). This area decreased by 18 percent to 271 ha over the next 53 years, with a similar decrease in width to 320 m. The average rate of change between 1869 and 1922 was -1.2 ha/yr. However, by 1951, island area expanded to 291 ha at a rate of 0.7 ha/yr, but island width continued to narrow (292 m).

During the period 1951 to 1978, Breton Island experienced the greatest amount of area loss. Island area was reduced by 52 percent, with a loss of 150 ha at a rate of 5.4 ha/yr, and the average island width narrowed to 268 m. Because its center area was breached, the island lost its unconsolidated and highly mobile central portion to leave two resistant ends that did not experience much change. Between 1978 and 1989, Breton Island slowly recovered and actually experienced a 23-ha increase in area to 164 ha, reversing from land loss to land gain at a rate of 2.2 ha/yr. Interestingly, average width continued to decrease (199 m) even though area was increasing. This was possible because the breached central portion of Breton Island almost completely recovered to cause area gain. Average island width did not increase, however, because the recovered central portion had always been narrower than the resistant ends. Therefore, when the resistant ends suffered concurrent erosion, an overall decrease in width occurred.

Breton Island's area decreased between 1869 and 1989 from 332 to 164 ha (fig. 50, table 36). The average rates of area change fluctuated between -5.4 and 2.2 ha/yr, which indicate reversing periods between land loss and gain in response to the breaching and healing process along the central island portion (fig. 51). In contrast, the average width of Breton Island experienced a continuous decrease from 1869 to 1989 (fig. 52).

Grand Gosier and Curlew Islands

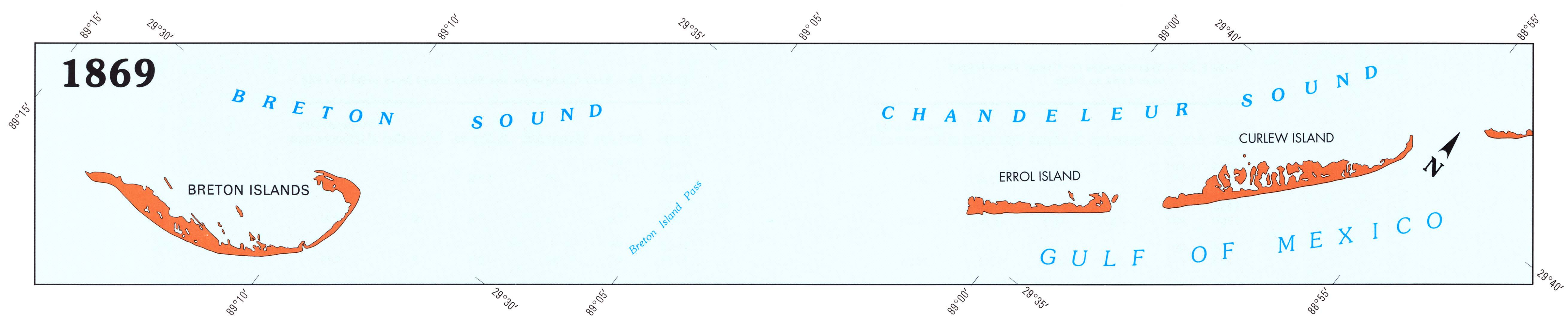
These barrier islands experienced extreme changes in configuration over the last 120 years, causing large fluctuations in average width and island area. In 1869, the average width was 423 m, and the area of Grand Gosier and Curlew islands was 453 ha (tables 34 and 37). By 1922, island area decreased dramatically to only 29 ha at an average rate of -8.0 ha/yr, and average island width was only 90 m (fig. 53). Tremendous land gain occurred by 1951 with island area expanding to 330 ha, a 1,038 percent increase at a rate of 10.4 ha/yr. Similarly, average width jumped 186 m to 276 m. Between 1951 and 1978, total area fell to 162 ha at a rate of 6.0 ha/yr. Changes in land area reversed again between 1978 and 1989, increasing 71 percent to 277 ha with a similar increase in island width to 249 m. For this period, Grand Gosier and Curlew islands experienced land gain at an average rate of 11.1 ha/yr.

Overall, the area of the islands declined between 1869 and 1989 from 453 to 277 ha (fig. 54). This is a total land loss of 39 percent at an average rate of -1.5 ha/yr (table 37). The rate of area change fluctuated between -8.0 to 11.1 ha/yr from 1869 to 1989, resulting in periods of land gain and loss similar to that of Breton Island (fig. 51). Likewise, average barrier width decreased from 423 m in 1869 to 249 m in 1989 (fig. 55). This signifies an average island narrowing rate of 1.5 m/yr between 1869 and 1989.

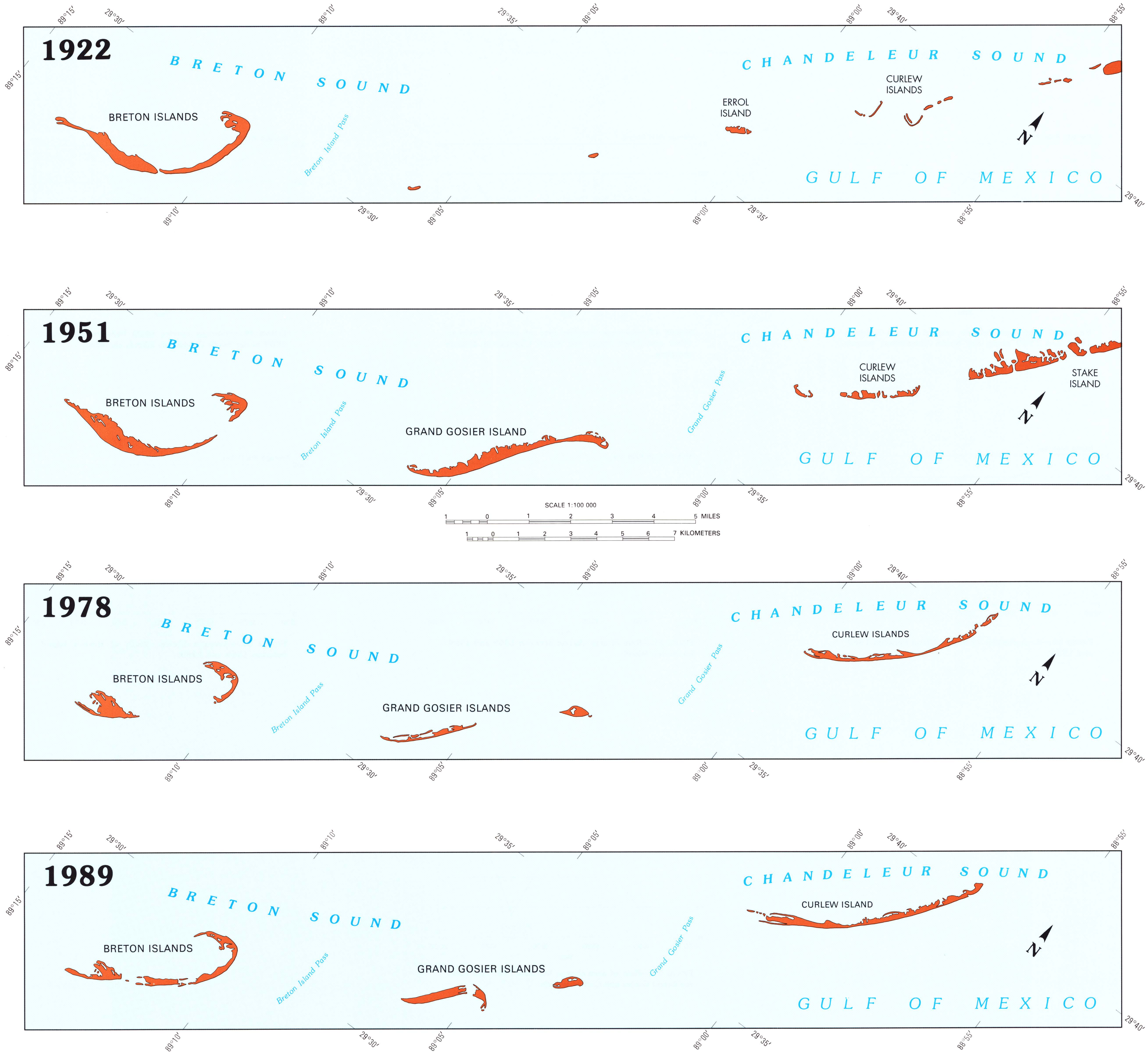
South Chandeleur Islands Summary

The area of the South Chandeleur Islands has shown an overall decline in area from 784 ha in 1869 to 441 ha in 1989 with fluctuations in the intervening years (fig. 56). A total loss of 343 ha, at an average loss rate of -2.9 ha/yr, has been determined (table 38). Interestingly, the average rate of area change fluctuated between -11.5 and 13.3 ha/yr from 1869 to 1989, showing cyclic periods of land gain during an overall trend of land loss (fig. 57). The barriers decreased in average width from 384 m in 1869 to 232 m in 1989. A comparison of barrier widths for 1869 and 1989 is shown in figure 58.

• Historic Shorelines •



South Chandeleur Islands



South Chandeleur Islands

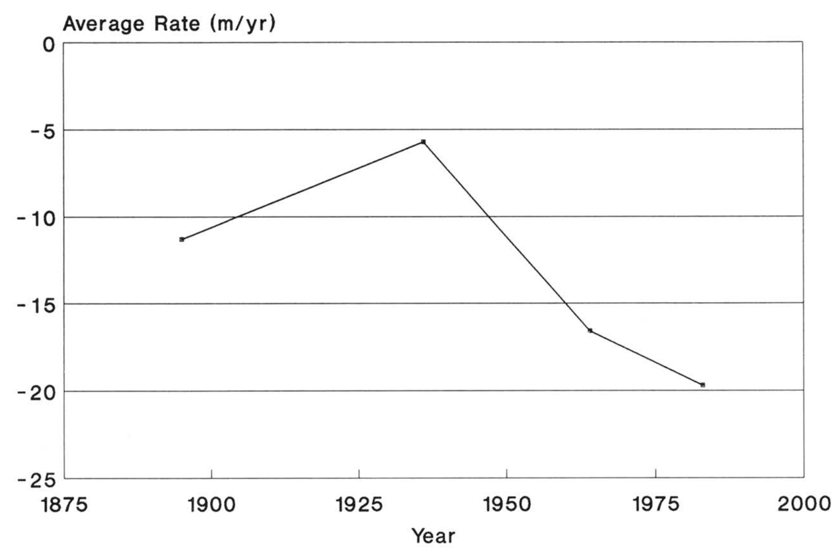


FIGURE 47.—Average gulfside rate of change between 1869 and 1989 along the South Chandeleur Islands shoreline.

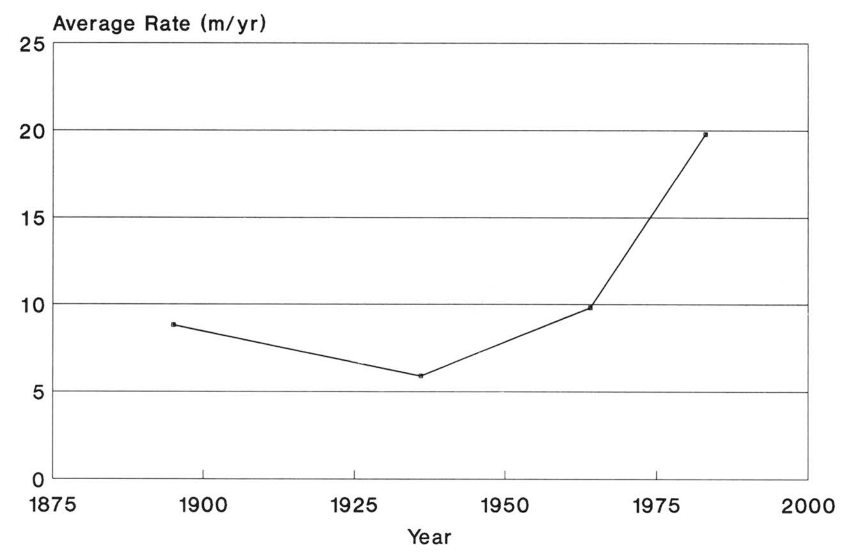


FIGURE 48.—Average bayside rate of change between 1869 and 1989 along the South Chandeleur Islands shoreline.

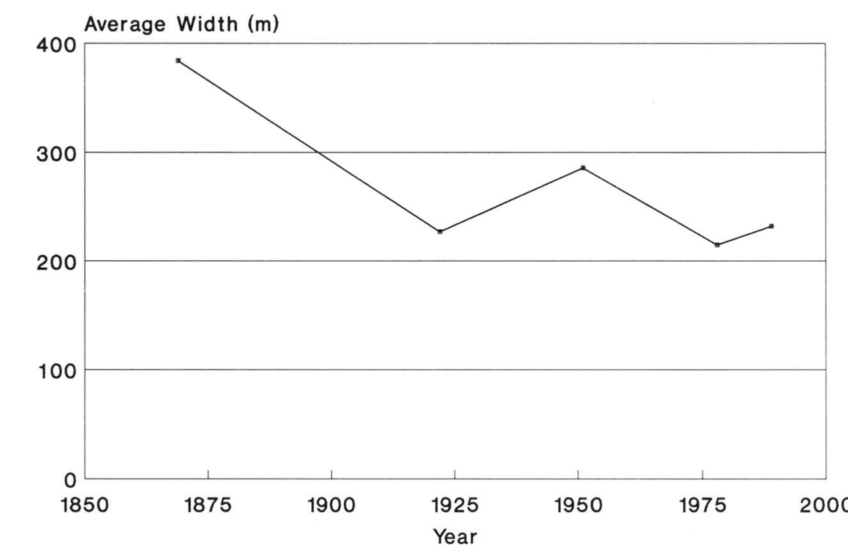


FIGURE 49.—Average barrier width between 1869 and 1989 of the South Chandeleur Islands shoreline.

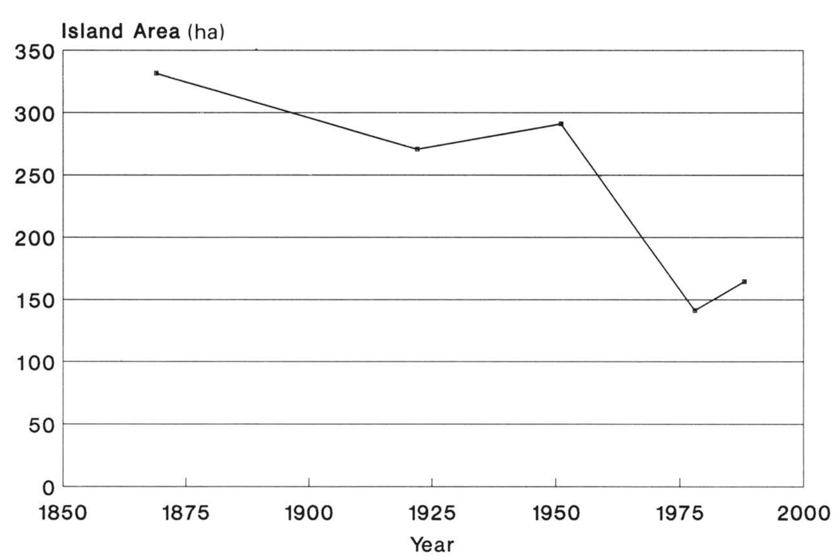


FIGURE 50.—Area changes of Breton Island between 1869 and 1989.

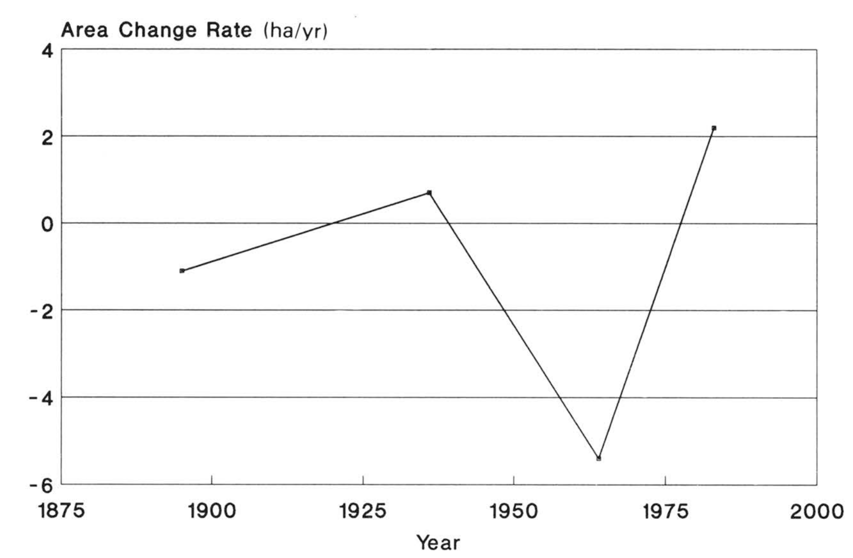


FIGURE 51.—Rate of area change between 1869 and 1989 for Breton Island.

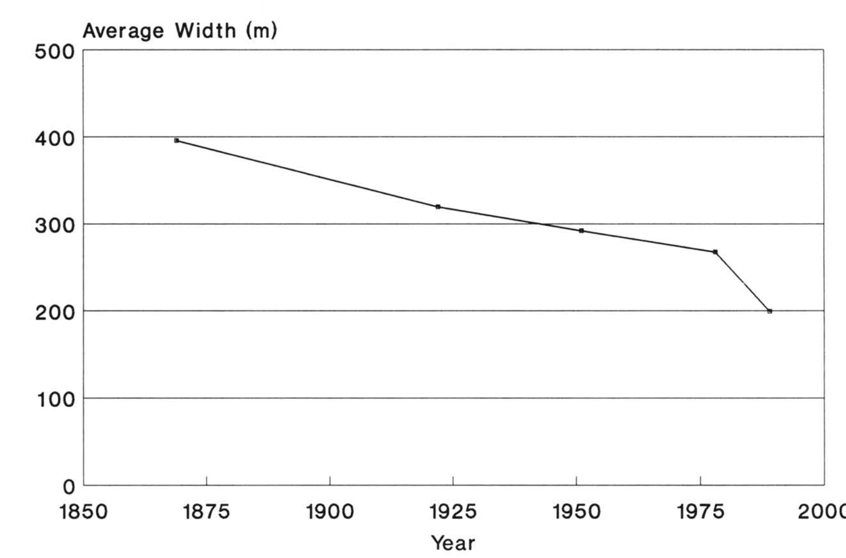


FIGURE 52.—Average barrier width of Breton Island between 1869 and 1989.

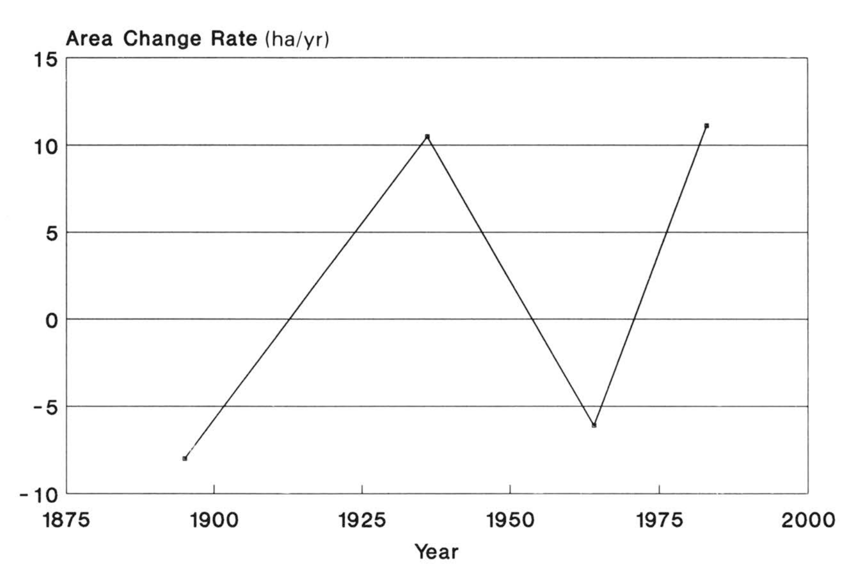
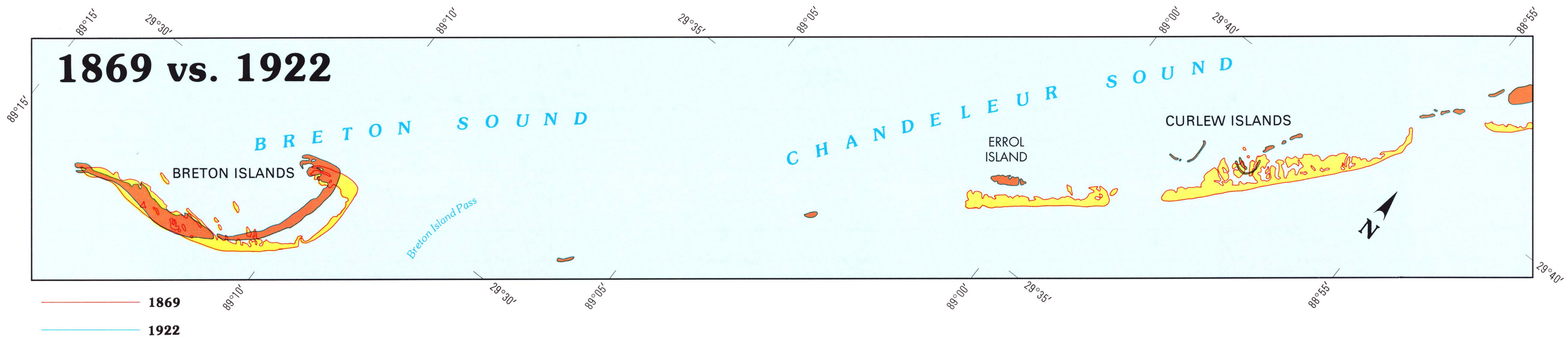
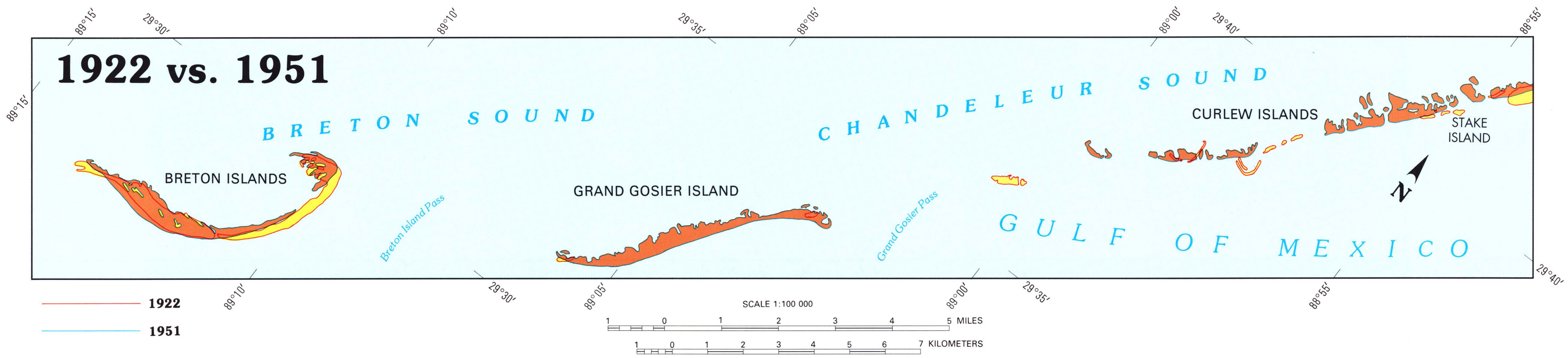


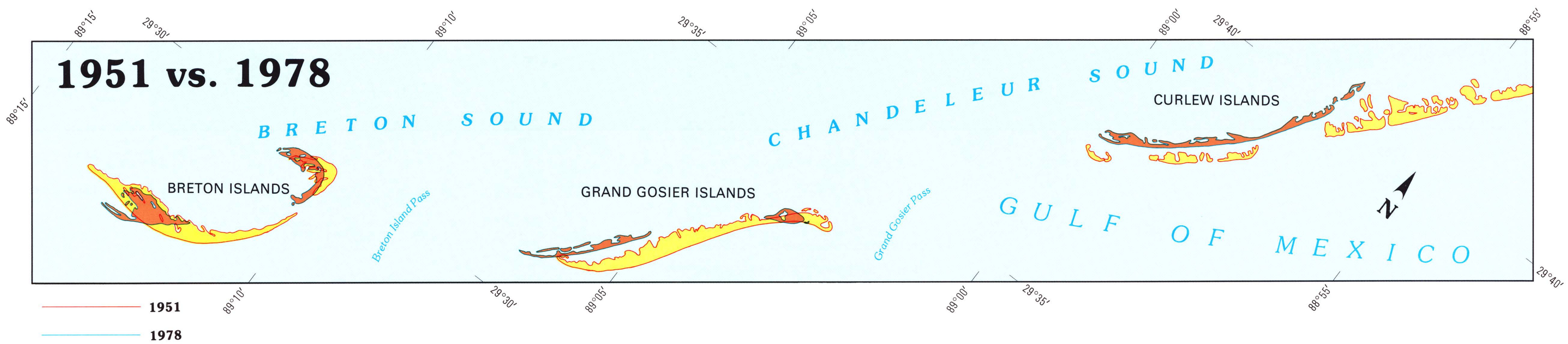
FIGURE 53.—Rate of area change between 1869 and 1989 for Grand Gosier and Curlew islands.

