FINAL REPORT

MISSISSIPPI COASTAL GEOLOGY

AND

REGIONAL MARINE STUDY

1990 - 1994

VOLUME 2

Mississippi Office of Geology / U. S. Geological Survey
Cooperative Agreement No. 14-08-0001-A0827

Submitted to:

U. S. Geological Survey
Center for Coastal Geology and Regional Marine Studies
600 4th Avenue, South
St. Petersburg, Florida 33701

by

Office of Geology
Mississippi Department of Environmental Quality
P. O. Box 20307
Jackson, Mississippi 39289-1307

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GEOLOGIC FRAMEWORK OF COASTAL HARRISON COUNTY AND MISSISSIPPI SOUND

by

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and

Ervin G. Otvos
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Introduction

Re-construction of the Mississippi Gulf Coast Pleistocene to Holocene geologic framework is a primary objective of the USGS/Mississippi Office of Geology cooperative study. Prior to the geologic framework analysis, a compilation of all previously published works on this subject was completed based on a preliminary list completed by Ervin Otvos in Year 1 of the study. This preliminary list was expanded considerably and published as Office of Geology Circular 5, "Bibliography of Mississippi Gulf Coast Geology and Related Topics" that is included as an attachment to this report. Pertinent publications from this bibliography were obtained by the Office of Geology.

Method of Investigation

Analysis of the framework geology began with the compilation of all previous core and drillhole information in the Mississippi Gulf Coast area. This was started by Ervin Otvos in Year 1 of the study. A total of 304 cores and drillholes were located in the coastal area of the mainland, the Mississippi Sound, bays, and the barrier islands. Most of these cores and drillholes are stored at the Gulf Coast Research Laboratory and are in various stages of analysis for descriptions, grainsizes, and foraminifer identifications. The data are in hard-copy form, and are in considerable disarray with regard to datums, locations, and detailed descriptions of the cores. Much of the core and drillhole information was then transferred in Year 2 to the Office of Geology

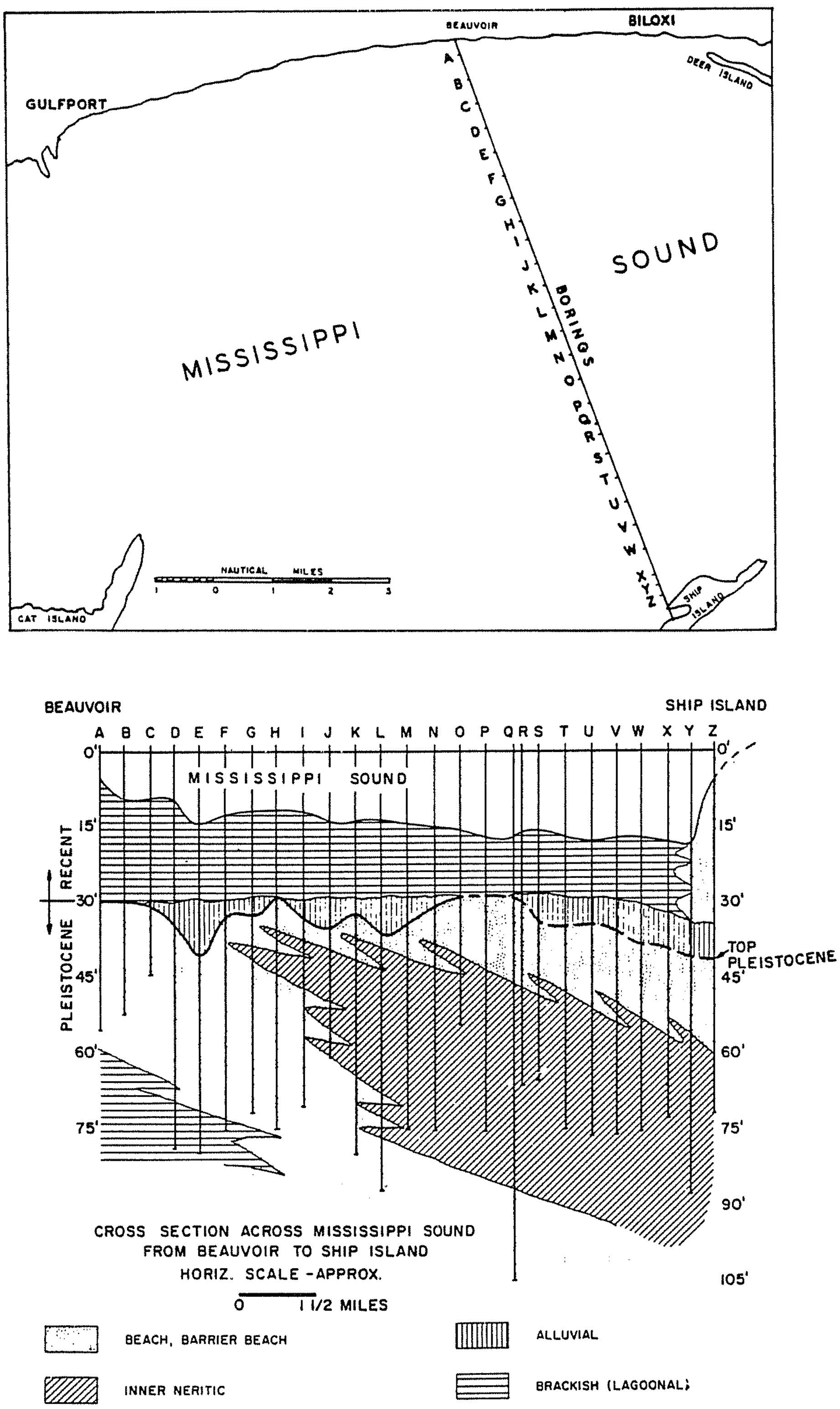

Figure 1. Late Pleistocene and Recent depositional environments between Beauvoir and Ship Island (from Rainwater, 1964)

for inclusion in our digital coastal core geological database. This database, when completed, will allow easy and accurate searching of the core data for future geologic investigations. The database is included as