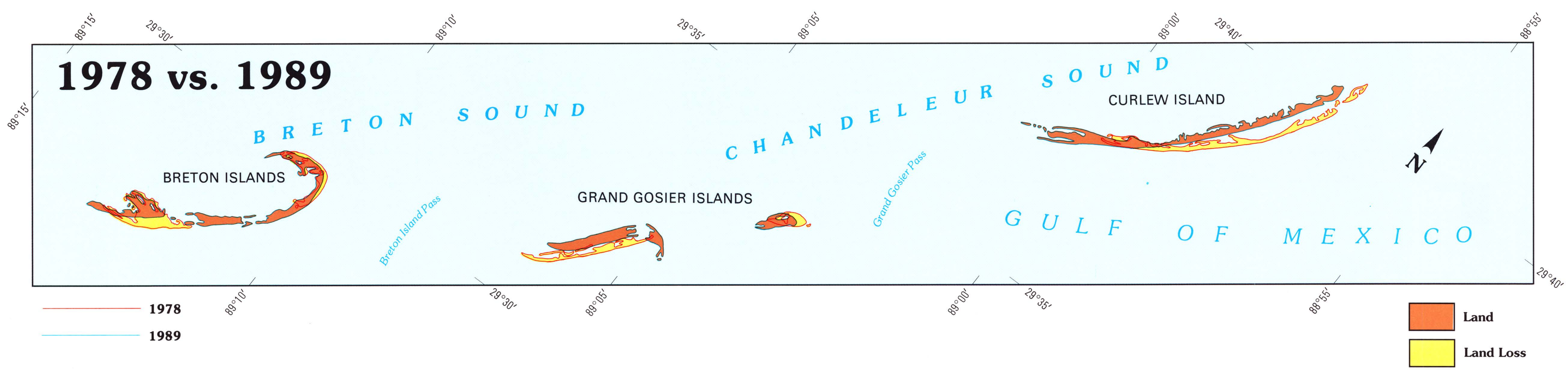
South Chandeleur Islands



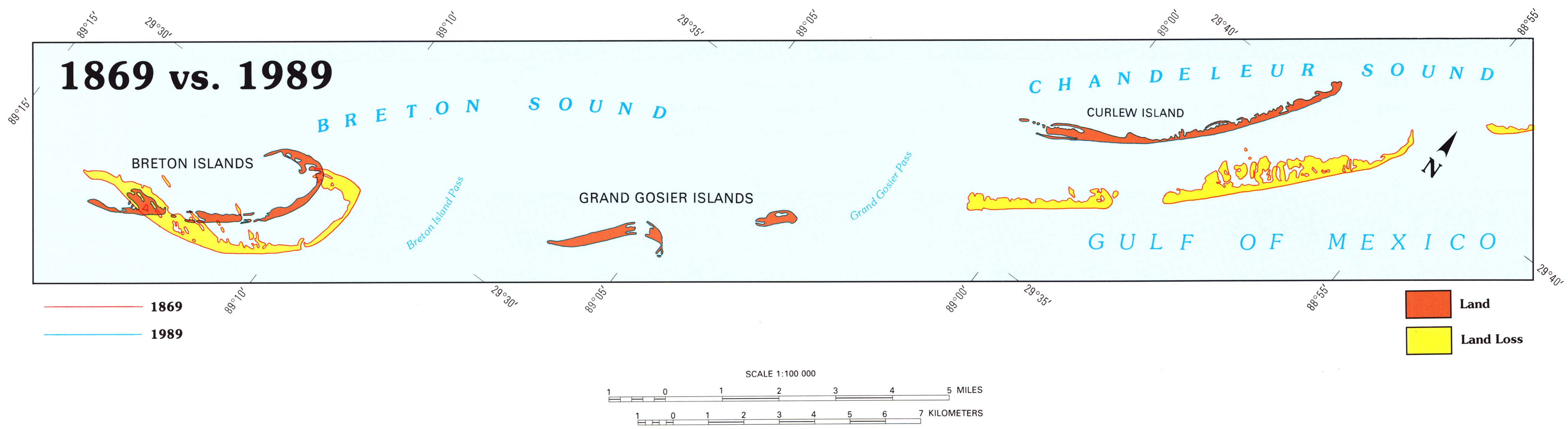
• Shoreline Change and Land Loss •







South Chandeleur Islands



South Chandeleur Islands

TABLE 31.—*South Chandeleur Islands bayside magnitude of change (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Transect coordinate		29° 27′ 15″	30″	45″	29° 28′ 00″	15″	30″	45″	29° 29′ 00″	15″	30″	45″	29° 30′ 00″	15″	30″	45″	29° 31′ 00″
Y	1869 - 1922	n.a.	n.a.	−148	−80	−122	128	437	662	847	795	202	n.a.	n.a.	n.a.	n.a.	n.a.
e	1922 - 1951	n.a.	n.a.	54	46	−72	175	156	140	n.a.	228	−193	142	n.a.	n.a.	n.a.	n.a.
a	1951 - 1978	n.a.	n.a.	−797	−154	n.a.	n.a.	n.a.	n.a.	n.a.	110	−31	120	n.a.	n.a.	n.a.	n.a.
r	1978 - 1989	n.a.	n.a.	−31	−38	n.a.	n.a.	n.a.	n.a.	58	−27	−11	−27	n.a.	n.a.	n.a.	n.a.
s	1869 - 1989	n.a.	n.a.	−922	−226	280	793	805	1170	1202	1106	−33	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Transect coordinate		15″	30″	45″	29° 32′ 00″	15″	30″	45″	29° 33′ 00″	15″	30″	45″	29° 34′ 00″	15″	30″	45″	29° 35′ 00″
Y	1869 - 1922	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1922 - 1951	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1951 - 1978	205	551	534	455	209	n.a.	n.a.	n.a.	n.a.	96	154	n.a.	n.a.	n.a.	n.a.	n.a.
r	1978 - 1989	215	253	296	362	249	n.a.	n.a.	n.a.	n.a.	57	−85	n.a.	n.a.	n.a.	n.a.	n.a.
s	1869 - 1989	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate		15″	30″	45″	29° 36′ 00″	15″	30″	45″	29° 37′ 00″	15″	30″	45″	29° 38′ 00″	15″	30″	45″	29° 39′ 00″
Y	1869 - 1922	n.a.	n.a.	n.a.	n.a.	n.a.	557	590	492	n.a.	n.a.	n.a.	n.a.	n.a.	875	n.a.	−113
e	1922 - 1951	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	65	n.a.	578
a	1951 - 1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	621	379	240	523	591	304
r	1978 - 1989	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−93	69	216	213	277	559
s	1869 - 1989	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2222	1848	2150	1539	1537	1527	1676	1857	1328

Transect #		49	50	51	52	53	54	55	56	57	58	59	60
Transect coordinate		15″	30″	45″	29° 40′ 00″	15″	30″	45″	29° 41′ 00″	15″	30″	45″	29° 42′ 00″
Y	1869 - 1922	466	650	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	982	1140
e	1922 - 1951	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	552	467	n.a.	155	61
a	1951 - 1978	n.a.	n.a.	n.a.	448	661	486	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1978 - 1989	625	520	498	307	482	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1869 - 1989	1497	1657	1916	1811	2712	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Breton Island bayside summary

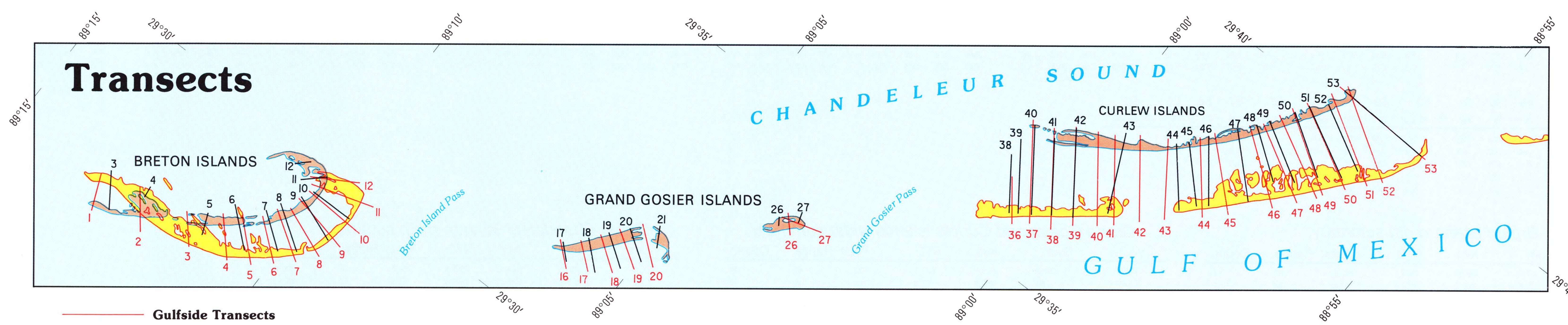
Years	Sum	Avg	STD	Total Range		Count
1869 - 1922	2721	302.3	373.6	847	−148	9
1922 - 1951	676	75.1	126.2	228	−193	9
1951 - 1978	−752	−150.4	338.6	120	−797	5
1978 - 1989	−76	−12.7	32.6	58	−38	6
1869 - 1989	4175	463.9	695.8	1202	−922	9

Grand Gosier and Curlew Islands bayside summary

Years	Sum	Avg	STD	Total Range		Count
1869 - 1922	3517	502.4	280.7	875	−113	7
1922 - 1951	643	321.5	256.5	578	65	2
1951 - 1978	6457	403.6	174.0	661	96	16
1978 - 1989	5020	278.9	201.6	625	−93	18
1869 - 1989	25277	1805.5	349.8	2712	1328	14

South Chandeleur Islands bayside summary

Years	Sum	Avg	STD	Total Range		Count
1869 - 1922	8360	464.4	392.9	1140	−148	18
1922 - 1951	2554	170.3	207.9	578	−193	15
1951 - 1978	5705	271.7	325.6	661	−797	21
1978 - 1989	4944	206.0	216.1	625	−93	24
1869 - 1989	29452	1280.5	832.3	2712	−922	23



Gulfside Transects
Bayside Transects

TABLE 32.—*South Chandeleur Islands gulfside magnitude of change (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Transect coordinate		29° 27′ 15″	30″	45″	29° 28′ 00″	15″	30″	45″	29° 29′ 00″	15″	30″	45″	29° 30′ 00″	15″	30″	45″	29° 31′ 00″
Y	1869 - 1922	−31	−102	−65	−327	−350	−436	−559	−668	−687	−648	−630	−72	n.a.	n.a.	n.a.	n.a.
e	1922 - 1951	−78	302	71	9	−120	−179	−237	−293	n.a.	−356	−268	−143	n.a.	n.a.	n.a.	n.a.
a	1951 - 1978	n.a.	169	−457	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−70	−196	−319	n.a.	n.a.	n.a.	−137
r	1978 - 1989	n.a.	−246	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	39	28	11	−45	n.a.	n.a.	n.a.	−324
s	1869 - 1989	702	123	n.a.	−590	−912	−948	−1042	−1103	−1085	−1046	−1083	−579	n.a.	n.a.	n.a.	n.a.

Transect #		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Transect coordinate		15″	30″	45″	29° 32′ 00″	15″	30″	45″	29° 33′ 00″	15″	30″	45″	29° 34′ 00″	15″	30″	45″	29° 35′ 00″
Y	1869 - 1922	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1922 - 1951	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1951 - 1978	−460	−611	−685	−689	n.a.	n.a.	n.a.	n.a.	n.a.	21	2	n.a.	n.a.	n.a.	n.a.	n.a.
r	1978 - 1989	−218	−221	−203	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	27	−188	n.a.	n.a.	n.a.	n.a.	n.a.
s	1869 - 1989	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate		15″	30″	45″	29° 36′ 00″	15″	30″	45″	29° 37′ 00″	15″	30″	45″	29° 38′ 00″	15″	30″	45″	29° 39′ 00″
Y	1869 - 1922	n.a.	n.a.	n.a.	−663	−610	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−1048	n.a.	−495	−1023	−1168
e	1922 - 1951	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−45	n.a.	−455	n.a.	n.a.
a	1951 - 1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−610	n.a.	−372	−426	−467	−500	n.a.	n.a.
r	1978 - 1989	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	72	−2	−113	−232	−266	−364	−416	−429
s	1869 - 1989	n.a.	n.a.	n.a.	n.a.	n.a.	−2084	−1961	−1916	−1884	n.a.	n.a.	−1751	−733	−1814	−1906	−1981

Transect #		49	50	51	52	53	54	55	56	57	58	59	60
Transect coordinate		15″	30″	45″	29° 40′ 00″	15″	30″	45″	29° 41′ 00″	15″	30″	45″	29° 42′ 00″
Y	1869 - 1922	−1212	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−1048	−755	−617
e	1922 - 1951	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	−399	−211	n.a.	53	−300	−310
a	1951 - 1978	n.a.	n.a.	−660	−995	−1253	−1001	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1978 - 1989	−419	−397	−403	−263	−356	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1869 - 1989	−1995	−2094	−2223	−2381	−2533	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Breton Island gulfside summary

Years	Sum	Avg	STD	Total Range		Count
1869 - 1922	−4575	−381.3	248.9	−31	−687	12
1922 - 1951	−1292	−117.5	180.4	302	−356	11
1951 - 1978	−873	−174.6	214.5	169	−457	5
1978 - 1989	−213	−42.6	105.7	39	−246	5
1869 - 1989	−7563	−687.5	561.5	702	−1103	11

Grand Gosier and Curlew Island gulfside summary

Years	Sum	Avg	STD	Total Range		Count
1869 - 1922	−6219	−888.4	269.8	−495	−1212	7
1922 - 1951	−899	−299.7	181.5	−45	−455	3
1951 - 1978	−8843	−552.7	337.1	21	−1253	16
1978 - 1989	−4715	−248.2	150.8	72	−429	19
1869 - 1989	−27256	−1946.9	395.4	−733	−2533	14

South Chandeleur Islands gulfside summary

Years	Sum	Avg	STD	Total Range		Count
1869 - 1922	−13214	−600.6	346.1	−31	−1212	22
1922 - 1951	−2959	−164.4	186.4	302	−455	18
1951 - 1978	−9716	−462.7	351.4	169	−1253	21
1978 - 1989	−4928	−205.3	165.2	72	−429	24
1869 - 1989	−34819	−1392.8	785.5	702	−2533	25

See page 46 for explanation of numbers.

South Chandeleur Islands

TABLE 33.—*South Chandeleur Islands bayside rate of change (meters per year)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinate		29° 27' 15"	30"	45"	29° 28' 00"	15"	30"	45"	29° 29' 00"	15"	30"	45"	29° 30' 00"	15"	30"	45"	29° 31' 00"	15"	30"	45"	29° 32' 00"	15"	30"	45"	29° 33' 00"
Y	1869 - 1922	n.a.	n.a.	-2.8	-1.5	-2.3	2.4	8.2	12.5	16.0	15.0	3.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1922 - 1951	n.a.	n.a.	1.9	1.6	-2.5	6.1	5.4	4.9	n.a.	7.9	-6.7	4.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1951 - 1978	n.a.	n.a.	-28.7	-5.5	n.a.	n.a.	n.a.	n.a.	n.a.	4.0	-1.1	4.3	n.a.	n.a.	n.a.	n.a.	7.4	19.8	19.2	16.4	7.5	n.a.	n.a.	n.a.
r	1978 - 1989	n.a.	n.a.	-3.0	-3.7	n.a.	n.a.	n.a.	n.a.	5.6	-2.6	-1.1	-2.6	n.a.	n.a.	n.a.	n.a.	20.7	24.3	28.5	34.8	23.9	n.a.	n.a.	n.a.
s	1869 - 1989	n.a.	n.a.	-7.7	-1.9	2.3	6.6	6.7	9.8	10.0	9.2	-0.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate		15"	30"	45"	29° 34' 00"	15"	30"	45"	29° 35' 00"	15"	30"	45"	29° 36' 00"	15"	30"	45"	29° 37' 00"	15"	30"	45"	29° 38' 00"	15"	30"	45"	29° 39' 00"
Y	1869 - 1922	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	10.5	11.1	9.3	n.a.	n.a.	n.a.	n.a.	n.a.	16.5	n.a.	-2.1
e	1922 - 1951	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	2.3	n.a.	20.1
a	1951 - 1978	n.a.	3.5	5.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	22.3	13.6	8.6	18.8	21.3	10.9
r	1978 - 1989	n.a.	5.5	-8.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-8.9	6.6	20.8	20.5	26.6	53.8
s	1869 - 1989	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	18.5	15.4	17.9	12.8	12.8	12.7	14.0	15.5	11.1

Transect #		49	50	51	52	53	54	55	56	57	58	59	60
Transect coordinate		15"	30"	45"	29° 40' 00"	15"	30"	45"	29° 41' 00"	15"	30"	45"	29° 42' 00"
Y	1869 - 1922	8.8	12.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	18.5	21.5
e	1922 - 1951	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	19.2	16.2	n.a.	5.4	2.1
a	1951 - 1978	n.a.	n.a.	n.a.	16.1	23.8	17.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1978 - 1989	60.1	50.0	47.9	29.5	46.3	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1869 - 1989	12.5	13.8	16.0	15.1	22.6	n.a.	n.a.	n.a.	n.a.	n.a.	n a.	n.a.

Breton Island bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1869 - 1922	51.3	5.7	7.0	16.0	-2.8	9
1922 - 1951	23.5	2.6	4.4	7.9	-6.7	9
1951 - 1978	-27.1	-5.4	12.2	4.3	-28.7	5
1978 - 1989	-7.3	-1.2	3.1	5.6	-3.7	6
1869 - 1989	34.8	3.9	5.8	10.0	-7.7	9

Grand Gosier and Curlew Islands bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1869 - 1922	66.4	9.5	5.3	16.5	-2.1	7
1922 - 1951	22.3	11.2	8.9	20.1	2.3	2
1951 - 1978	232.3	14.5	6.3	23.8	3.5	16
1978 - 1989	482.7	26.8	19.4	60.1	-8.9	18
1869 - 1989	210.6	15.0	2.9	22.6	11.1	14

South Chandeleur Islands bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1869 - 1922	157.7	8.8	7.4	21.5	-2.8	18
1922 - 1951	88.7	5.9	7.2	20.1	-6.7	15
1951 - 1978	205.2	9.8	11.7	23.8	-28.7	21
1978 - 1989	475.4	19.8	20.8	60.1	-8.9	24
1869 - 1989	245.4	10.7	6.9	22.6	-7.7	23

TABLE 34.—*South Chandeleur Islands width measurements (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinate		29° 27' 15"	30"	45"	29° 28' 00"	15"	30"	45"	29° 29' 00"	15"	30"	45"	29° 30' 00"	15"	30"	45"	29° 31' 00"	15"	30"	45"	29° 32' 00"	15"	30"	45"	29° 33' 00"
Y	1869	257	754	571	273	224	237	137	72	126	67	1240	793	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1922	94	590	550	101	169	179	209	269	286	223	248	918	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1951	147	917	562	260	208	126	100	31	n.a.	92	192	578	n.a.	n.a.	n.a.	177	239	352	384	443	549	407	254	202
r	1978	n.a.	957	43	n.a.	n.a.	n.a.	n.a.	n.a.	126	129	102	248	n.a.	n.a.	82	245	214	180	231	47	n.a.	n.a.	n.a.	n.a.
s	1989	128	688	10	226	217	47	249	157	224	133	119	192	n.a.	n.a.	n.a.	135	258	283	299	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate		15"	30"	45"	29° 34' 00"	15"	30"	45"	29° 35' 00"	15"	30"	45"	29° 36' 00"	15"	30"	45"	29° 37' 00"	15"	30"	45"	29° 38' 00"	15"	30"	45"	29° 39' 00"
Y	1869	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	468	361	351	299	270	248	222	524	n.a.	n.a.	290	711	733	723	644
e	1922	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	243	185	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	10	n.a.	18	99	62
a	1951	122	142	594	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	280	49	n.a.	166	194	100	102	n.a.	n.a.
r	1978	n.a.	337	845	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	56	332	112	189	223	161	56	82
s	1989	220	342	571	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	30	26	410	329	230	303	186	174	214	279	189	242

Transect #		49	50	51	52	53	54	55	56	57	58	59	60
Transect coordinate		15"	30"	45"	29° 40' 00"	15"	30"	45"	29° 41' 00"	15"	30"	45"	29° 42' 00"
Y	1869	613	442	487	143	86	n.a.	n.a.	n.a.	n.a.	191	83	38
e	1922	54	n.a.	n.a.	n.a.	n.a.	n.a.	50	90	n.a.	68	448	282
a	1951	n.a.	n.a.	266	301	731	91	197	350	527	275	211	230
r	1978	171	166	151	170	141	213	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1989	273	271	208	n.a.	259	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Breton Island width summary

Years	Sum	Avg	STD	Total	Range	Count
1869	4751	395.9	350.1	1240	67	12
1922	3836	319.7	233.8	918	94	12
1951	3213	292.1	262.3	917	31	11
1978	1605	267.5	314.3	957	43	6
1989	2390	199.2	163.2	688	10	12

Grand Gosier and Curlew Islands width summary

Years	Sum	Avg	STD	Total	Range	Count
1869	7615	423.1	197.1	733	86	18
1922	721	90.1	77.3	243	10	8
1951	6342	275.7	171.5	731	49	23
1978	4322	205.8	162.2	845	47	21
1989	5731	249.2	110.6	571	26	23

South Chandeleur Islands width summary

Years	Sum	Avg	STD	Total	Range	Count
1869	12678	384.2	272.3	1240	38	33
1922	5445	226.9	209.4	918	10	24
1951	11148	285.8	196.6	917	31	39
1978	6009	214.6	205.4	957	43	28
1989	8121	232.0	133.2	688	10	35

TABLE 35.—*South Chandeleur Islands gulfside rate of change (meters per year)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinate		29° 27' 15"	30"	45"	29° 28' 00"	15"	30"	45"	29° 29' 00"	15"	30"	45"	29° 30' 00"	15"	30"	45"	29° 31' 00"	15"	30"	45"	29° 32' 00"	15"	30"	45"	29° 33' 00"
Y	1869 - 1922	-0.6	-1.9	-1.2	-6.2	-6.6	-8.2	-10.5	-12.6	-13.0	-12.2	-11.9	-1.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
e	1922 - 1951	-2.7	10.5	2.5	0.3	-4.2	-6.2	-8.2	-10.2	n.a.	-12.4	-9.3	-5.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
a	1951 - 1978	n.a.	6.1	-16.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-2.5	-7.1	-11.5	n.a.	n.a.	n.a.	-4.9	-16.5	-22.0	-24.6	-24.8	n.a.	n.a.	n.a.	n.a.
r	1978 - 1989	n.a.	-23.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	3.8	2.7	1.1	-4.3	n.a.	n.a.	n.a.	-31.2	-21.0	-21.3	-19.5	n.a.	n.a.	n.a.	n.a.	n.a.
s	1869 - 1989	5.9	1.0	n.a.	-4.9	-7.6	-7.9	-8.7	-9.2	-9.0	-8.7	-9.0	-4.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Transect #		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate		15"	30"	45"	29° 34' 00"	15"	30"	45"	29° 35' 00"	15"	30"	45"	29° 36' 00"	15"	30"	45"	29° 37' 00"	15"	30"	45"	29° 38' 00"	15"	30"	45"	29° 39' 00"
Y	1869 - 1922	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-12.5	-11.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-19.8	n.a.	-9.3	-19.3	-22.0
e	1922 - 1951	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-1.6	n.a.	-15.8	n.a.	n.a.
a	1951 - 1978	n.a.	0.8	0.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-21.9	n.a.	-13.4	-15.3	-16.8	-18.0	n.a.	n.a.
r	1978 - 1989	n.a.	2.6	-18.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6.9	-0.2	-10.9	-22.3	-25.6	-35.0	-40.0	-41.3
s	1869 - 1989	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-17.4	-16.3	-16.0	-15.7	n.a.	n.a.	-14.6	-6.1	-15.1	-15.9	-16.5

Transect #		49	50	51	52	53	54	55	56	57	58	59	60
Transect coordinate		15"	30"	45"	29° 40' 00"	15"	30"	45"	29° 41' 00"	15"	30"	45"	29° 42' 00"
Y	1869 - 1922	-22.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-19.8	-14.2	-11.6
e	1922 - 1951	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-13.9	-7.3	n.a.	1.8	-10.4	-10.8
a	1951 - 1978	n.a.	n.a.	-23.7	-35.8	-45.1	-36.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
r	1978 - 1989	-40.3	-38.2	-38.8	-25.3	-34.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
s	1869 - 1989	-16.6	-17.5	-18.5	-19.8	-21.1	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Breton Island gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1869 - 1922	-86.3	-7.2	4.7	-0.6	-13.0	12
1922 - 1951	-44.9	-4.1	6.3	10.5	-12.4	11
1951 - 1978	-31.4	-6.3	7.7	6.1	-16.4	5
1978 - 1989	-20.5	-4.1	10.2	3.8	-23.7	5
1869 - 1989	-63.0	-5.7	4.7	5.9	-9.2	11

Grand Gosier and Curlew Islands gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1869 - 1922	-117.3	-16.8	5.1	-9.3	-22.9	7
1922 - 1951	-31.2	-10.4	6.3	-1.6	-15.8	3
1951 - 1978	-318.1	-19.9	12.1	0.8	-45.1	16
1978 - 1989	-453.4	-23.9	14.5	6.9	-41.3	19
1869 - 1989	-227.1	-16.2	3.3	-6.1	-21.1	14

South Chandeleur Islands gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1869 - 1922	-249.3	-11.3	6.5	-0.6	-22.9	22
1922 - 1951	-102.7	-5.7	6.5	10.5	-15.8	18
1951 - 1978	-349.5	-16.6	12.6	6.1	-45.1	21
1978 - 1989	-473.8	-19.7	15.9	6.9	-41.3	24
1869 - 1989	-290.2	-11.6	6.5	5.9	-21.1	25

See page 46 for explanation of numbers.

South Chandeleur Islands

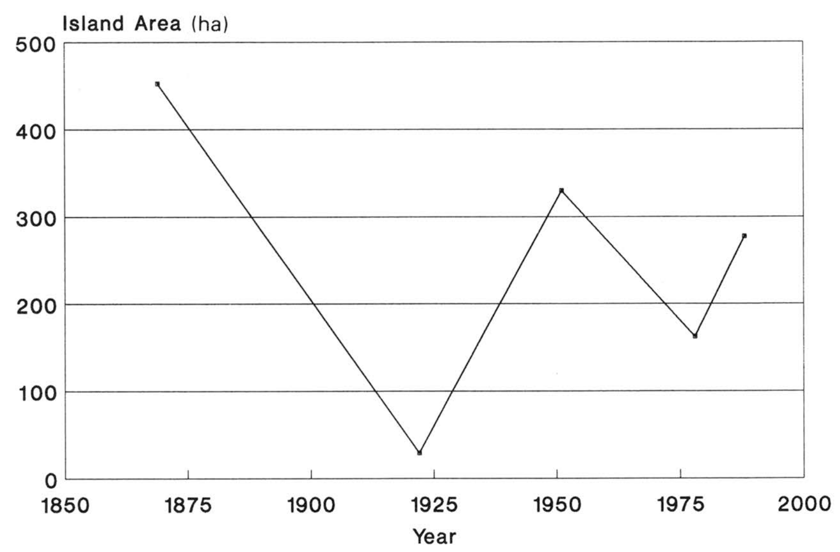


FIGURE 54.—Area changes of Grand Gosier and Curlew islands between 1869 and 1989.

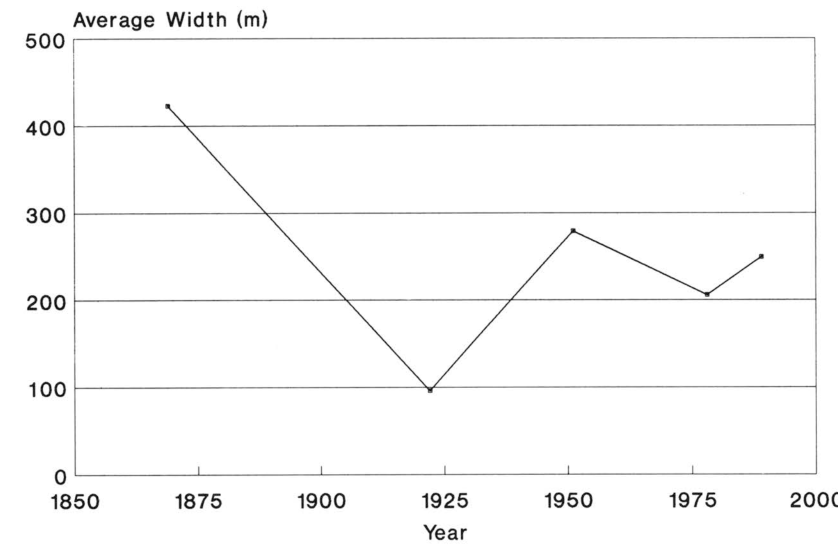


FIGURE 55.—Average barrier width of Grand Gosier and Curlew islands between 1869 and 1989.

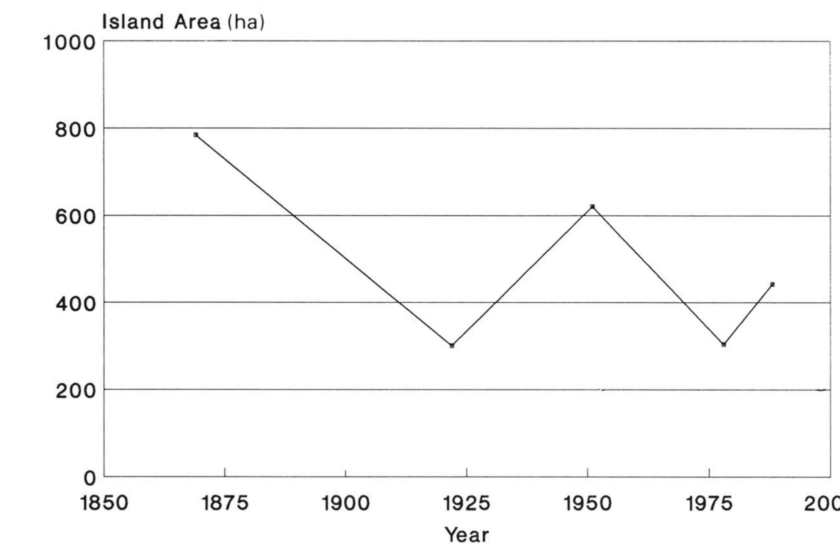


FIGURE 56.—Area changes between 1869 and 1989 of the South Chandeleur Islands.

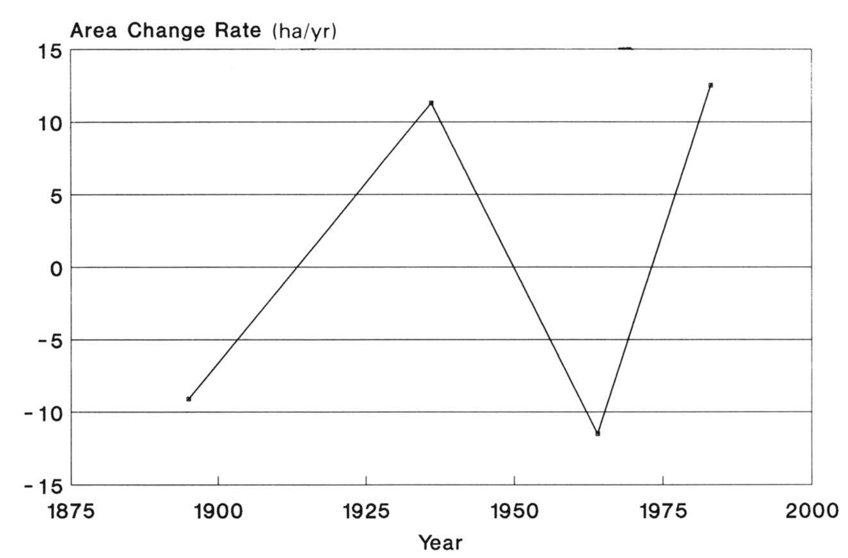


FIGURE 57.—Rate of area change between 1869 and 1989 for South Chandeleur Islands.

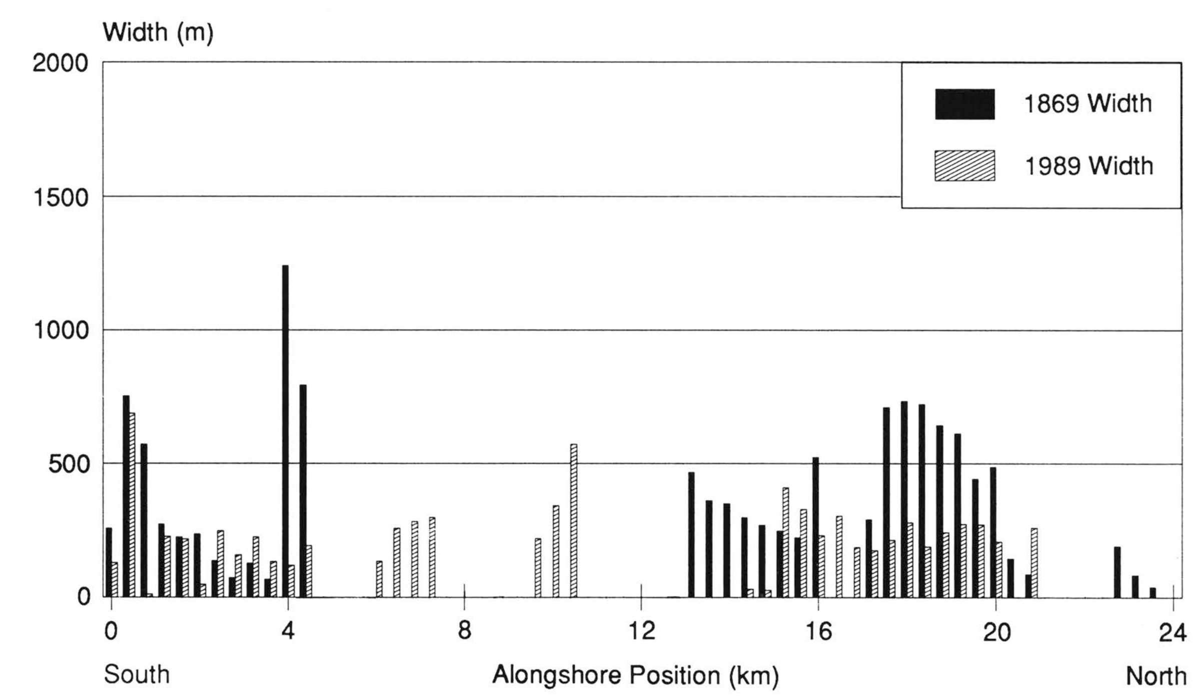


FIGURE 58.—Comparison of the 1869 and 1989 barrier widths along the South Chandeleur Islands shoreline.

TABLE 36.—*Area changes for Breton Island from 1869 to 1989*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1869 1922	332 271	-61	-18%	-1.2	2051
1922 1951	271 291	20	7%	0.7	N.A.
1951 1978	291 141	-150	-52%	-5.4	2004
1978 1989	141 164	23	16%	2.2	N.A.
1869 1989	332 164	-169	-51%	-1.4	2106

TABLE 37.—*Area changes of the Grand Gosier and Curlew islands from 1869 to 1989*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1869 1922	453 29	-424	-94%	-8.0	1926
1922 1951	29 330	301	1,038%	10.4	N.A.
1951 1978	330 162	-168	-51%	-6.0	2005
1978 1989	162 277	115	71%	11.1	N.A.
1869 1989	453 277	-176	-39%	-1.5	2174

TABLE 38.—*Area changes of South Chandeleur Islands from 1869 to 1989*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1869 1922	784 300	-484	-62%	-9.1	1955
1922 1951	300 624	324	108%	11.3	N.A.
1951 1978	624 303	-321	-51%	-11.5	2003
1978 1989	303 441	138	46%	13.3	N.A.
1869 1989	784 441	-343	-44%	-2.9	2199

North Chandeleur Islands—1855 to 1989

Morphology

The North Chandeleur Islands are dominated by a large, arcuate-shaped barrier island that protects three groups of smaller, irregular-shaped islands that lie to the west. In 1855, Chandeleur Island was a fairly continuous barrier island except for breaches along the north-central portion of the shoreline (1885 map). One of the major breaches was known as Schooners Pass; its name indicates how the pass was utilized at the time. At the northern end lies Hewes Point, a large recurved spit complex, and the terminus of longshore sediment transport for the northern half of the barrier island arc. The gulf shoreline forms a smooth arc, but the bay shoreline is crenulate and dominated by washover fans and ebb-tidal deltas. In addition, two other prominent morphological features along the bay shoreline include Redfish Point and Monkey Bayou, interpreted as possible relict distributary systems of the St. Bernard delta. In 1922, several breaches along the north central island shoreline closed, except for three or four, the most prominent of which is still Schooners Pass (1922 map). At this point, the island arc was narrowest at both ends and widest in the central portion. Since then the southern end also has developed some surge channels. A detailed description of surge channels and other related storm impact features is provided by Boothroyd and others (1985). The back-barrier islands (North, New Harbor, and Freemason islands) are moving and deteriorating, especially Freemason Islands, which consist predominately of reworked oyster shells and are therefore, highly mobile.

By 1951, Schooners Pass had closed, but to the north an unnamed inlet remained opened (1951 map). The southern tip of the arc became detached to form Stake Island. Chandeleur Island suffered a devastating hurricane impact by Camille in 1969, which fragmented the arc into numerous smaller islands. However, by 1978, the arc had recovered, and all breaches healed. To the south, Stake and Palos islands disappeared, and the back-barrier islands underwent a major contraction. The 1988 map shows that Chandeleur Island has maintained its overall arcuate shape, smooth gulf shoreline, and highly irregular bay shoreline. Although the back-barrier islands remained, their shapes were very different and sizes greatly reduced.

Shoreline Movement

Comparisons of shoreline position along the North Chandeleur Islands are made for the periods 1855 vs. 1922, 1922 vs. 1951, 1951 vs. 1978, 1978 vs. 1989, and 1855 vs. 1989. Shoreline change is presented in terms of direction, magnitude, and rate of change, as well as island width. These were obtained from 172 shore-normal transects along the gulf and bay shorelines (transects map, tables 39, 40, 41, 42, and 43).

The average gulfside rate of change between 1855 and 1922 was -5.3 m/yr (table 43). This average rate slightly increased to -5.6 m/yr between 1922 and 1951 and increased nearly twofold to -10.0 m/yr between 1951 and 1978 (fig. 59). This doubling of the gulfside rate of change between 1951 and 1978 includes the impact of Hurricane Camille, a category 5 hurricane that made landfall in 1969 at Pass Christian, Miss., after crossing the Chandeleur Islands (Neumann and others, 1985). This large storm severely weakened the overall morphological structure of the Chandeleur Island system, making the arc more susceptible to subsequent storm events. For the period 1978 to 1989, the high average rate of gulfside movement was maintained and even increased to -12.2 m/yr (fig. 59). Contributing to this high rate of shoreline retreat were the impacts of Hurricane Frederic (1979) and Hurricanes Elena and Juan (1985) (Neumann and others, 1985; Case, 1986).

The bay shoreline also was migrating landward. For the period between 1855 and 1922, the average rate of change was 2.2 m/yr (fig. 60, table 41). This average rate increased over twofold to 5.4 m/yr between 1922 and 1951 but decreased to 3.3 m/yr for the period 1951 through 1978. Between 1978 and 1989, the average rate increased to 5.3 m/yr (fig. 60). For the past 134 years, the bay shoreline migrated landward primarily in response to washover deposition associated with extratropical and tropical storms.

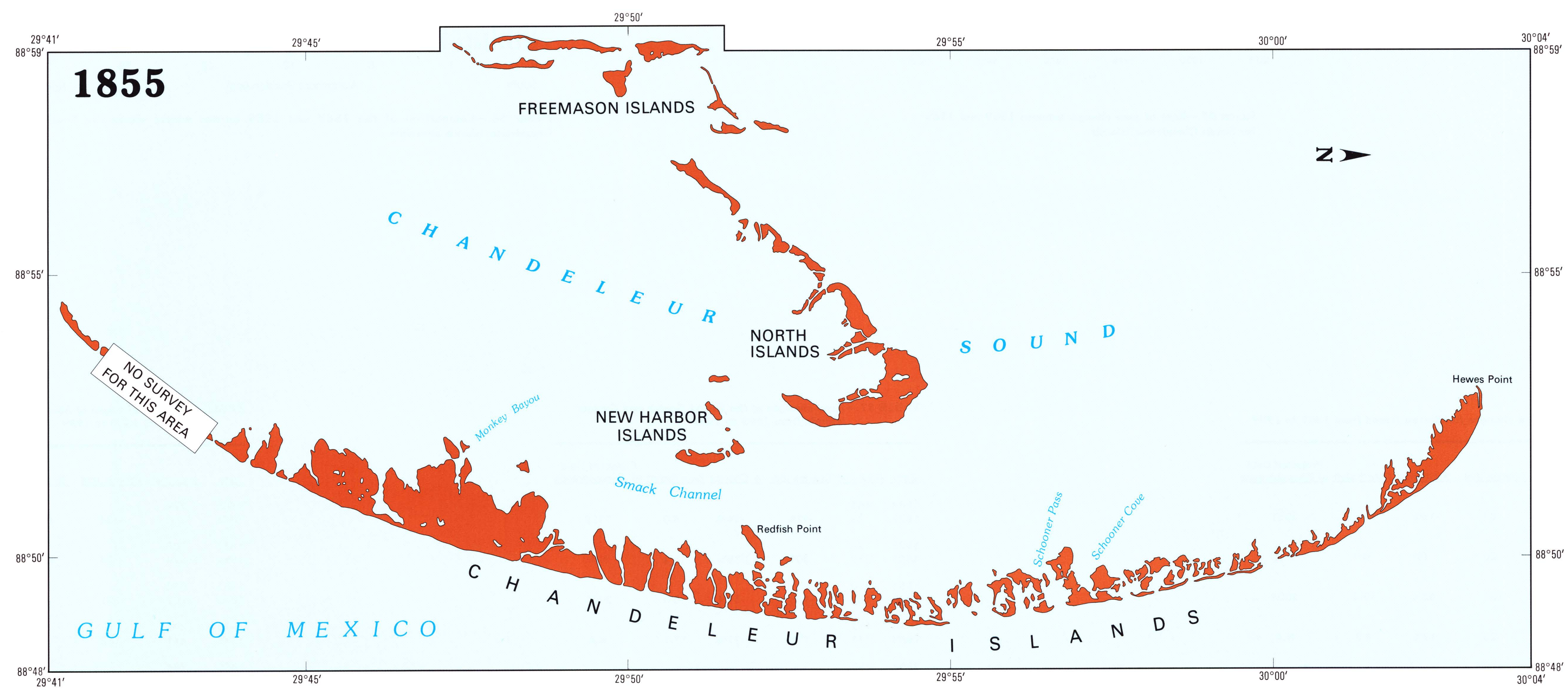
The 1855 vs. 1989 map illustrates land loss for the North Chandeleur Islands and presents a quantitative summary of changes along the gulf and bay shorelines. The rate of change between 1855 and 1989 along the gulf shoreline ranged from -0.2 to -17.6 m/yr, with an average change rate of -6.5 m/yr (table 43). The rate of bayside change for the same period ranged between 15.0 and -2.0 m/yr with an average change rate of 2.9 m/yr (table 41). The gulf and bay shorelines are rapidly migrating landward, but the gulf shoreline is migrating twice as fast (-6.5 m/yr vs. 2.9 m/yr), causing net deterioration of the islands.

Area and Width Change

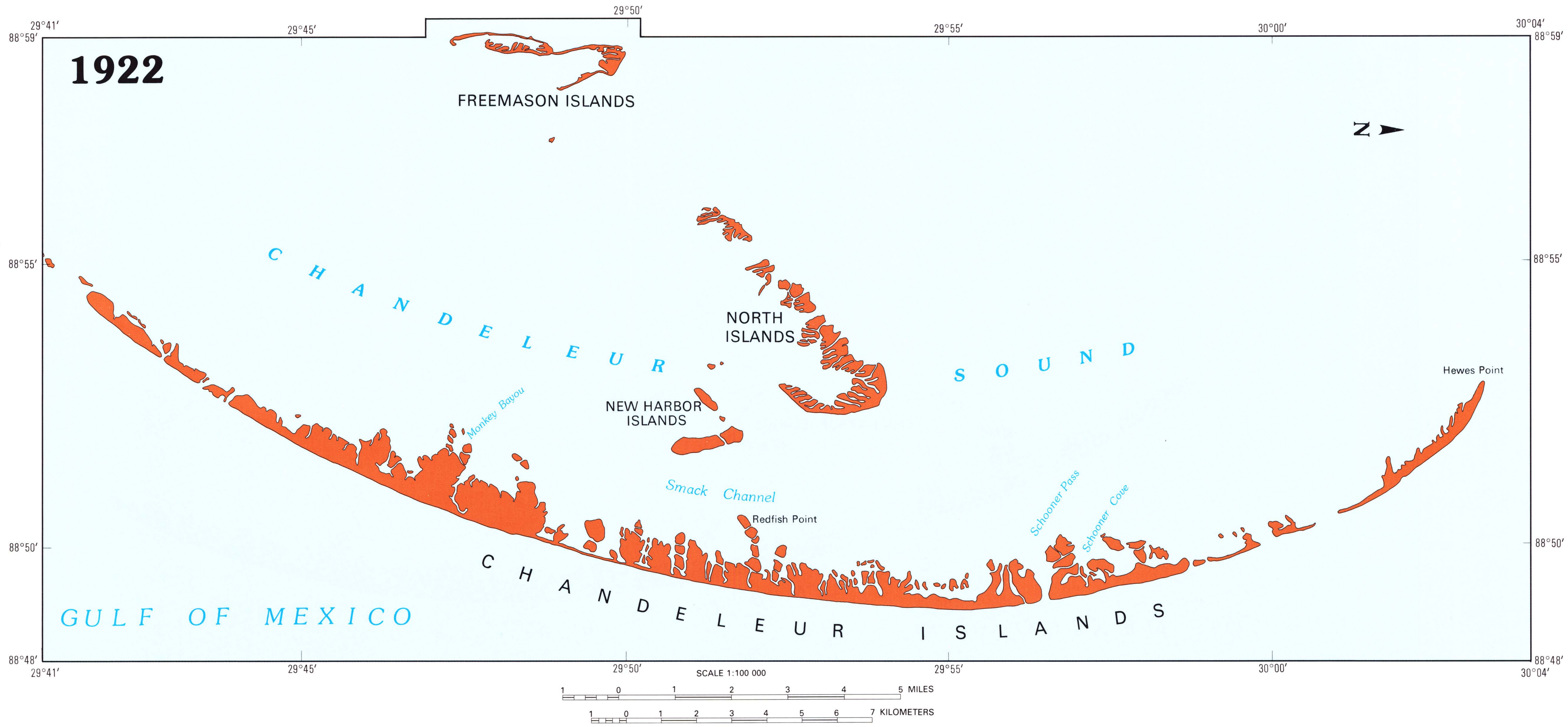
To better understand area changes, comparisons are made to general trends in barrier width (tables 42 and 44). In 1855, Chandeleur Island contained 2,763 ha of land with an average width of 941 m. By 1922, total area further decreased to 2,485 ha, while average width decreased to 670 m. During the period 1855 to 1922, the rate of area change was -4.1 ha/yr (fig. 61). However, by 1951, the island arc increased in area to 2,588 ha. This was consistent with an increase in average width to 678 m. For the period 1922 to 1951, the average rate of area change was 3.6 ha/yr, indicating a reverse from land loss to land gain. Not surprisingly, Chandeleur Island lost the most area between 1951 and 1978, which coincides with the impact of Hurricane Camille in 1969. The island arc lost 31 percent, or 792 ha, of its land area at a rate of -28.5 ha/yr. Correspondingly, average barrier width decreased to 506 m. By 1989, both area and width only slightly decreased to 1,749 ha and 475 m, respectively, and the rate of area change slowed to -4.5 ha/yr (fig. 61).

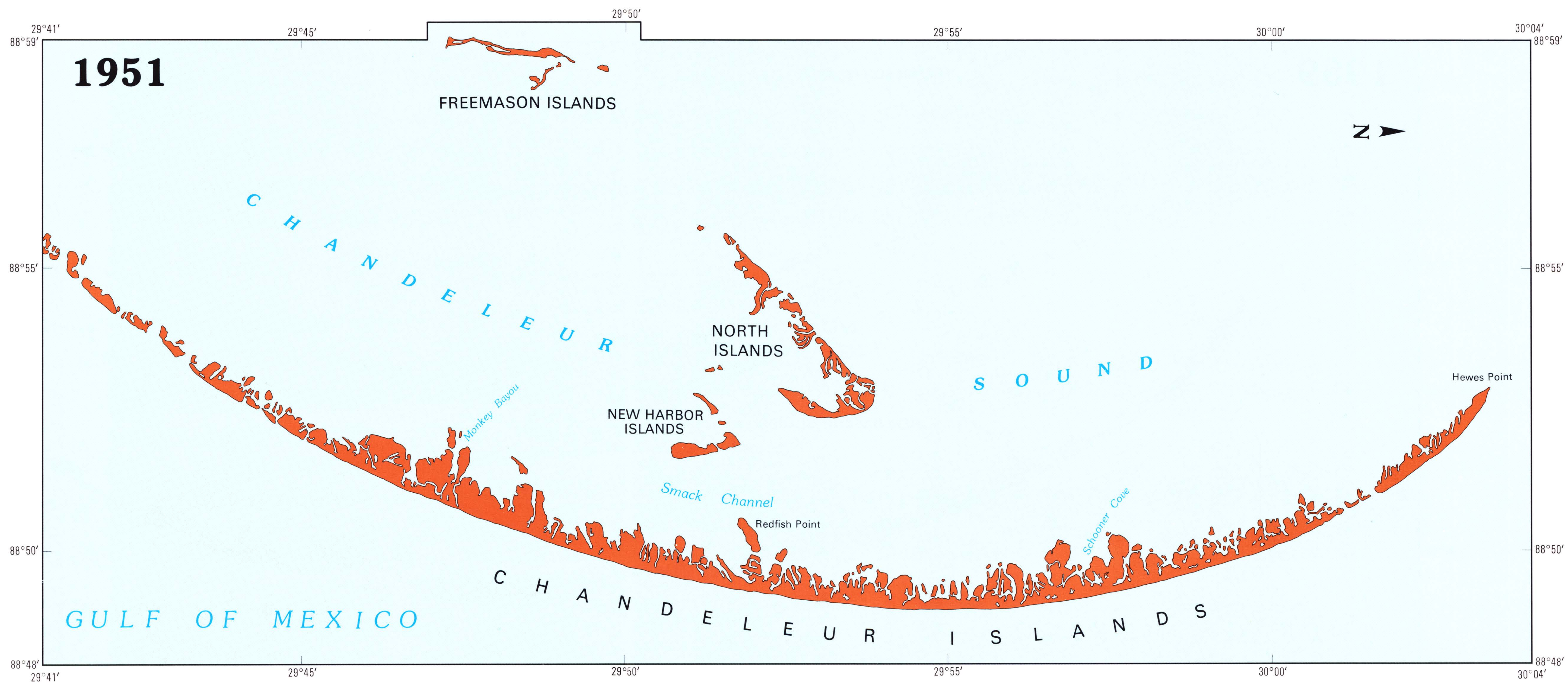
Over the last 134 years, Chandeleur Island has experienced a decrease in area from 2,763 to 1,749 ha (fig. 62, table 44), at an average loss rate of 7.6 ha/yr. This represents a 37 percent decrease in island area, most of which occurred between 1951 and 1978. Compared with other barrier islands along the Louisiana coast, the area of Chandeleur Island has decreased at a slower rate. Between 1855 and 1989, both the gulf and bay shorelines migrated landward. However, the gulf shoreline migrated landward more than twice as fast as the bay shoreline (-6.5 m/yr vs. 2.9 m/yr, respectively), causing island width to narrow (fig. 63, table 42). The barrier island decreased in average width from 941 m in 1855 to 475 m in 1989, representing an average narrowing rate of 3.5 m/yr for the past 134 years (fig. 63). Barrier widths for 1855 and 1989 are shown in figure 64. Meanwhile, area changes decreased for North and Freemason islands but remained stable for New Harbor Islands (tables 45, 46, and 47).

• Historic Shorelines •

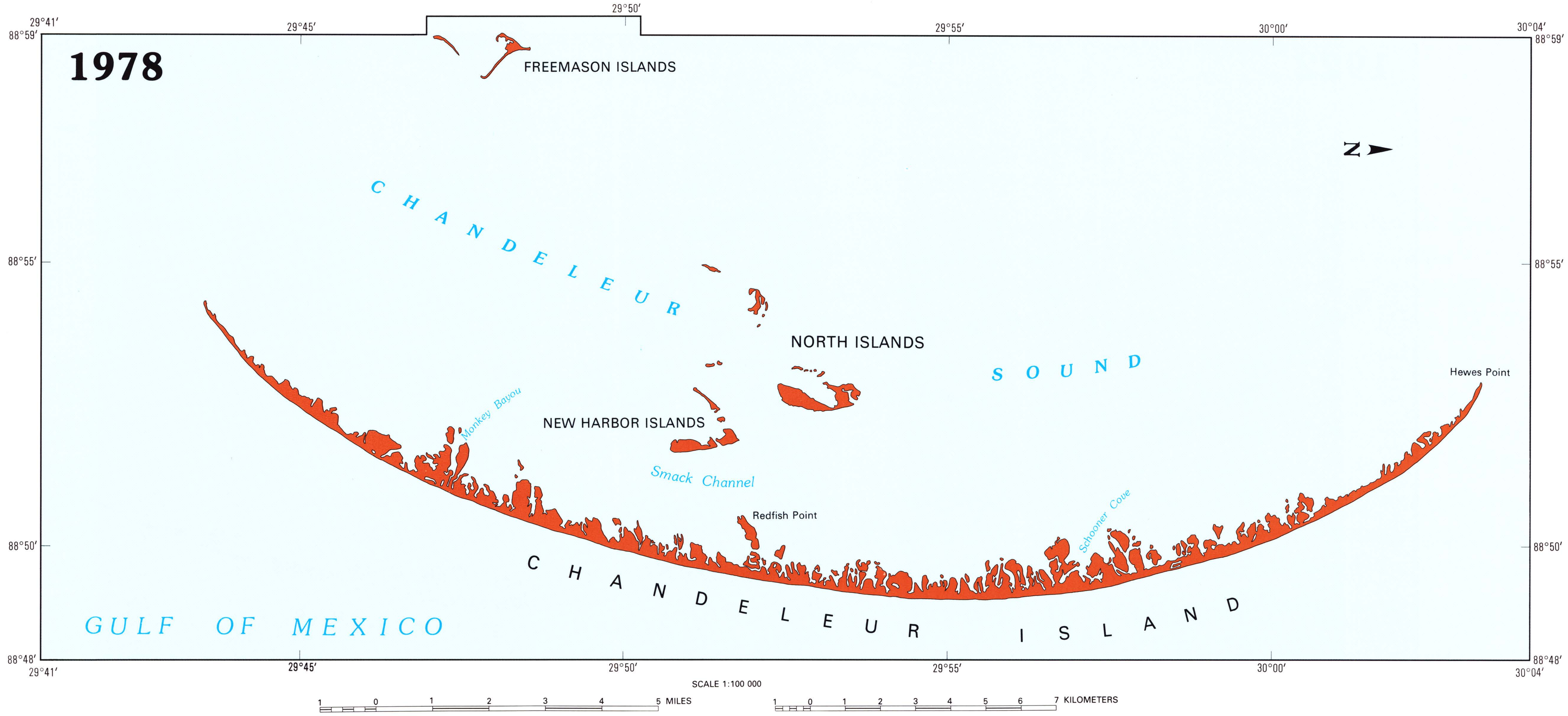


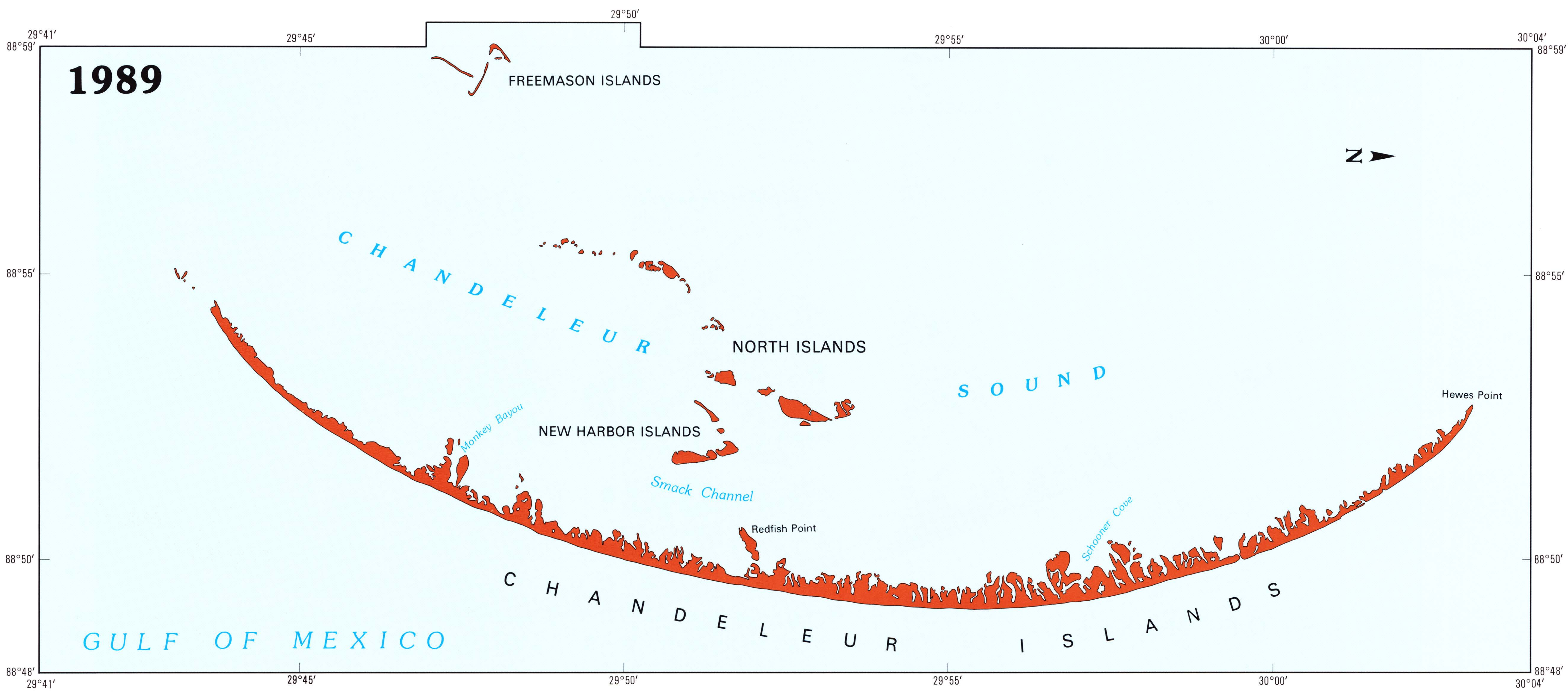
North Chandeleur Islands





North Chandeleur Islands





North Chandeleur Islands

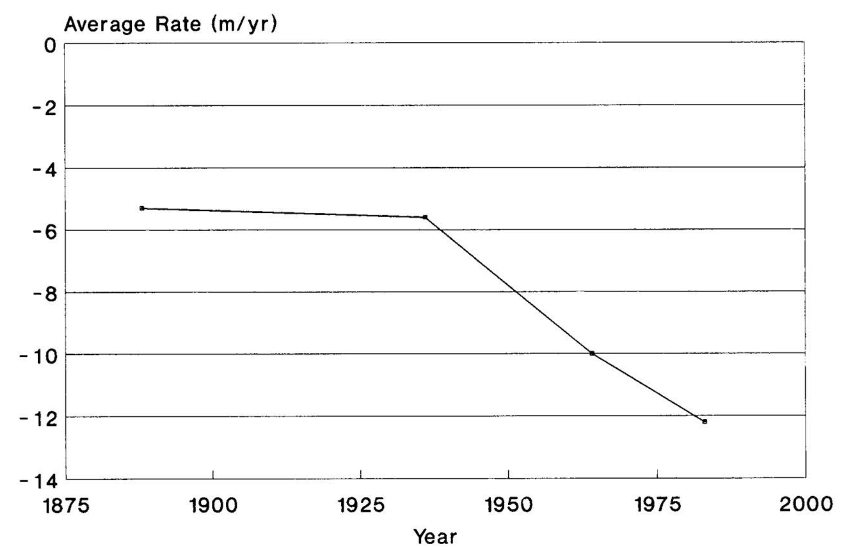


FIGURE 59.—Average gulfside rate of change between 1855 and 1989 along Chandeleur Island.

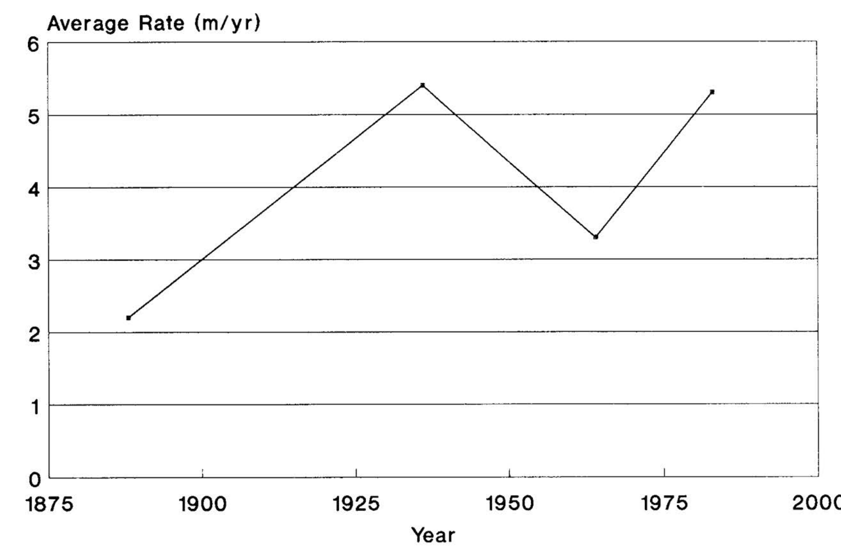


FIGURE 60.—Average bayside rate of change between 1855 and 1989 along Chandeleur Island.

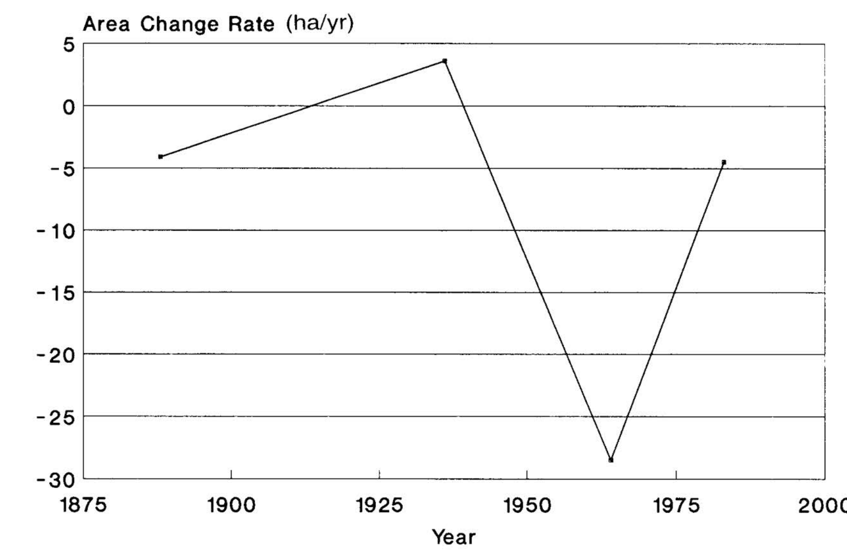


FIGURE 61.—Rate of area change between 1855 and 1989 of Chandeleur Island.

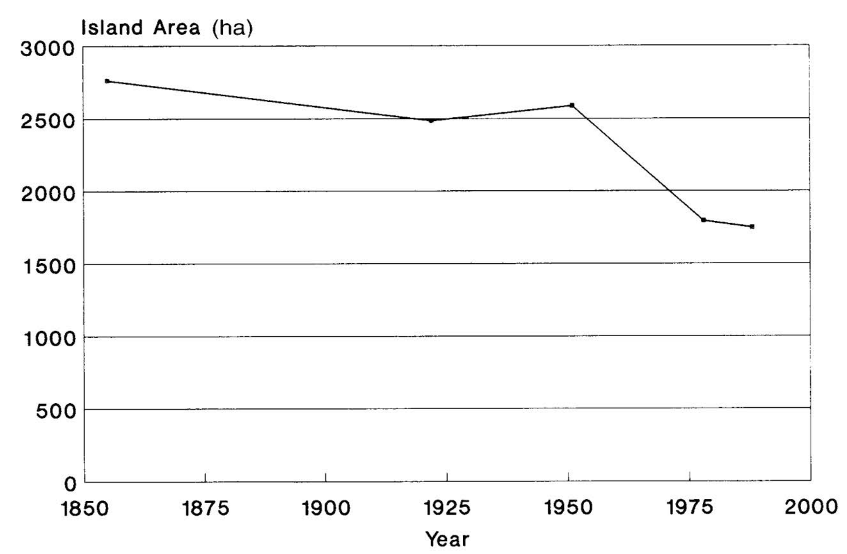


FIGURE 62.—Area changes between 1855 and 1989 of Chandeleur Island.

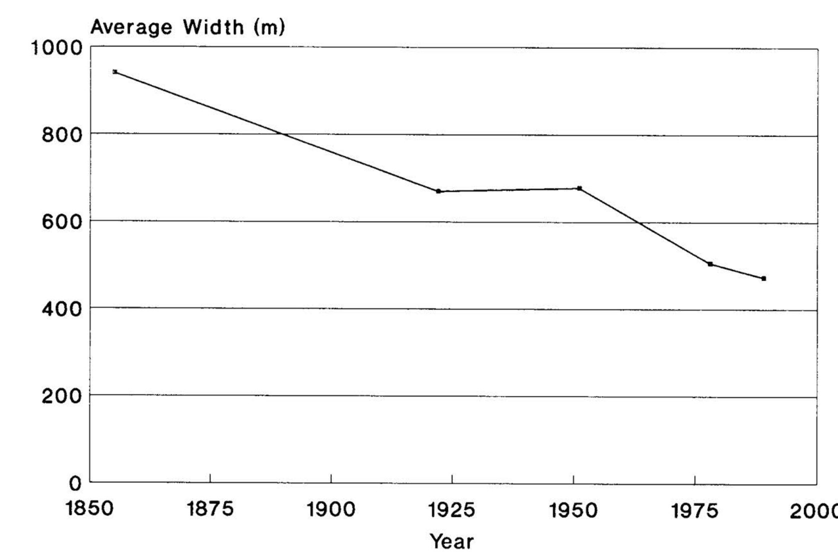


FIGURE 63.—Average barrier width between 1855 and 1989 along Chandeleur Island.

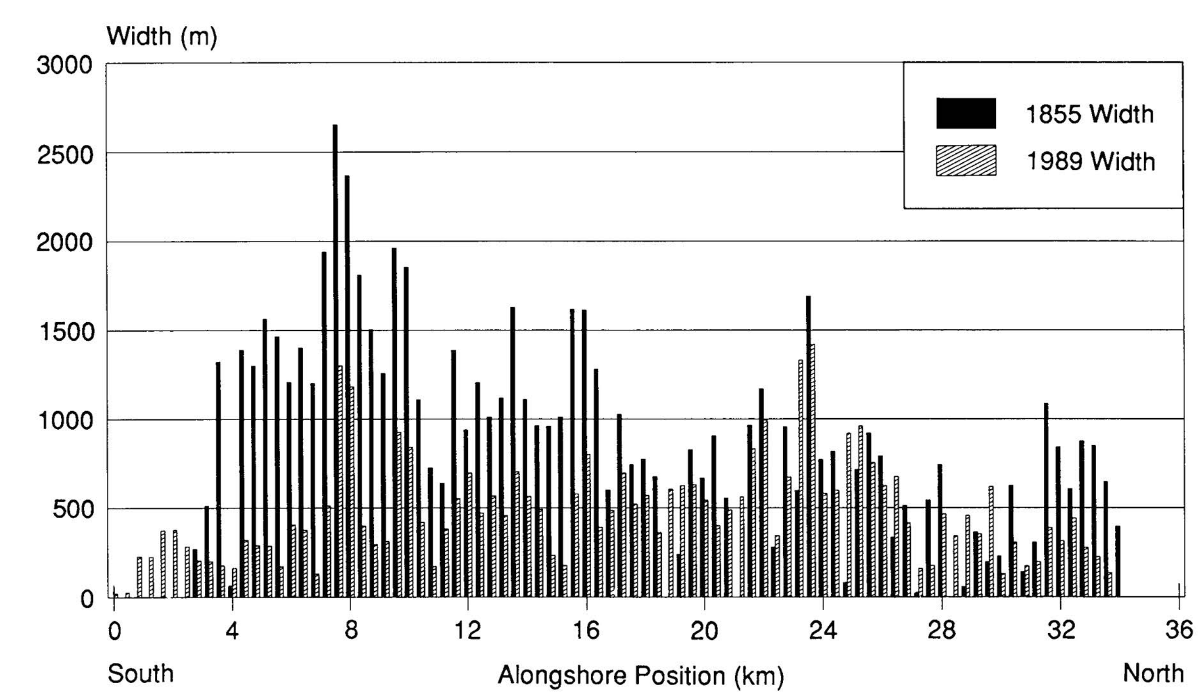
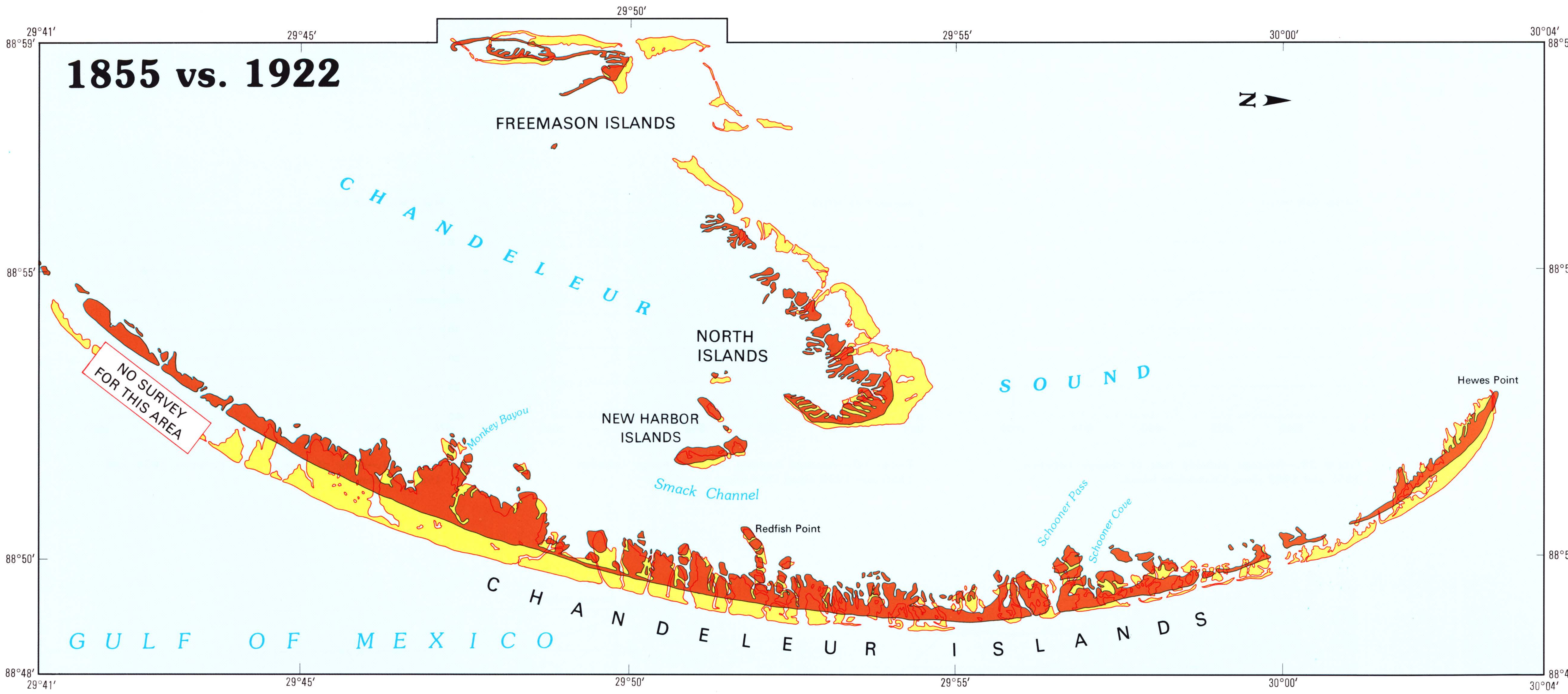


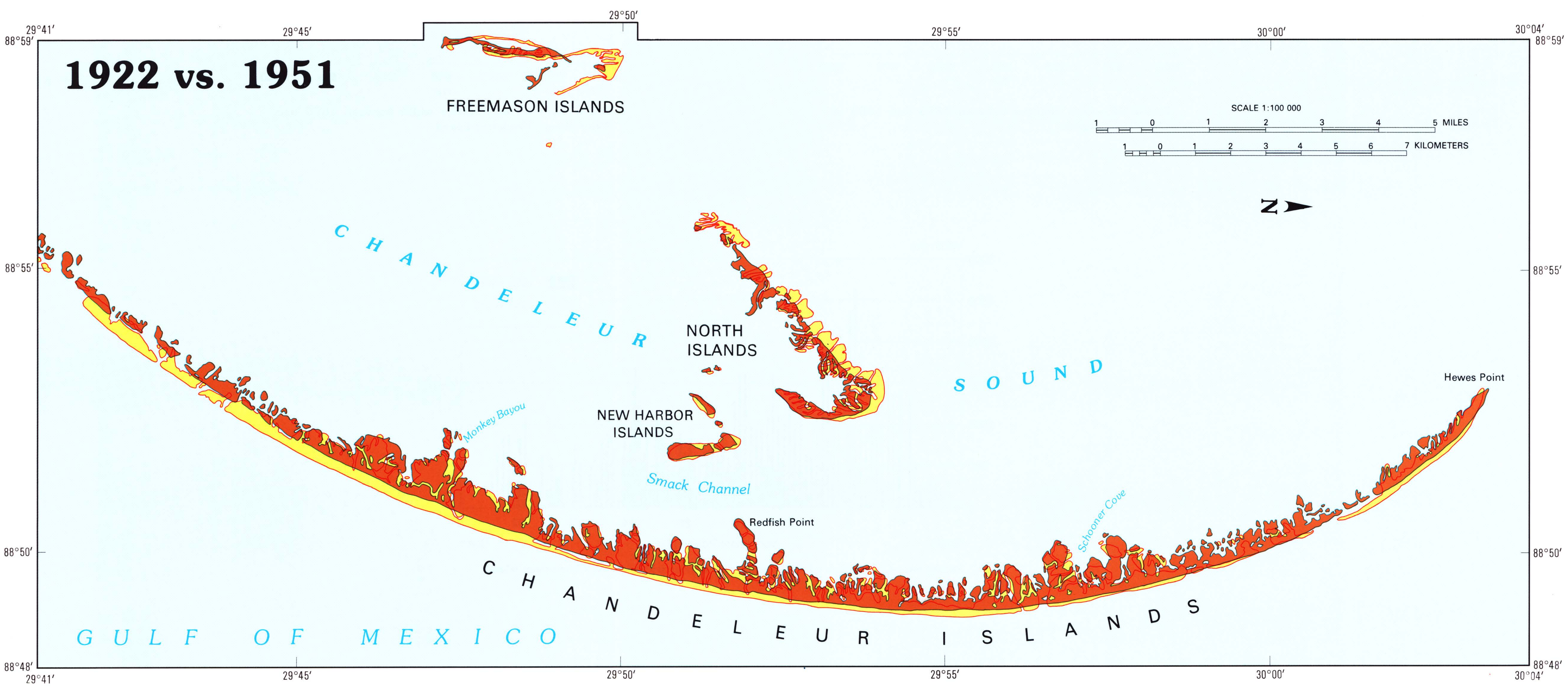
FIGURE 64.—Comparison of 1855 and 1989 barrier widths along Chandeleur Island.

North Chandeleur Islands



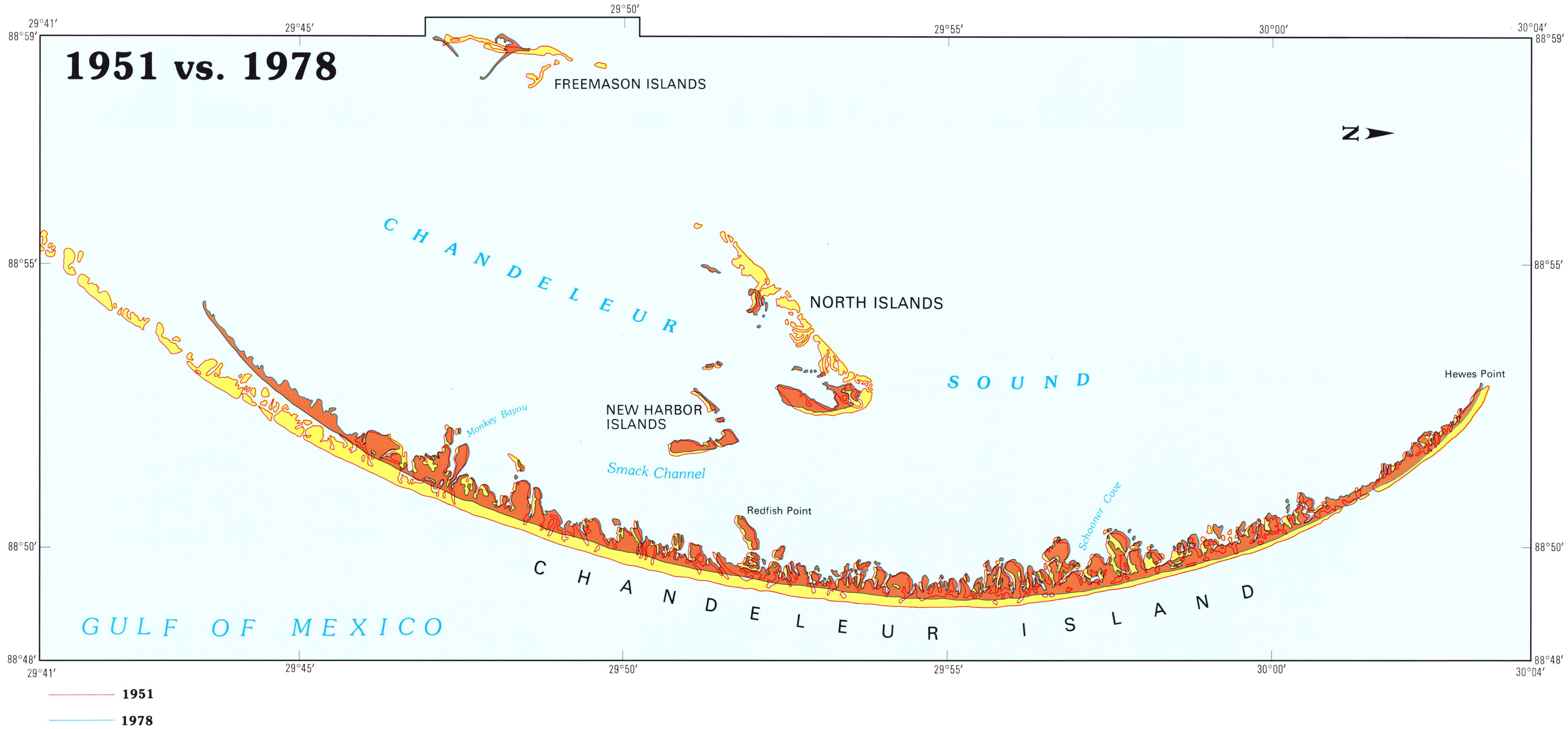
1855
1922

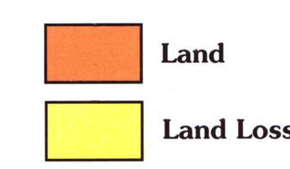
• Shoreline Change and Land Loss •

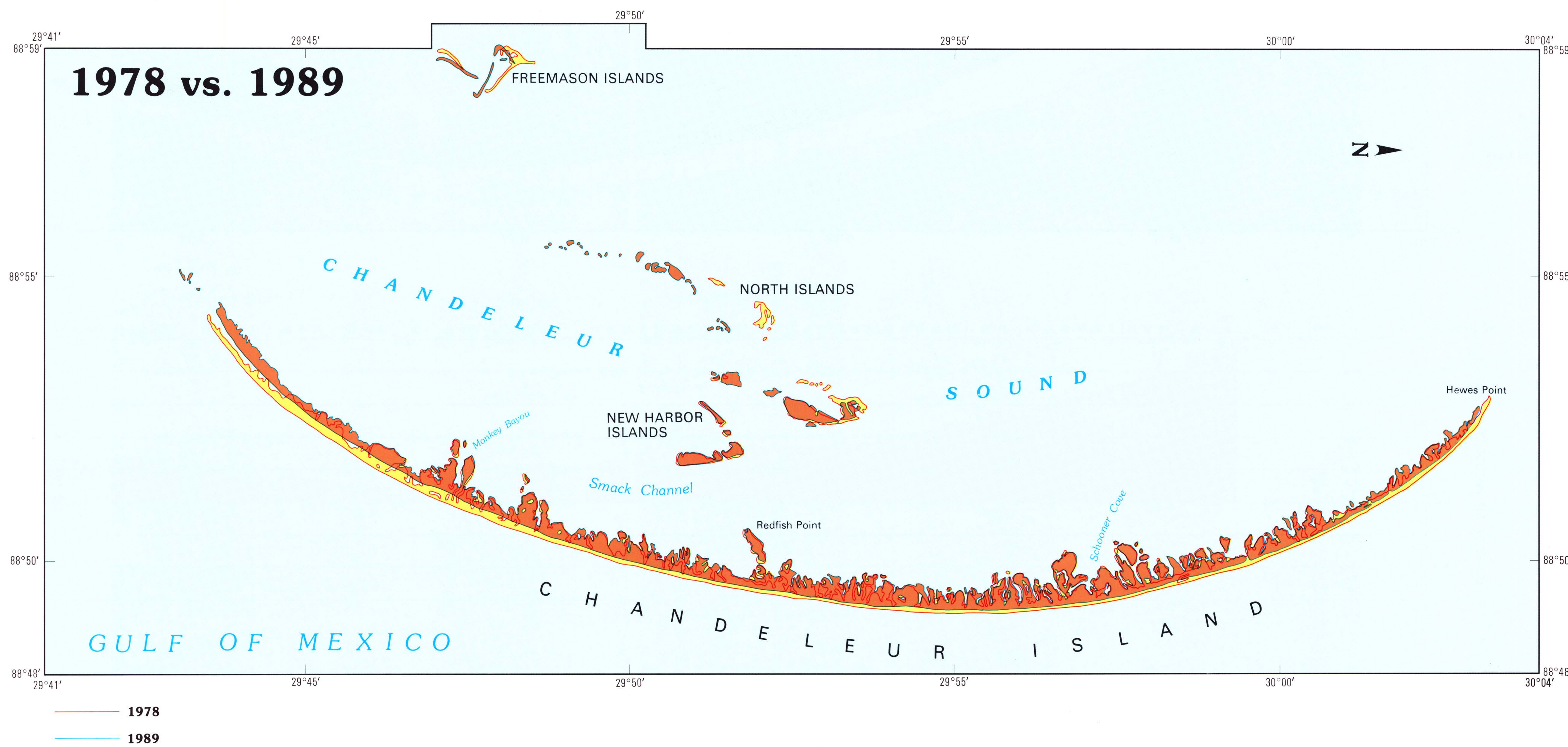


1922
1951

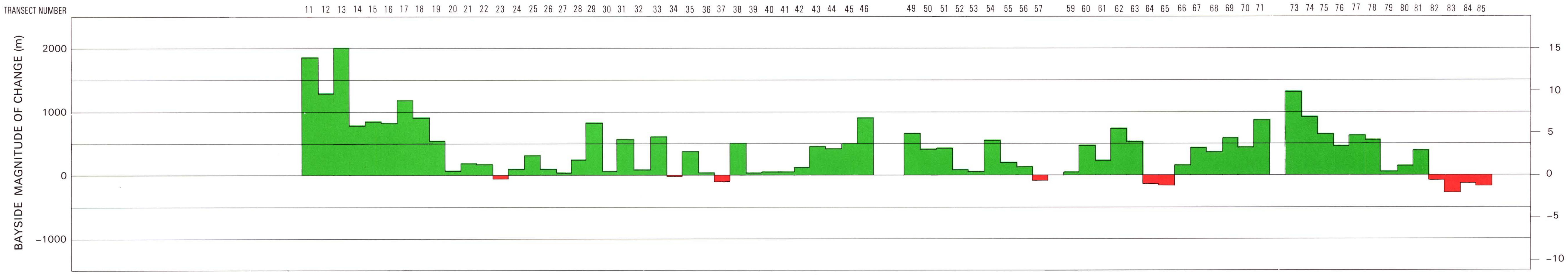
North Chandeleur Islands

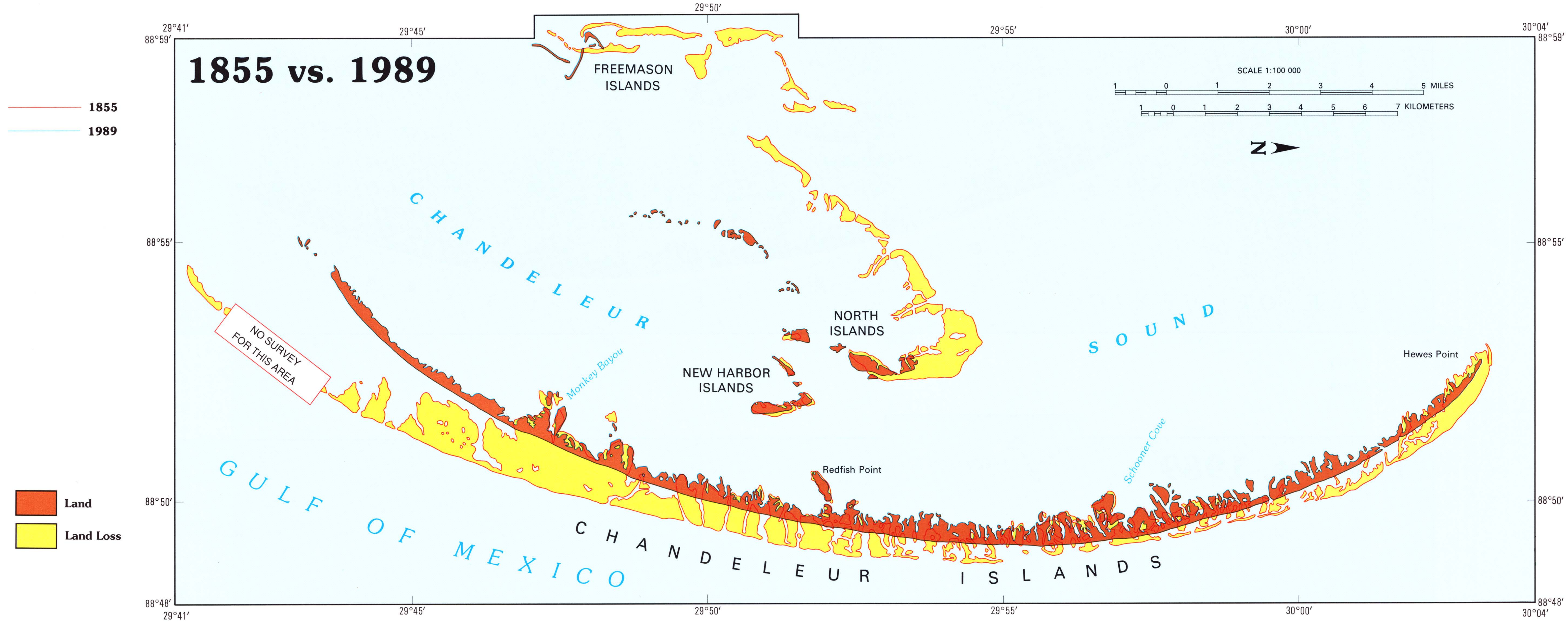


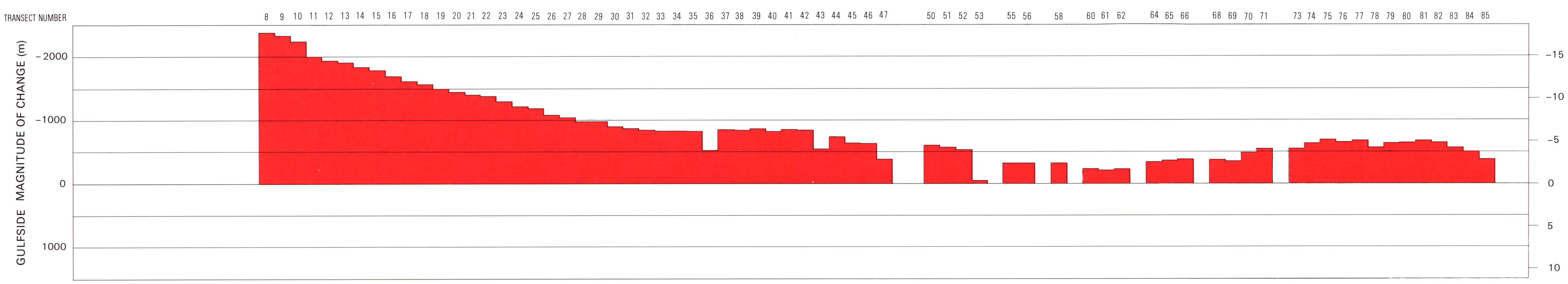




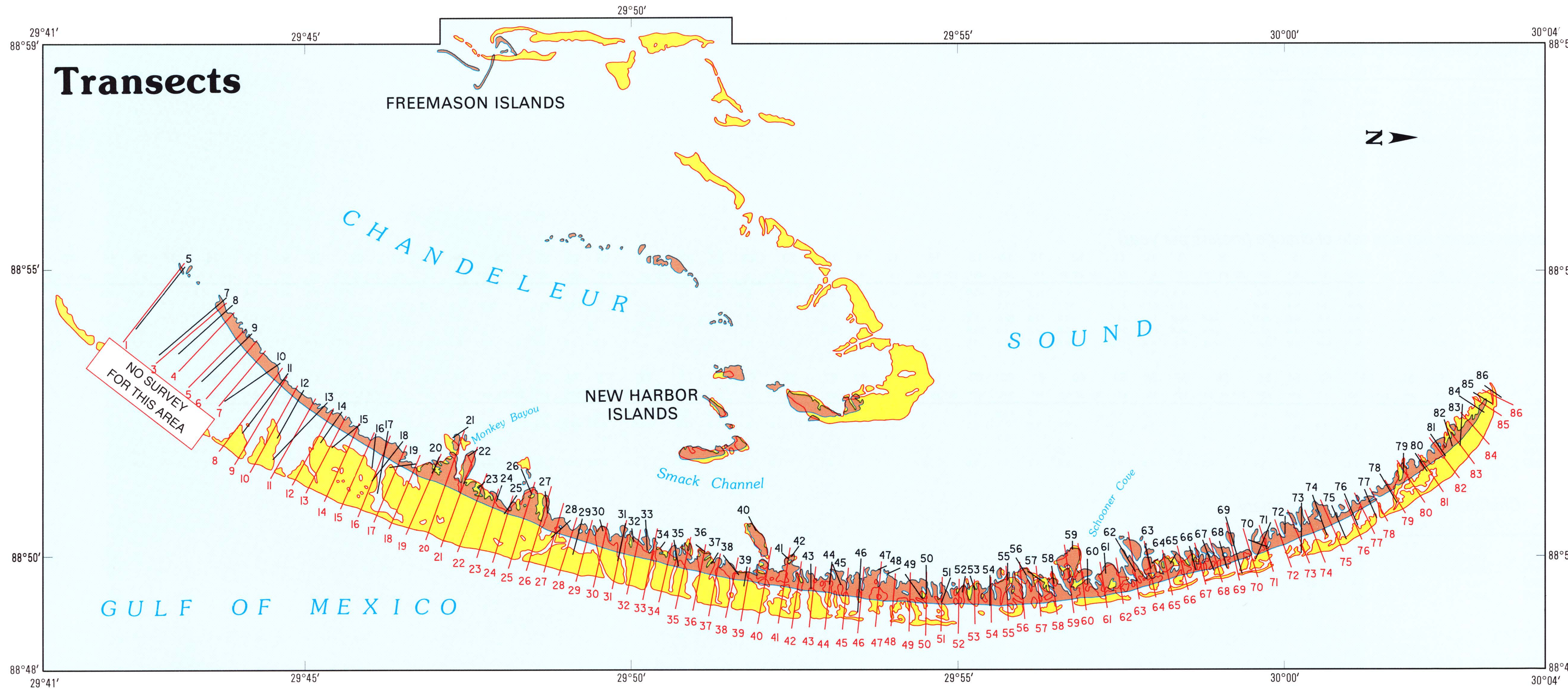
North Chandeleur Islands







North Chandeleur Islands



Gulfside Transects

Bayside Transects

TABLE 39.—*North Chandeleur Islands bayside magnitude of change (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinate		29° 42' 15"	30"	45"	29° 43' 00"	15"	30"	45"	29° 44' 00"	15"	30"	45"	29° 45' 00"	15"	30"	45"	29° 46' 00"	15"	30"	45"	29° 47' 00"	15"	30"	45"	29° 48' 00"
Y	1855-1922	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.a.	n.a.	n.a.	726	277	1286	119	226	546	1360	732	362	69	196	215	5	257
e	1922-1951	52	n.a.	n.a.	n.a.	281	n.a.	470	39	496	709	610	480	5	31	−46	272	−152	251	224	14	39	−20	−11	−177
a	1951-1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	1351	1276	727	337	302	467	713	611	270	−8	−35	−84	−165	−23	−30	−15	−33	−9
r	1978-1989	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	479	384	424	332	223	58	4	14	400	−1	1	4	124	1	−7	−7	1	3
s	1855-1989	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.a.	n.a.	n.a.	1861	1282	2008	775	850	809	1174	903	545	61	198	173	−38	74

Transect #		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate		15"	30"	45"	29° 49' 00"	15"	30"	45"	29° 50' 00"	15"	30"	45"	29° 51' 00"	15"	30"	45"	29° 52' 00"	15"	30"	45"	29° 53' 00"	15"	30"	45"	29° 54' 00"
Y	1855-1922	359	72	−410	−251	−99	−21	−330	69	624	56	161	107	−91	556	22	37	65	82	506	26	94	895	n.a.	n.a.
e	1922-1951	−56	40	439	471	506	91	382	57	24	−33	−6	−93	19	−15	−245	36	−12	38	−18	27	−78	−91	−12	−7
a	1951-1978	−6	−5	−17	−2	129	−29	510	−27	−24	−27	−7	−19	−21	−32	234	−44	−14	−8	−53	−19	142	36	−20	−9
r	1978-1989	−2	−14	1	14	279	−5	−4	−8	−16	−5	217	9	−9	3	−9	−3	0	−2	5	366	334	60	−19	−10
s	1855-1989	295	93	13	232	815	36	558	91	608	−9	365	4	−102	512	2	26	39	110	440	400	492	900	n.a.	n.a.

Transect #		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
Transect coordinate		15"	30"	45"	29° 55' 00"	15"	30"	45"	29° 56' 00"	15"	30"	45"	29° 57' 00"	15"	30"	45"	29° 58' 00"	15"	30"	45"
Y	1855-1922	371	110	332	−44	−40	n.a.	25	71	−13	n.a.	118	319	83	799	463	−44	−42	−336	−354
e	1922-1951	276	20	77	105	86	416	151	50	−58	n.a.	−3	148	235	−83	63	−60	−92	467	764
a	1951-1978	−8	3	1	0	−14	97	32	3	−17	−10	−75	−85	−83	20	−8	−8	2	26	18
r	1978-1989	−2	271	1	7	4	11	−15	−8	2	−11	−9	82	−13	−15	−9	−5	−15	−9	−10
s	1855-1989	637	404	411	68	36	524	193	116	−86	n.a.	31	464	222	721	509	−117	−147	148	418

Transect #		68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Transect coordinate		29° 59' 00"	15"	30"	45"	30° 00' 00"	15"	30"	45"	30° 01' 00"	15"	30"	45"	30° 02' 00"	15"	30"	45"	30° 03' 00"	15"	30"
Y	1855-1922	−235	234	232	443	n.a.	753	−145	n.a.	136	142	81	−64	−217	−83	−271	−637	−225	−312	−99
e	1922-1951	684	184	218	382	165	138	1099	n.a.	257	230	258	−68	369	445	204	273	22	53	−76
a	1951-1978	−89	185	−17	32	49	402	−46	−60	116	229	94	−52	4	30	−15	86	−4	−3	105
r	1978-1989	−6	−35	3	12	4	16	−9	−14	−52	11	118	225	−12	−3	11	14	103	104	n.a.
s	1855-1989	354	568	436	869	n.a.	1309	899	644	457	612	551	41	144	389	−71	−264	−104	−158	n.a.

Chandeleur Island bayside summary

Years	Sum	Avg	STD	Total Range		Count
1855-1922	10456	149.4	363.0	1360	−637	70
1922-1951	12430	155.4	242.3	1099	−245	80
1951-1978	7260	90.8	260.9	1351	−165	80
1978-1989	4366	55.3	123.4	479	−52	79
1855-1989	27823	391.9	443.5	2008	−264	71

See page 46 for explanation of numbers.

North Chandeleur Islands

TABLE 40.—*North Chandeleur Islands gulfside magnitude of change (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinate		29° 42' 15"	30"	45"	29° 43' 00"	15"	30"	45"	29° 44' 00"	15"	30"	45"	29° 45' 00"	15"	30"	45"	29° 46' 00"	15"	30"	45"	29° 47' 00"	15"	30"	45"	29° 48' 00"
Y	1855-1922	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-992	-1003	-977	-860	-836	-822	-840	-849	-790	-733	-710	-667	-642	-655	-616	-556	-534
e	1922-1951	-411	n.a.	-451	n.a.	-311	-283	-314	-342	-460	-293	-275	-273	-285	-242	-227	-247	-264	-242	-283	-272	-267	-265	-256	-250
a	1951-1978	n.a.	n.a.	-1459	n.a.	-1261	-1107	-982	-775	-606	-721	-659	-599	-563	-536	-465	-416	-381	-357	-302	-263	-238	-255	-251	-248
r	1978-1989	n.a.	n.a.	-276	-286	-229	-254	-266	-259	-250	-238	-205	-216	-218	-223	-244	-231	-218	-225	-234	-256	-237	-226	-214	-175
s	1855-1989	n.d.	n.d.	n.d	n.d.	n.d.	n.d.	n.d.	-2368	-2319	-2229	-1999	-1924	-1888	-1841	-1785	-1684	-1596	-1534	-1486	-1433	-1397	-1362	-1277	-1207

Transect #		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate		15"	30"	45"	29° 49' 00"	15"	30"	45"	29° 50' 00"	15"	30"	45"	29° 51' 00"	15"	30"	45"	29° 52' 00"	15"	30"	45"	29° 53' 00"	15"	30"	45"	29° 54' 00"
Y	1855-1922	-493	-502	-470	-465	-442	-361	-329	-341	-321	-295	-310	-13	-351	-323	-333	-320	-330	-351	-64	-285	-191	-221	31	n.a.
e	1922-1951	-237	-192	-175	-139	-139	-146	-140	-105	-132	-129	-121	-147	-147	-146	-130	-148	-150	-132	-127	-112	-95	-90	-88	-82
a	1951-1978	-241	-230	-243	-259	-285	-275	-267	-286	-281	-281	-279	-256	-250	-260	-239	-218	-245	-255	-242	-246	-248	-239	-221	-227
r	1978-1989	-193	-146	-125	-108	-92	-98	-112	-103	-86	-98	-101	-101	-104	-102	-157	-119	-106	-93	-92	-91	-81	-68	-94	-101
s	1855-1989	-1164	-1070	-1013	-971	-958	-880	-848	-835	-820	-803	-811	-517	-852	-831	-859	-805	-831	-831	-525	-734	-615	-618	-372	n.a.

Transect #		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
Transect coordinate		15"	30"	45"	29° 55' 00"	15"	30"	45"	29° 56' 00"	15"	30"	45"	29° 57' 00"	15"	30"	45"	29° 58' 00"	15"	30"	45"
Y	1855-1922	n.a.	-191	-140	-92	394	n.a.	50	32	n.a.	n.a.	n.a.	-7	5	-61	n.a.	-91	-73	-85	n.a.
e	1922-1951	-106	-95	-144	-171	-184	-172	-128	-104	-95	n.a.	-71	-32	-53	-16	-31	-72	-88	-85	n.a.
a	1951-1978	-214	-208	-171	-174	-151	-143	-157	-164	-141	-134	-123	-125	-92	-89	-95	-109	-117	-112	-109
r	1978-1989	-92	-99	-91	-83	-81	-78	-68	-51	-53	-55	-60	-60	-56	-49	-45	-54	-69	-71	-53
s	1855-1989	n.a.	-593	-546	-520	-22	n.a.	-303	-287	n.a.	-300	n.a.	-224	-196	-215	n.a.	-326	-347	-353	n.a.

Transect #		68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Transect coordinate		29° 59' 00"	15"	30"	45"	30° 00' 00"	15"	30"	45"	30° 01' 00"	15"	30"	45"	30° 02' 00"	15"	30"	45"	30° 03' 00"	15"	30"
Y	1855-1922	n.a.	-110	-250	-323	n.a.	-377	-387	n.a.	-417	-345	-172	-221	-298	-368	-336	-241	-148	-77	58
e	1922-1951	n.a.	-60	-46	-3	n.a.	27	-51	n.a.	-138	-234	-254	-220	-123	-90	-94	-90	-51	49	85
a	1951-1978	-91	-79	-75	-102	-106	-107	-119	-106	-54	-19	-29	-71	-84	-81	-100	-171	-194	-213	-123
r	1978-1989	-61	-79	-106	-89	-82	-82	-58	-51	-38	-68	-90	-110	-125	-116	-91	-53	-79	-126	n.a.
s	1855-1989	-355	-328	-477	-517	n.a.	-539	-615	-688	-647	-666	-545	-622	-630	-655	-621	-555	-472	-367	n.a.

Chandeleur Island gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1855-1922	-24433	-359.3	291.1	394	-1003	68
1922-1951	-12702	-160.8	106.1	85	-460	79
1951-1978	-23069	-277.9	260.3	-19	-1459	83
1978-1989	-10523	-126.8	70.8	-38	-286	83
1855-1989	-61423	-877.5	553.8	-22	-2368	70

TABLE 41.—*North Chandeleur Islands bayside rate of change (meters per year)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinate		29° 42' 15"	30"	45"	29° 43' 00"	15"	30"	45"	29° 44' 00"	15"	30"	45"	29° 45' 00"	15"	30"	45"	29° 46' 00"	15"	30"	45"	29° 47' 00"	15"	30"	45"	29° 48' 00"
Y	1855-1922	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.a.	n.a.	n.a.	10.8	4.1	19.1	1.8	3.4	8.1	20.2	10.9	5.4	1.0	2.9	3.2	0.1	3.8
e	1922-1951	1.8	n.a.	n.a.	n.a.	9.8	n.a.	16.3	1.4	17.2	24.6	21.2	16.7	0.2	1.1	-1.6	9.4	-5.3	8.7	7.8	0.5	1.4	-0.7	-0.4	-6.1
a	1951-1978	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	48.6	45.9	26.2	12.1	10.9	16.8	25.6	22.0	9.7	-0.3	-1.3	-3.0	-5.9	-0.8	-1.1	-0.5	-1.2	-0.3
r	1978-1989	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	46.1	36.9	40.8	31.9	21.4	5.6	0.4	1.3	38.5	-0.1	0.1	0.4	11.9	0.1	-0.7	-0.7	0.1	0.3
s	1855-1989	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.a.	n.a.	n.a.	13.9	9.5	15.0	5.8	6.3	6.0	8.7	6.7	4.1	0.5	1.5	1.3	-0.3	0.6

Transect #		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate		15"	30"	45"	29° 49' 00"	15"	30"	45"	29° 50' 00"	15"	30"	45"	29° 51' 00"	15"	30"	45"	29° 52' 00"	15"	30"	45"	29° 53' 00"	15"	30"	45"	29° 54' 00"
Y	1855-1922	5.3	1.1	-6.1	-3.7	-1.5	-0.3	-4.9	1.0	9.3	0.8	2.4	1.6	-1.4	8.3	0.3	0.5	1.0	1.2	7.5	0.4	1.4	13.3	n.a.	n.a.
e	1922-1951	-1.9	1.4	15.2	16.4	17.6	3.2	13.3	2.0	0.8	-1.1	-0.2	-3.2	0.7	-0.5	-8.5	1.3	-0.4	1.3	-0.6	0.9	-2.7	-3.2	-0.4	-0.2
a	1951-1978	-0.2	-0.2	-0.6	-0.1	4.6	-1.0	18.3	-1.0	-0.9	-1.0	-0.3	-0.7	-0.8	-1.2	8.4	-1.6	-0.5	-0.3	-1.9	-0.7	5.1	1.3	-0.7	-0.3
r	1978-1989	-0.2	-1.3	0.1	1.3	26.8	-0.5	-0.4	-0.8	-1.5	-0.5	20.9	0.9	-0.9	0.3	-0.9	-0.3	0	-0.2	0.5	35.2	32.1	5.8	-1.8	-1.0
s	1855-1989	2.2	0.7	0.1	1.7	6.1	0.3	4.2	0.7	4.5	-0.1	2.7	0	-0.8	3.8	0	0.2	0.3	0.8	3.3	3.0	3.7	6.7	n.a.	n.a.

Transect #		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
Transect coordinate		15"	30"	45"	29° 55' 00"	15"	30"	45"	29° 56' 00"	15"	30"	45"	29° 57' 00"	15"	30"	45"	29° 58' 00"	15"	30"	45"
Y	1855-1922	5.5	1.6	4.9	-0.7	-0.6	n.a.	0.4	1.1	-0.2	n.a.	1.8	4.7	1.2	11.9	6.9	-0.7	-0.6	-5.0	-5.3
e	1922-1951	9.6	0.7	2.7	3.6	3.0	14.4	5.2	1.7	-2.0	n.a.	-0.1	5.1	8.2	-2.9	2.2	-2.1	-3.2	16.2	26.5
a	1951-1978	-0.3	0.1	0	0	-0.5	3.5	1.2	0.1	-0.6	-0.4	-2.7	-3.1	-3.0	0.7	-0.3	-0.3	0.1	0.9	0.6
r	1978-1989	-0.2	26.1	0.1	0.7	0.4	1.1	-1.4	-0.8	0.2	-1.1	-0.9	7.9	-1.3	-1.4	-0.9	-0.5	-1.4	-0.9	-1.0
s	1855-1989	4.7	3.0	3.1	0.5	0.3	3.9	1.4	0.9	-0.6	n.a.	0.2	3.5	1.7	5.4	3.8	-0.9	-1.1	1.1	3.1

Transect #		68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Transect coordinate		29° 59' 00"	15"	30"	45"	30° 00' 00"	15"	30"	45"	30° 01' 00"	15"	30"	45"	30° 02' 00"	15"	30"	45"	30° 03' 00"	15"	30"
Y	1855-1922	-3.5	3.5	3.4	6.6	n.a.	11.2	-2.2	n.a.	2.0	2.1	1.2	-1.0	-3.2	-1.2	-4.0	-9.5	-3.3	-4.6	-1.5
e	1922-1951	23.8	6.4	7.6	13.3	5.7	4.8	38.2	n.a.	8.9	8.0	9.0	-2.4	12.8	15.5	7.1	9.5	0.8	1.8	-2.6
a	1951-1978	-3.2	6.7	-0.6	1.2	1.8	14.5	-1.7	-2.2	4.2	8.2	3.4	-1.9	0.1	1.1	-0.5	3.1	-0.1	-0.1	3.8
r	1978-1989	-0.6	-3.4	0.3	1.2	0.4	1.5	-0.9	-1.3	-5.0	1.1	11.3	21.6	-1.2	-0.3	1.1	1.3	9.9	10.0	n.a.
s	1855-1989	2.6	4.2	3.2	6.5	n.a.	9.7	6.7	4.8	3.4	4.6	4.1	0.3	1.1	2.9	-0.5	-2.0	-0.8	-1.2	n.a.

Chandeleur Island bayside summary

Years	Sum	Avg	STD	Total	Range	Count
1855-1922	155.4	2.2	5.4	20.2	-9.5	70
1922-1951	431.6	5.4	8.4	38.2	-8.5	80
1951-1978	261.2	3.3	9.4	48.6	-5.9	80
1978-1989	419.8	5.3	11.9	46.1	-5.0	79
1855-1989	207.2	2.9	3.3	15.0	-2.0	71

TABLE 42.—*North Chandeleur Islands width measurements (meters)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinate		29° 42' 15"	30"	45"	29° 43' 00"	15"	30"	45"	29° 44' 00"	15"	30"	45"	29° 45' 00"	15"	30"	45"	29° 46' 00"	15"	30"	45"	29° 47' 00"	15"	30"	45"	29° 48' 00"
Y	1855	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	268	510	1323	63	1389	1301	1564	1466	1207	1402	1201	1938	2653	2366	1810	1504	1257
e	1922	553	357	527	208	333	156	297	481	399	473	215	793	803	710	907	1464	971	625	1342	2163	1978	1192	1154	1093
a	1951	252	n.a.	153	n.a.	107	557	412	467	491	538	492	470	246	572	924	1090	1091	690	1068	1844	1687	914	780	765
r	1978	n.a.	n.a.	21	21	100	95	204	156	200	361	326	302	437	82	416	632	602	210	769	1587	1429	622	515	510
s	1989	20	24	227	226	373	374	281	204	198	175	161	319	289	285	170	404	375	130	512	1300	1181	398	295	310

Transect #		25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate		15"	30"	45"	29° 49' 00"	15"	30"	45"	29° 50' 00"	15"	30"	45"	29° 51' 00"	15"	30"	45"	29° 52' 00"	15"	30"	45"	29° 53' 00"	15"	30"	45"	29° 54' 00"
Y	1855	1963	1856	1108	726	638	1388	940	1204	1011	1119	1630	1109	961	959	1012	1619	1611	1280	600	1026	743	775	675	n.a.
e	1922	1534	1034	447	385	41	1080	328	969	292	872	1268	1061	629	733	710	892	1403	847	956	768	506	465	833	958
a	1951	1368	1211	299	388	556	937	570	886	528	685	1163	956	609	600	358	942	1170	761	871	684	410	572	675	985
r	1978	1104	958	517	133	441	642	300	581	594	404	733	678	296	340	289	709	916	485	568	423	178	341	472	712
s	1989	923	841	417	171	380	551	695	469	565	457	701	563	490	232	175	576	801	389	485	697	518	568	360	602

Transect #		49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67
Transect coordinate		15"	30"	45"	29° 55' 00"	15"	30"	45"	29° 56' 00"	15"	30"	45"	29° 57' 00"	15"	30"	45"	29° 58' 00"	15"	30"	45"
Y	1855	240	825	667	903	554	n.a.	965	1170	278	957	596	1690	770	817	81	716	920	790	334
e	1922	764	377	388	296	252	429	1023	1245	968	n.a.	1519	1580	884	767	284	1152	933	326	n.a.
a	1951	938	646	262	270	744	665	1053	1224	678	879	1521	1609	800	759	1528	1137	942	396	561
r	1978	719	455	435	316	568	610	920	1060	262	750	1403	1498	646	662	1451	1021	824	307	243
s	1989	624	629	543	398	488	560	832	995	342	674	1331	1419	581	597	919	960	755	625	676

Transect #		68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Transect coordinate		29° 59' 00"	15"	30"	45"	30° 00' 00"	15"	30"	45"	30° 01' 00"	15"	30"	45"	30° 02' 00"	15"	30"	45"	30° 03' 00"	15"	30"
Y	1855	512	24	544	743	n.a.	57	363	196	227	624	142	307	1087	840	606	875	850	646	394
e	1922	n.a.	75	79	204	n.a.	185	53	n.a.	61	65	120	135	246	205	262	364	435	215	186
a	1951	359	317	102	694	545	259	488	712	147	180	318	180	307	503	97	428	370	275	272
r	1978	252	346	234	554	326	257	495	662	281	250	238	201	417	424	529	105	119	105	126
s	1989	414	158	174	465	341	455	351	618	130	305	172	196	387	313	440	276	225	134	n.a.

Chandeleur Island width summary

Years	Sum	Avg	STD	Total	Range	Count
1855	71485	940.6	542.8	2653	24	76
1922	54282	670.1	468.2	2163	41	81
1951	56959	678.1	387.8	1844	97	84
1978	42482	505.7	346.8	1587	21	84
1989	40359	474.8	286.7	1419	20	85

See page 46 for explanation of numbers.

North Chandeleur Islands

TABLE 43.—*North Chandeleur Islands gulfside rate of change (meters per year)*

Transect #		1	2	3	4	5	6	7	8	9	10	11	12
Transect coordinate		29° 42' 15"	30"	45"	29° 43' 00"	15"	30"	45"	29° 44' 00"	15"	30"	45"	29° 45' 00"
Years	1855-1922	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-14.7	-14.9	-14.5	-12.8	-12.4
	1922-1951	-14.3	n.a.	-15.7	n.a.	-10.8	-9.8	-10.9	-11.9	-16.0	-10.2	-9.5	-9.5
	1951-1978	n.a.	n.a.	-52.5	n.a.	-45.4	-39.8	-35.3	-27.9	-21.8	-25.9	-23.7	-21.5
	1978-1989	n.a.	n.a.	-26.5	-27.5	-22.0	-24.4	-25.6	-24.9	-24.0	-22.9	-19.7	-20.8
	1855-1989	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	-17.6	-17.3	-16.6	-14.9	-14.3

Transect #		13	14	15	16	17	18	19	20	21	22	23	24
Transect coordinate		15"	30"	45"	29° 46' 00"	15"	30"	45"	29° 47' 00"	15"	30"	45"	29° 48' 00"
Years	1855-1922	-12.2	-12.5	-12.6	-11.7	-10.9	-10.5	-9.9	-9.5	-9.7	-9.2	-8.3	-7.9
	1922-1951	-9.9	-8.4	-7.9	-8.6	-9.2	-8.4	-9.8	-9.4	-9.3	-9.2	-8.9	-8.7
	1951-1978	-20.3	-19.3	-16.7	-15.0	-13.7	-12.8	-10.9	-9.5	-8.6	-9.2	-9.0	-8.9
	1978-1989	-21.0	-21.4	-23.5	-22.2	-21.0	-21.6	-22.5	-24.6	-22.8	-21.7	-20.6	-16.8
	1855-1989	-14.1	-13.7	-13.3	-12.5	-11.9	-11.4	-11.1	-10.7	-10.4	-10.1	-9.5	-9.0

Transect #		25	26	27	28	29	30	31	32	33	34	35	36
Transect coordinate		15"	30"	45"	29° 49' 00"	15"	30"	45"	29° 50' 00"	15"	30"	45"	29° 51' 00"
Years	1855-1922	-7.3	-7.5	-7.0	-6.9	-6.6	-5.4	-4.9	-5.1	-4.8	-4.4	-4.6	-0.2
	1922-1951	-8.2	-6.7	-6.1	-4.8	-4.8	-5.1	-4.9	-3.6	-4.6	-4.5	-4.2	-5.1
	1951-1978	-8.7	-8.3	-8.7	-9.3	-10.3	-9.9	-9.6	-10.3	-10.1	-10.1	-10.0	-9.2
	1978-1989	-18.6	-14.0	-12.0	-10.4	-8.8	-9.4	-10.8	-9.9	-8.3	-9.4	-9.7	-9.7
	1855-1989	-8.7	-8.0	-7.5	-7.2	-7.1	-6.6	-6.3	-6.2	-6.1	-6.0	-6.0	-3.8

Transect #		37	38	39	40	41	42	43	44	45	46	47	48
Transect coordinate		15"	30"	45"	29° 52' 00"	15"	30"	45"	29° 53' 00"	15"	30"	45"	29° 54' 00"
Years	1855-1922	-5.2	-4.8	-4.9	-4.8	-4.9	-5.2	-1.0	-4.2	-2.8	-3.3	0.5	n.a.
	1922-1951	-5.1	-5.1	-4.5	-5.1	-5.2	-4.6	-4.4	-3.9	-3.3	-3.1	-3.1	-2.8
	1951-1978	-9.0	-9.4	-8.6	-7.8	-8.8	-9.2	-8.7	-8.8	-8.9	-8.6	-7.9	-8.2
	1978-1989	-10.0	-9.8	-15.1	-11.4	-10.2	-8.9	-8.8	-8.8	-7.8	-6.5	-9.0	-9.7
	1855-1989	-6.3	-6.2	-6.4	-6.0	-6.2	-6.2	-3.9	-5.5	-4.6	-4.6	-2.8	n.a.

Transect #		49	50	51	52	53	54	55	56	57	58	59	60	61
Transect coordinate		15"	30"	45"	29° 55' 00"	15"	30"	45"	29° 56' 00"	15"	30"	45"	29° 57' 00"	15"
Years	1855-1922	n.a.	-2.8	-2.1	-1.4	5.9	n.a.	0.7	0.5	n.a.	n.a.	n.a.	-0.1	0.1
	1922-1951	-3.7	-3.3	-5.0	-5.9	-6.4	-6.0	-4.4	-3.6	-3.3	n.a.	-2.5	-1.1	-1.8
	1951-1978	-7.7	-7.5	-6.2	-6.3	-5.4	-5.1	-5.6	-5.9	-5.1	-4.8	-4.4	-4.5	-3.3
	1978-1989	-8.8	-9.5	-8.8	-8.0	-7.8	-7.5	-6.5	-4.9	-5.1	-5.3	-5.8	-5.8	-5.4
	1855-1989	n.a.	-4.4	-4.1	-3.9	-0.2	n.a.	-2.3	-2.1	n.a.	-2.2	n.a.	-1.7	-1.5

Transect #		62	63	64	65	66	67	68	69	70	71	72	73	74
Transect coordinate		30"	45"	29° 58' 00"	15"	30"	45"	29° 59' 00"	15"	30"	45"	30° 00' 00"	15"	30"
Years	1855-1922	-0.9	n.a.	-1.4	-1.1	-1.3	n.a.	n.a.	-1.6	-3.7	-4.8	n.a.	-5.6	-5.8
	1922-1951	-0.6	-1.1	-2.5	-3.1	-3.0	n.a.	n.a.	-2.1	-1.6	-0.1	n.a.	0.9	-1.8
	1951-1978	-3.2	-3.4	-3.9	-4.2	-4.0	-3.9	-3.3	-2.8	-2.7	-3.7	-3.8	-3.8	-4.3
	1978-1989	-4.7	-4.3	-5.2	-6.6	-6.8	-5.1	-5.9	-7.6	-10.2	-8.6	-7.9	-7.9	-5.6
	1855-1989	-1.6	n.a.	-2.4	-2.6	-2.6	n.a.	-2.6	-2.4	-3.6	-3.8	n.a.	-4.0	-4.6

Transect #		75	76	77	78	79	80	81	82	83	84	85	86
Transect coordinate		45"	30° 01' 00"	15"	30"	45"	30° 02' 00"	15"	30"	45"	30° 03' 00"	15"	30"
Years	1855-1922	n.a.	-6.2	-5.1	-2.6	-3.3	-4.4	-5.5	-5.0	-3.6	-2.2	-1.1	0.9
	1922-1951	n.a.	-4.8	-8.1	-8.8	-7.6	-4.3	-3.1	-3.3	-3.1	-1.8	1.7	3.0
	1951-1978	-3.8	-1.9	-0.7	-1.0	-2.6	-3.0	-2.9	-3.6	-6.2	-7.0	-7.7	-4.4
	1978-1989	-4.9	-3.7	-6.5	-8.7	-10.6	-12.0	-11.2	-8.8	-5.1	-7.6	-12.1	n.a.
	1855-1989	-5.1	-4.8	-5.0	-4.1	-4.6	-4.7	-4.9	-4.6	-4.1	-3.5	-2.7	n.a.

Chandeleur Island gulfside summary

Years	Sum	Avg	STD	Total	Range	Count
1855-1922	-363.0	-5.3	4.3	5.9	-14.9	68
1922-1951	-441.0	-5.6	3.7	3.0	-16.0	79
1951-1978	-829.8	-10.0	9.4	-0.7	-52.5	83
1978-1989	-1011.8	-12.2	6.8	-3.7	-27.5	83
1855-1989	-457.4	-6.5	4.1	-0.2	-17.6	70

TABLE 44.—*Area changes for Chandeleur Island from 1855 to 1989*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1855	2,763				
1922	2,485	-278	-10%	-4.1	2528
1922	2,485				
1951	2,588	103	4%	3.6	N.A.
1951	2,588				
1978	1,796	-792	-31%	-28.5	2041
1978	1,796				
1989	1,749	-47	-3%	-4.5	2360
1855	2,763				
1989	1,749	-1,014	-37%	-7.6	2218

TABLE 45.—*Area changes of North Islands from 1855 to 1989*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1855	589				
1922	391	-198	-34%	-2.9	2057
1922	391				
1951	280	-111	-28%	-3.9	2023
1951	280				
1978	110	-170	-61%	-6.1	1996
1978	110				
1989	109	-1	-1%	-0.1	3079
1855	589				
1989	109	-480	-81%	-3.6	2019

TABLE 46.—*Area Changes of the New Harbor Islands from 1855 to 1989*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1855	72				
1922	94	22	31%	0.3	N.A.
1922	94				
1951	70	-24	-25%	-0.8	2039
1951	70				
1978	63	-7	-10%	-0.3	2188
1978	63				
1989	75	12	19%	1.2	N.A.
1855	72				
1989	75	3	4%	.02	N.A.

TABLE 47.—*Area changes of the Freemason Islands from 1855 to 1989*

Date	Area (ha)	Change (ha)	% Change	Rate (ha/yr)	Projected Date of Disappearance
1855	218				
1922	100	-118	-54%	-1.8	1978
1922	100				
1951	52	-48	-48%	-1.7	1982
1951	52				
1978	21	-31	-60%	-1.1	1997
1978	21				
1989	12	-9	-43%	-0.9	2002
1855	218				
1989	12	-206	-94%	-1.5	1997

See page 46 for explanation of numbers.

CLASSIFICATION OF SHORELINE CHANGE

Classification of the distribution and rate of change along Louisiana's barrier shoreline has been compiled and presented in past studies (Morgan and Larimore, 1957; Adams and others, 1978; Penland and Boyd, 1981; Morgan and Morgan, 1983; Dolan and others, 1985; Britsch and Kemp, 1990). These studies, however, were compiled using various methodologies, techniques, time periods, scales, and accuracy standards, which may have led to inconsistencies. Furthermore, they neither use rectified aerial photography nor discuss total potential error in detail. This study differs from previous work because it is based on approximately 880 shore-normal transects derived from digital shorelines compiled from large-scale data sources (1:33,000 or larger) using the most advanced computer mapping technology available. Moreover, temporal data were comprehensive from the 1850's to 1989, providing both long-term and short-term rates of change, and spatial consistency was maintained among data sources (table 48).

Shoreline movement along Louisiana's barrier shoreline was divided into three broad categories based on direction and rate (m/yr) of change: shoreline advance, stability, and retreat (summary map). For this study, the terms advance and retreat were used to describe shoreline movement in contrast to the terms erosion and accretion, which imply volumetric changes. For example, retreating barrier islands can preserve volume when migrating landward (both the gulf and bay shorelines) and therefore, are not eroding but merely migrating.

Based on the adopted classification scheme, the summary map illustrates that the majority of Louisiana's barrier shoreline is suffering from high rates of coastal retreat. The Timbalier Islands section of the Bayou Lafourche barrier shoreline experienced the highest average rate of landward migration. The Plaquemines barrier system, however, experienced the lowest average rate of shoreline change at -5.5 m/yr between 1884 and 1988. Only six small areas had stable or advancing shorelines: the western portions of Timbalier, Grand Terre (Barataria Pass area), and Shell islands; the eastern portion of Grand Isle; the area east of Fontanelle Pass; and the southern portion of Breton Island. These stable or accretionary areas are related to spit processes in conjunction with an adjacent tidal entrance, except the area east of Fontanelle Pass, which is related to the capture of longshore sediment transport by jetties.

CONCLUSIONS

Louisiana's barrier island systems have undergone landward migration, area loss, and island narrowing as a result of a complex interaction among subsidence, sea level rise, wave processes, inadequate sediment supply, and intense human disturbance. Consequently, the structural continuity of the barrier shoreline weakens as the barrier islands narrow, fragment, and finally disappear. In the past 100 years, total barrier island area in Louisiana has declined 55% at a rate of 63 ha/yr. This deterioration will continue to destroy Louisiana's coastline until coastal restoration techniques that complement natural processes are implemented to restore and fortify the shoreline.

The Isles Dernieres barrier system experienced retreat rates along the gulf shoreline that averaged 11.1 m/yr between 1887 and 1988, while the bayside rate of change averaged -0.6 m/yr between 1906 and 1988. Erosion of the gulf and bay shorelines caused island width to narrow from 1,171 m in the 1890's to 375 m in 1988. Consequently, gulf and bay shorelines are converging to cause the core of the barrier island arc to remain essentially stationary through time. Moreover, the area of Isles Dernieres decreased from 3,532 ha in 1890's to 771 ha in 1988, which is a loss of 2,761 ha at a rate of 28.2 ha/yr. The 2,761-ha loss represents a 78 percent decrease in island area since the 1890's. If this rate of loss continues, Isles Dernieres is projected to disappear and evolve into a subaqueous, inner-shelf shoal by the year 2015.

The Timbalier Islands experienced landward migration along the gulf and bay shorelines at average rates of -15.2 m/yr and 11.7 m/yr, respectively. However, Timbalier and East Timbalier islands must be examined separately to provide a more accurate representation of shoreline movement in response to dominant coastal processes. Between 1887 and 1988, the gulf shoreline of Timbalier Island retreated landward at 5.0 m/yr while the bay shoreline migrated seaward at 2.4 m/yr. But more importantly, Timbalier Island migrated laterally by spit processes over 6.5 km to the west. Also, island width narrowed from 1,293 m in 1887 to 415 m in 1988. The area of Timbalier Island decreased from 1,485 ha in 1887 to 542 ha in 1988, which is a loss of 64 percent, or 943 ha, at a rate of 9.3 ha/yr. At this rate, Timbalier Island is not projected to disappear until the year 2046, but short-term rates indicate a more serious problem, with a projected disappearance date by the year 2000. East Timbalier Island experienced the highest gulfside retreat rate (-23.1 m/yr) for any barrier island shoreline, not only in Louisiana but in the country. Correspondingly, the bay shoreline raced landward as well, averaging 24.0 m/yr. Initially, the rapid rate of landward migration of the gulf and bay shorelines was caused by washover processes, but extensive seawall construction beginning in the late 1950's terminated this process. Interestingly, width and area for East Timbalier Island increased between 1887 and 1988. Average island width increased from 264 to 333 m and area expanded from 193 ha in 1887 to 238 ha in 1988, which is a gain of 23 percent, or 45 ha, at a rate of 0.4 ha/yr.

Caminada-Moreau Headland and Grand Isle experienced shoreline retreat at an average gulfside rate of -7.9 m/yr between 1887 and 1988, while at the same time, the bay shoreline was essentially stable. However, for shoreline change analysis, this coastal segment was further divided into the Caminada-Moreau Headland and Grand Isle. The gulf shoreline of the Caminada-Moreau Headland averaged 13.3 m/yr of shoreline retreat between 1887 and 1988, while the bay shoreline advanced 4.1 m/yr for the same period. In contrast, the average gulfside rate of shoreline change along Grand Isle advanced 0.9 m/yr, while the bay shoreline retreated at an average rate of 1.0 m/yr. The average area of Grand Isle decreased only slightly from 1,059 to 960 ha between 1887 and 1988, which is a loss of only 9 percent at a rate of 1.0 ha/yr. At this rate, Grand Isle is projected to disappear in the year 2948. Average width for Grand Isle also showed stability, remaining constant at approximately 690 m. The eastern end of Grand Isle was the only portion along this barrier shoreline to experience shoreline advance. Beach replenishment probably contributed to Grand Isle's stability over the years.

The Plaquemines barrier system experienced the lowest rate of gulfside retreat, averaging 5.5 m/yr with a bayside rate of 0.4 m/yr between 1884 and 1988. Two islands along the Plaquemines shoreline were examined individually: Grand Terre and Shell. Grand Terre Islands migrated landward along the gulf shoreline at -3.9 m/yr for the period 1884 and 1988, while the bay shoreline migrated seaward at 2.2 m/yr. Therefore, the core of the island was stationary, causing the width to narrow from 909 to 530 m and the area to diminish from 1,699 ha in 1884 to 513 ha in 1988; this is a loss of 70 percent at a rate of 11.4 ha/yr. If this rate of land loss continues, Grand Terre Islands are projected to disappear by the year 2033. Shell Island migrated landward along the gulf shoreline more rapidly than Grand Terre Islands, averaging 6.0 m/yr. But, the bay shoreline also migrated landward at 3.4 m/yr, causing the entire island to migrate landward instead of maintaining a stationary position. The width of Shell Island narrowed from 177 to 122 m between 1884 and 1988 with a similar decrease in area from 127 to 69 ha. This is a loss of 46 percent at a rate of 0.6 ha/yr. If this long-term rate of land loss continues, Shell Island will not disappear until the early twenty-second century. However, the short-term rate loss of 5.0 ha/yr between 1973 and 1988 projects a disappearance date of 2002.

The South Chandeleur Islands underwent the second highest average rate of gulfside retreat between 1869 and 1989 at 11.6 m/yr, with the bay shoreline migrating landward also at a high rate of 10.7 m/yr. During rapid landward migration, average barrier width decreased from 384 to 232 m. Area decreased from 784 to 441 ha, representing a land loss of 44 percent, at a rate of 2.9 ha/yr. Individually, Breton Island migrated landward along the gulf and bay shorelines between 1869 and 1989 at -5.7 and 3.9 m/yr, respectively. Similarly, area was reduced from 332 to 164 ha, which is a 51 percent loss at an average rate of 1.4 ha/yr. For the same period, Grand Gosier and Curlew islands migrated landward at even higher rates along the gulf and bay shorelines at 16.2 and 15.0 m/yr, respectively. Area decreased from 453 to 277 ha, which is a 39 percent loss at an average rate of 1.5 ha/yr. Overall, the South Chandeleur Islands are narrowing as they rapidly migrate landward. This type of migration is similar to East Timbalier and Shell islands.

The North Chandeleur Islands are characterized by an average retreat rate of 6.5 m/yr along the gulf shoreline between 1855 and 1988. The bay shoreline migrated landward also but was twice as slow as the gulf shoreline at 2.9 m/yr. As a result, average island width narrowed by about 50 percent from 941 m in 1855 to 473 m in 1989, with a 37 percent decrease in island area from 2,763 to 1,749 ha. The total loss was 1,014 ha at an average rate of 7.6 ha/yr. Once again, the North Chandeleur Islands display a narrowing trend as they rapidly migrate landward similar to East Timbalier, Shell, and South Chandeleur islands.

Finally, the Louisiana barrier shoreline is dominated by two types of island evolution: *landward rollover* and *in-place breakup*. Landward rollover is dominated by washover processes capable of eroding and transporting sediment from the gulf shoreline, across the barrier island, and depositing this sediment along the bay shoreline; both the gulf and bay shorelines migrate landward. This appears to be associated with barrier islands having sufficient sediment to migrate landward under relative sea level rise (East Timbalier Island, 1887 to 1956; Chandeleur Island). When in-place breakup occurs, sediment is not transported across the entire barrier because there is an inadequate sediment supply and/or the barrier island is too wide to be completely overwashed. Seaward migration along the bayside shoreline occurs in response to wave activity (erosion) and subsidence. This type of evolution is associated with barrier island systems that are rapidly deteriorating and have short life expectancies (Isles Dernieres, Grand Terre Islands). Systems where in-place breakup occurs are the most critical areas of barrier island land loss and need the greatest attention.

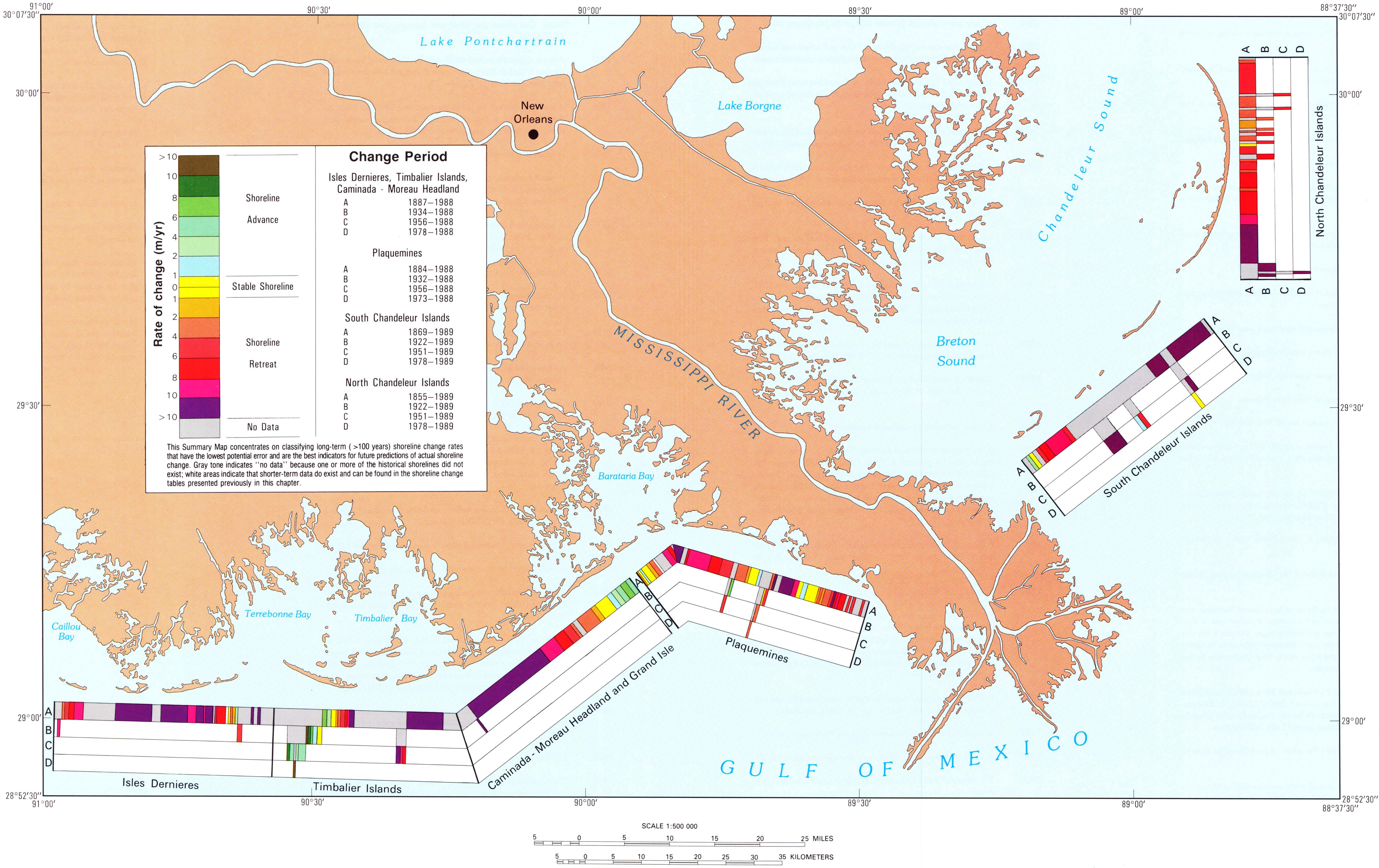
TABLE 48.—***Summary of Louisiana's barrier island shoreline change statistics.***

		GULFSIDE SHORELINE CHANGE RATES (m/yr)						ISLAND AREA CHANGE RATES (ha/yr)		PROJECTED DATE OF DISAPPEARANCE (yr)		BAYSIDE SHORELINE CHANGE RATES (m/yr)					
		Long Term*			Short Term**			Long Term*	Short Term**	Long Term*	Short Term**	Long Term*			Short Term**		
BARRIER SYSTEM	ISLAND/BEACH	Avg.	STD	Total Range	Avg.	STD	Total Range					Avg.	STD	Total Range	Avg.	STD	Total Range
1. Isles Dernieres		-11.1	5.2	3.4 / -23.2	-19.2	12.7	6.0 / -64.3	-28.2	-47.2	2015	2004	-0.6	5.8	23.5 / -4.9	-2.7	15.5	43.4 / -24.3
	Raccoon	-7.2	2.1	-3.4 / -9.7	-17.7	7.3	-8.2 / -34.0	-7.7	-6.8	1999	2000	-2.4	0.9	-1.2 / -4.3	2.0	16.1	31.4 / -21.9
	Whiskey	-16.3	2.6	-12.9 / -22.0	-30.1	16.3	-11.6 / -64.3	-3.7	-12.7	2042	2007	-1.7	1.8	3.5 / -4.5	5.4	17.7	43.4 / -19.0
	Trinity	-11.0	1.2	-9.8 / -14.4	-17.8	4.5	-9.9 / -25.3	---	-18.9	---	2007	-1.6	2.3	4.0 / -4.6	-8.4	12.5	38.4 / -24.3
	East	-4.8	3.9	3.4 / -10.7	-8.7	9.5	6.0 / -21.0	---	-9.0	---	1998	-2.7	1.4	-0.7 / -4.9	-8.8	7.0	0.1 / -24.2
	Wine	-22.9	0.4	-22.5 / -23.2	---	---	--- ---	-1.5	---	1995	---	22.4	0.9	23.5 / 21.3	---	---	--- ---
2. Bayou Lafourche																	
Timbalier Islands		-15.2	11.6	8.0 / -33.3	-14.0	23.7	27.6 / -84.6	-8.9	-71.5	2076	1999	11.7	15.0	32.7 / -14.6	-7.8	24.8	52.2 / -122.7
	Timbalier	-2.4	5.9	8.0 / -13.0	-7.0	16.5	27.6 / -54.0	-9.3	-45.7	2046	2000	-5.0	3.1	-1.0 / -15.0	-14.1	26.7	52.2 / -122.7
	East Timbalier	-23.1	4.4	-16.3 / -33.3	-21.2	28.7	4.6 / -84.6	0.4	-25.7	---	1997	24.0	4.3	33.0 / 18.0	-1.2	21.4	41.1 / -61.3
Caminada—Moreau Headland and Grand Isle		-7.9	8.4	6.2 / -20.0	-6.5	11.5	16.7 / -42.0	---	---	---	---	-0.1	2.4	7.0 / -2.8	-3.0	4.3	5.5 / -13.0
	Caminada—Moreau Headland	-13.3	5.6	-2.9 / -20.0	-13.6	7.8	-2.8 / -42.0	---	---	---	---	4.1	1.9	7.0 / 1.9	-1.8	1.4	0.4 / -3.7
	Grand Isle	0.9	3.1	6.2 / -3.4	5.2	5.7	16.7 / -2.5	-1.0	1.1	2948	---	-1.0	1.3	2.8 / -2.8	-3.2	4.6	5.5 / -13.0
3. Plaquemines		-5.5	4.5	1.9 / -15.6	-9.9	11.1	14.9 / -70.1	---	---	---	---	0.4	4.5	12.5 / -4.7	3.7	17.8	66.1 / -19.8
	Grand Terre	-3.9	3.5	1.9 / -9.2	-7.9	6.5	5.9 / -15.6	-11.4	-10.8	2033	2036	-2.2	1.9	1.5 / -4.7	-1.2	6.8	17.2 / -7.5
	Shell	-10.1	2.8	-2.5 / -12.5	-24.2	17.6	-3.6 / -70.1	-0.6	-5.0	2103	2002	7.9	12.0	12.5 / 2.4	20.6	12.4	66.1 / -1.1
4. Chandeleur Islands																	
South Chandeleur Islands		-11.6	6.5	5.9 / -21.1	-19.7	15.9	6.9 / -41.3	-2.9	13.3	2199	---	10.7	6.9	22.6 / -7.7	19.8	20.8	60.1 / -8.9
	Breton	-5.7	4.7	5.9 / -9.2	-4.1	10.2	3.8 / -23.7	-1.4	2.2	2106	---	3.9	5.8	10.0 / -7.7	-1.2	3.1	5.6 / -3.7
	Grand Gosier/ Curlew	-16.2	3.3	-6.1 / -21.1	-23.9	14.5	6.9 / -41.3	-1.5	11.1	2174	---	15.0	2.9	22.6 / 11.1	26.8	19.4	60.1 / -8.9
North Chandeleur Islands																	
	Chandeleur	-6.5	4.1	-0.2 / -17.6	-12.2	6.8	-3.7 / -27.5	-7.6	-4.5	2218	2360	2.9	3.3	15.0 / -2.0	5.3	11.9	46.1 / -5.0
	North	---	---	--- ---	---	---	--- ---	-3.6	-0.1	2019	3079	---	---	--- ---	---	---	--- ---
	New Harbor	---	---	--- ---	---	---	--- ---	0.0	1.2	---	---	---	---	--- ---	---	---	--- ---
	Freemason	---	---	--- ---	---	---	--- ---	-1.5	-0.9	1997	2002	---	---	--- ---	---	---	--- ---

* Long Term - Shoreline record covering more than 100 years.
(except long-term island area rate for Whiskey Island — 54 years)

** Short Term - Shoreline record for the last 10 — 15 years.

Summary Map



Recommended citation for this chapter:

McBride, R. A., Penland, Shea, Hiland M. W., Williams, S. J., Westphal, K. A., Jaffe, B. E., and Sallenger, A. H., Jr., 1992, Analysis of barrier shoreline change in Louisiana from 1853 to 1989, *in* Williams, S. J., Penland, Shea, and Sallenger, A. H., Jr., eds., Louisiana barrier island erosion study—atlas of barrier shoreline changes in Louisiana from 1853 to 1989: U.S. Geological Survey Miscellaneous Investigations Series I-2150-A, p. 36-97.

Appendix A Louisiana's Hurricane History

YEAR	STORM
1711	A major three-day storm was reported in early September just south of Lake Pontchartrain.
1722	The first recorded great hurricane in Louisiana history occurred in September.
1723	On September 11 a hurricane struck New Orleans and destroyed nearly all homes and buildings.
1772	A storm disrupted shipping along the Mississippi River in late August and early September.
1776	A minor storm did minimal damage to the buildings in New Orleans.
1778	A storm between October 7-10 destroyed Balize.
1779	On August 12 a severe storm battered New Orleans and the surrounding region, destroying homes, ships and other human-made features.
1780	An August 24 storm struck the Louisiana coast and sunk every ship anchored in the Mississippi.
1781	A mid-August storm passed near New Orleans.
1793	A mid-August storm passed near New Orleans, destroying crops and devastating rural areas.
1794 *	A mid-August storm devastated rural areas near New Orleans.
1794 *	A storm struck the Louisiana coast in August.
1800	A mid-August storm passed near New Orleans.
1811	A mid-August storm passed near New Orleans.
1812 *	A violent mid-August hurricane struck New Orleans.
1812 *	On August 19 a great hurricane struck the New Orleans area, destroyed the city's levees and ships, and resulted in a number of deaths.
1819	Although primarily centered on Bay St. Louis, Mississippi, a July storm was also felt in east Louisiana, with a small amount of damage recorded in New Orleans.
1821	Little damage was recorded in New Orleans from a September storm.
1822	In early July, a hurricane battered the shoreline between Mobile and New Orleans.
1831	This storm, described as the Barbados to Louisiana Hurricane, was one of the great hurricanes of the century. It moved east of New Orleans, destroying homes and sinking ships. The death toll was estimated at 1,500. On the Isle of Barataria (believed to be Grand Isle) the storm's winds and a 2-m storm surge destroyed a fishing village and killed 150 people.
1837	A storm called the "Racer's Hurricane" left a path of destruction over 3,000 km long in the northern Gulf of Mexico. In the inundated areas of New Orleans, six people died, and marine interests suffered considerable losses around Lake Pontchartrain.
1846	A rare April storm battered the mouth of the Mississippi River at Balize.
1848	Three hurricanes made landfall in the northern Gulf of Mexico. In early August, one storm moved up the Mississippi damaging crops, but property losses were apparently minimal.
1855	A September 15 storm destroyed the Gulf coast from Lake Pontchartrain to Gulf Shores.
1856	On Sunday, August 10, the Isles Dernieres storm decimated Louisiana's coast. The resort community at Isles Dernieres was destroyed, and approximately 400 people died.
1860	Three hurricanes struck the middle Gulf Coast in late summer and early fall. One of them inundated property adjacent to Lake Pontchartrain and was responsible for 13 deaths.
1865	A September storm concentrated its energy between Orange, Texas, and Cameron, Louisiana.
1867	Galveston, Texas, and western Louisiana were devastated by this storm, but damage to south Louisiana's coastal communities was minor.
1872	A July storm affected the area east of the Mississippi Delta.
1875	A September storm came ashore in Texas and turned east through the middle of Louisiana; it had no direct effect on Louisiana's coast.
1877	A September hurricane paralleled the Louisiana coast from Isles Dernieres to the mouth of the river—a track that caused considerable shoreline change.
1879	Making landfall near Vermilion and Atchafalaya bays, a late-August, early-September hurricane did little damage along Lousiana's coast.
1882	A September hurricane affected the entire Gulf of Mexico. Winds at Port Eads, Louisiana, were recorded at over 145 km/hr.
1885	Three hurricanes brushed Louisiana's coastal margins between August 29 and October 2.
1886	An October storm struck the Louisiana-Texas border. Fifty people were killed in Cameron Parish, and a 1-m storm surge was recorded at Cheniere Caminada.
1887	Seventeen hurricanes were recorded in the United States in 1887. One October storm made landfall in Louisiana and damaged New Orleans considerably. The city's levees were breached, and extensive flooding occurred.
1888	An August hurricane crossed the Louisiana coast near Vermilion Bay with winds measured at 145 km/hr near New Orleans.
1889	A storm crossed Mexico's Yucatan Peninsula, turned north, and crossed the Gulf of Mexico, nicking the Mississippi Delta on September 22.
1892	A small hurricane hit southeast Louisiana.
1893	A storm made landfall near Barataria Bay without warning, allowing no time for evacuation. From 1,000 to 2,000 people were killed from the storm's two-day rampage. Communities at Cheniere Caminada and Grand Isle were hit hard. At least 150 fishing vessels were sunk and numerous shrimp-drying platforms and associated settlements were destroyed. Fort Livingston was also severely damaged.
1897	A September hurricane came through the Florida Keys and took aim at Louisiana, crossing the coast near Vermilion Bay on September 12.
1898	A small hurricane hit Louisiana's coast.
1900	Six thousand people died on September 8 when a hurricane inundated Galveston Island, Texas, with a 6-m storm surge. Minimal damage occurred in coastal Louisiana, but the water rose over a meter in 10 minutes at Pilottown. Almost all of New Orleans' east bank was under water. Levees were breached, and water poured into the Crescent City.
1901	A small hurricane did minimal damage in Louisiana, but there was considerable loss of life east of Bay St. Louis, Mississippi.
1904	A small November storm swept pass the Mississippi Delta.
1905	A small hurricane came ashore in Louisiana on September 29.
1906	An estimated 350 people were killed in a Louisiana-Mississippi storm.
1909	About 350 people died in September when a storm flooded most of the Louisiana coast with wind speeds of over 200 km/hr and a 5-m storm surge at Timbalier Island and the hamlet of Sea Breeze. The community at Manila Village was nearly demolished.
1915	Two hundred seventy-five people died when a hurricane struck the Mississippi Delta on September 29. In New Orleans, 25,000 structures with an estimated value of $13 million were damaged or destroyed. A 4-m storm surge was reported. Grand Isle's storm surge was estimated at three meters; nearly the entire island was under water.
1916	A small October storm affected the area east of the Mississippi Delta, but did minimal damage.
1918	An extreme storm killed 34 people and did $5 million in damage to the communities in western Louisiana.
1920	A small September hurricane crossed Louisiana's coast near Last Island. One person was killed, and damages were estimated at $1,450,000.
1923	A tropical depression from the eastern Pacific crossed Mexico and became a Gulf of Mexico hurricane. It crossed Louisiana's coast near Isles Dernieres on October 15.
1926	A hurricane crossed the Louisiana coast near Timbalier Island on August 26 with a 3-m storm surge. Twenty-five people were killed, and damages were estimated at $4 million.
1931	A small July hurricane did minor damage to Louisiana's coast.
1932	A small hurricane made landfall at Morgan City, Louisiana, on September 19. Another storm in October along the Louisiana and Mississippi Gulf coasts did minor damage.
1934	A small storm crossed the Louisiana coast near Isles Dernieres on June 16 and was responsible for six deaths and $2,605,000 in damages at Morgan City, Louisiana.
1936	A small July hurricane did minor damage to Louisiana's coast.
1937	A small September hurricane did minor damage to Louisiana's coast, but dropped 42 cm of precipitation on New Orleans.
1938	Hurricane-force winds battered the Lousiana and Texas coasts on August 14. Damage was estimated at $243,000.
1939	An estimated $1.7 million in damages were assessed from New Orleans east as a result of a September 26 hurricane.
1940	On August 7 and 8, the Louisiana and Texas coasts were lashed by hurricane winds and a 1-m storm surge.
1947	Over 2.5 m of water flooded New Orleans from a September hurricane that tracked directly over New Orleans. It generated a surge that easily overtopped the region's protective levees. Thirty-four people were killed, and over $100 million in damages were assessed.
1948	A September 4 hurricane made landfall near Grand Isle, Louisiana recorded nearly $900,000 in damages.
1949	A minor storm crossed Louisiana's coast on September 4.
1954	A minor storm crossed Vermilion Bay on July 29.
1955	A minor storm killed two people on August 1 along the Louisiana-Mississippi border. Another storm on August 27 killed four people in Louisiana.
1956	Hurricane Flossy struck Grand Island and Eugene Island in September, putting over two meters of water outside the levees protecting New Orleans' eastern boundary. Two and one half meters of water flowed over areas of Grand Isle. Eight people were killed, and property damages were estimated at $22 million.
1957	Hurricane Audrey's 4-m storm surge hit the coast near Calcasieu Pass on June 27. Many people refused to evacuate and over 500 died. Property damages were estimated at $150 million.
1960	Hurricane Ethel passed near the Mississippi Delta.
1961	Hurricane Carla, one of the most severe Gulf hurricanes, caused high tides and inundated many of the low-lying communities along Louisiana's coast with from 1-2 m of water.
1964	Hurricane Hilda hit Louisiana's coast in late September and early October. Hilda caused considerable damage to offshore and coastal oil installations and generated a surge height of 1.5 m at Grand Isle. The storm caused considerable damage to the beach at Grand Isle and cut through the western end of the island and Cheniere Caminada.
1965	Hurricane Betsy roared into southern Florida and Louisiana on September 8 with winds over 250 km/hr. Grand Isle was inundated with nearly a 3-m surge height. The entire island was covered, and nearly all buildings were swept away, demolished, or severely damaged. In southeast Louisiana, 81 people were killed, 17,600 injured, and 250,000 evacuated. The storm was responsible for over $1.4 billion in damages within an inundated area that exceeded 1.2 million hectares.
1969	On August 17 Hurricane Camille—one of the most violent storms ever to hit the U.S. mainland—killed over 300 people. A 6-m storm surge was recorded near New Orleans.
1971	Hurricane Edith crossed the Louisiana coast near Cameron on September 16.
1974	Louisiana citizens from Eugene Island to Lake Charles were affected by Hurricane Carmen.
1977	Hurricane Babe crossed Louisiana's coast near Point-Au-Fer.
1979	Hurricane Frederic ravaged southern Alabama, and Hurricane Bob hit Grand Isle.
1985	Six hurricanes made landfall in the United States. Danny, Elena, and Juan battered the Louisiana coast. These storms were responsible for at least $4 billion in property damages. Three million coastal residents were evacuated.
1988	Hurricane Florence crossed the Mississippi Delta on September 8 and brought high water to Mississippi. Eight days later, Hurricane Gilbert hit Mexico with 300 km/hr winds. Its waves severely eroded Louisiana's barrier islands.

* These accounts may refer to the same storm, but the historical material is inconclusive.

Appendix B Coastal Erosion and Wetlands Loss Tables

TABLE B1.—*Rate of shoreline change for U.S. coastal states and regions [Symbol used: —, no data]*

Region	Mean (m/yr)[1]	Standard Deviation	Total Range	N[2]
Atlantic Coast	-0.8	3.2	25.5 to 24.6	510
Maine	-0.4	0.6	1.9 to -0.5	16
New Hampshire	0.0	—	-0.5 to -0.5	4
Massachusetts	-0.9	1.9	4.5 to -4.5	48
Rhode Island	-0.5	0.1	-0.3 to -0.7	17
New York	0.1	3.2	18.8 to -2.2	42
New Jersey	-1.0	5.4	25.5 to -15.0	39
Delaware	0.1	2.4	5.0 to -2.3	7
Maryland	-1.5	3.0	1.3 to -8.8	9
Virginia	-4.2	5.5	0.9 to -24.6	34
North Carolina	-0.6	2.1	9.4 to -6.0	101
South Carolina	-2.0	3.8	5.9 to -17.7	57
Georgia	0.7	2.8	5.0 to -4.0	31
Florida	-0.1	1.2	5.0 to -2.9	105
Gulf of Mexico	-1.8	2.7	8.8 to -15.3	358
Florida	-0.4	1.6	8.8 to -4.5	118
Alabama	-1.1	0.6	0.8 to -3.1	16
Mississippi	-0.6	2.0	0.6 to -6.4	12
Louisiana	-4.2	3.3	3.4 to -15.3	106
Texas	-1.2	1.4	0.8 to -5.0	106
Pacific Coast	0.0	1.5	10.0 to -5.0	305
California	-0.1	1.3	10.0 to -4.2	164
Oregon	-0.1	1.4	5.0 to -5.0	86
Washington	-0.5	2.2	5.0 to -3.9	46
Alaska	-2.4	2.0	2.9 to -6.0	69

[1]Negative values indicate erosion; positive values indicate accretion.
[2]Total number of 3-minute grid cells over which the statistics are calculated.
(Data from U.S. Geological Survey, 1988.)

TABLE B2.—*Distribution of coastal wetlands in the United States [Symbol used: —, data not available]*

Region and State	Wetland Area (hectares)				
	Salt Marsh	Fresh Marsh	Tidal Flats	Swamp	Total
Northeast					
Maine	6,723	10,409	23,612	10,125	50,868
New Hampshire	3,038	—	—	—	3,038
Massachusetts	19,481	6,116	16,808	10,085	52,488
Rhode Island	3,200	0	0	23,126	26,325
Connecticut	6,723	—	—	—	6,723
New York	10,814	1,377	—	—	12,191
Pennsylvania	0	324	0	0	324
New Jersey	88,047	8,789	19,683	191,282	307,800
Delaware	31,631	2,876	4,577	49,977	89,060
Maryland	66,258	10,368	729	7,857	85,212
Virginia	61,682	8,100	—	—	69,782
Subtotal	297,594	48,357	65,408	292,451	703,809
Southeast					
North Carolina	64,314	37,260	—	853,538	955,112
South Carolina	149,648	26,123	—	—	175,770
Georgia	151,592	12,758	3,848	115,830	284,027
Florida (Atlantic)	38,840	155,277	—	104,895	299,012
Subtotal	404,393	231,417	3,848	1,074,263	1,713,920
Gulf of Mexico					
Florida (Gulf)	174,677	31,388	—	393,134	599,198
Alabama	5,913	4,293	—	61,277	71,483
Mississippi	25,920	1,620	—	30,780	58,320
Louisiana	708,183	278,964	—	177,066	1,164,213
Texas	158,112	31,874	—	16,322	206,307
Subtotal	1,072,805	348,138	0	678,578	2,099,520
West Coast					
California	8,748	1,782	5,427	1,377	17,334
Oregon	7,614	2,552	10,206	—	20,372
Washington	9,599	7,128	891	11,826	29,444
Subtotal	25,961	11,462	16,524	13,203	67,149
Total	**1,800,752**	**639,374**	**85,779**	**2,058,494**	**4,584,398**
(% of total)	(39)	(14)	(2)	(45)	(100)

Data converted to metric units from Alexander and others (1986, p. 6). Sums of some columns or rows may not exactly equal totals shown because of the conversion procedure and subsequent rounding.

TABLE B3.—*Distribution of U.S. coastal wetlands in the Gulf of Mexico [Symbol used: —, data not available]*

Region and State	County	Wetland Area (hectares)				
		Salt Marsh	Fresh Marsh	Flats	Swamp	Total
Gulf of Mexico						
Florida	Bay	2,683	332	—	17,358	20,373
	Charlotte	4,927	—	—	6,838	11,765
	Citrus	12,410	—	—	6,233	18,644
	Collier	16,902	—	—	33,180	50,082
	Dixie	9,530	—	—	16,568	26,098
	Escambia	1,102	—	—	5,376	6,477
	Franklin	8,310	930	—	58,602	67,842
	Gulf	256	2,662	—	47,999	50,917
	Hernando	4,564	—	—	9,784	14,349
	Hillsborough	993	233	—	3,740	4,966
	Jefferson	1,848	—	—	7,063	8,911
	Lee	5,751	—	—	17,485	23,236
	Levy	15,881	85	—	5,318	21,285
	Manatee	438	111	—	2,415	2,965
	Monroe	64,613	26,304	—	89,895	180,812
	Okaloos	264	—	—	10,881	11,145
	Pasco	1,501	—	—	1,347	2,848
	Pinellas	—	—	—	2,421	2,421
	Santa Rosa	3,217	18	—	16,099	19,333
	Sarasota	362	—	—	380	743
	Taylor	9,686	—	—	18,626	28,312
	Wakulla	7,936	723	—	3,455	12,114
	Walton	1,488	—	—	12,065	13,553
	Subtotal	174,663	31,398	0	393,130	599,190
Alabama	Baldwin	1,601	2,859	—	42,489	46,948
	Mobile	4,328	1,430	—	18,786	24,543
	Subtotal	5,928	4,289	0	61,275	71,492
Mississippi	Hancock	8,910	608	—	7,290	16,808
	Harrison	3,240	203	—	2,228	5,670
	Jackson	13,770	810	—	21,263	35,843
	Subtotal	25,920	1,620	0	30,780	58,320
Louisiana	Assumption	0	0	—	0	0
	Cameron	147,070	115,139	—	83	262,292
	Iberia	37,463	4,253	—	2,228	43,943
	Jefferson	28,553	7,493	—	11,543	47,588
	Lafourche	86,063	9,518	—	6,885	102,465
	Livingston	0	0	—	608	608
	Orleans	17,415	608	—	3,240	21,263
	Plaquemines	117,045	18,428	—	10,125	145,598
	St. Bernard	86,873	0	—	4,050	90,923
	St. Charles	8,100	6,885	—	7,290	22,275
	St. James	0	0	—	17,415	17,415
	St. John Bap.	2,633	1,823	—	25,718	30,173
	St. Mary	7,898	39,083	—	36,855	83,835
	St. Tammany	12,960	5,468	—	8,303	26,730
	Tangipahoa	0	5,063	—	22,275	27,338
	Terrebonne	121,095	63,383	—	17,820	202,298
	Vermilion	35,033	1,823	—	2,633	39,488
	Subtotal	708,197	278,962	0	177,068	1,164,227
Texas	Aransas	3,629	1,814	—	—	5,443
	Brasoria	17,107	2,333	—	1,296	20,736
	Calhoun	9,331	6,221	—	—	15,552
	Chambers	25,142	—	—	259	25,402
	Galveston	17,885	—	—	—	17,885
	Harris	778	59	—	4,666	5,702
	Jackson	1,296	1,296	—	—	2,592
	Jefferson	54,691	4,406	—	1,555	60,653
	Kleberg	—	4,666	—	—	4,666
	Matagorda	13,219	1,037	—	778	15,034
	Nueces	—	1,037	—	—	1,037
	Orange	10,368	3,629	—	7,258	21,254
	Refugio	1,555	1,555	—	—	3,110
	San Patricio	2,333	2,592	—	—	4,925
	Victoria	778	1,037	—	518	2,333
	Subtotal	158,112	31,882	0	16,330	206,323
Total Gulf of Mexico		**1,072,820**	**348,149**	**0**	**678,583**	**2,099,552**

Data converted to metric units from Alexander and others (1986, p. B4). Sums of some columns or rows may not exactly equal totals shown because of the conversion procedure and subsequent rounding.

Acknowledgments

The authors would like to thank Mark R. Byrnes, Randall Detro, George F. Hart, Philip B. Larimore, Klaus Meyer-Arendt, and Robert A. Morton for their technical reviews and comments of various chapters.

Historic maps presented in Chapter 2, and some of the historic maps digitized for Chapter 4, were provided by the Cartographic Information Center of the Department of Geography and Anthropology at Louisiana State University, and the assistance of Joyce N. Rolston, Map Librarian, is appreciated. Historic photographs were provided by the Louisiana Collection of the State Library, the Louisiana Department of Wildlife and Fisheries, the Biloxi Public Library, the Historic New Orleans Collection, the National Archives, the Smithsonian Institution, and Fonville Winans. Special thanks are extended to Mr. Bernard Davis and Mrs. William W. McMichael, who opened their family collections of photographs of events hitherto recorded only in written literature. The authors thank the knowledgeable and accommodating staffs of Hill Memorial Library and the Business Administration/Documents Department of Middleton Library, both of Louisiana State University; the Biloxi Public Library; the Historic New Orleans Collection; the National Archives; and the Smithsonian Institution for help in locating photographs, charts, maps, and textual and miscellaneous material related to the settlement history of Louisiana's coastal zone.

Computer support, including the invaluable technical advice of Farrell W. Jones, Systems Manager, was provided by the CADGIS Research Laboratory of Louisiana State University. We thank Mark R. Byrnes and Karen E. Ramsey for technical support and advice on personal-computer-based applications. Claudia C. Holland provided editorial assistance on early drafts of Chapter 4.

Numerous student assistants at the Louisiana Geological Survey contributed to production. Chris Copley, Rhonda Brewer, and Brian Savell assisted in digitizing and plotting coastal data in Chapter 4. Word processing for the atlas was done by Annetta Taylor, Eella Yokum, and Vanessa Burford. Cartographic assistance was provided by Matthew Morris, Peter Dufrene, Maria Marcello, and Lacey Picou, and editorial assistance by Paul Hebert.

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CONVERSION FACTORS

Measurements appearing in the text of the Atlas are generally given in metric units. Many of the illustrations and tables in the Atlas, however, are reprinted or only somewhat modified (with permission) from other published sources, some of which are copyrighted; therefore measurements in the cited material are presented in their original form. The following conversion table is provided to aid the reader in making conversions from metric to U.S. customary units and from U.S. customary to metric, as needed.

U.S. customary to metric units

Multiply	By	To obtain
inch (in)	2.54	centimeter (cm)
foot (ft	0.3048	meter (m)
yard (yd)	0.9144	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (sq mi *or* mi^2)	2.59	square kilometers (sq km *or* km^2)
acre	4,047	square meter (sq m *or* m^2)
acre	2.471	hectare (ha) (ha=10,000 m^2)
pound (lb)	453.592	grams (g)
ton	0.9072	metric tonne (t) (t=1,000 kg)
quart (qt)	0.9464	liter (L)
gallon (gal)	3.785	liter (L)
bushel (bu)	35.238	liter (L)
degree Fahrenheit (°F)	([1])	degree Celsius (°C)

Metric to U.S. customary units

centimeter (cm)	0.3937	inch (in)
meter (m)	3.28	foot (ft)
meter (m)	1.094	yard (yd)
kilometer (km)	0.6214	mile (mi)
square kilometer (sq km *or* m^2)	0.3861	square mile (sq mi *or* mi^2)
square meter (sq m or m^2)	10.764	square foot (sq ft *or* ft^2)
hectare (ha) (ha= 10,000 m^2)	0.4047	acre (a)
metric tonne (t)	1.102	ton
liter (L)	1.057	quart (qt)
liter (L)	0.264	gallon (gal)
liter (L)	0.284	bushel (bu)
degree Celsius (°C)	([2])	degree Fahrenheit (°F)

[1] Temp °F=1.8 K–459.67. [2] Temp °F=1.8 temp+32.

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849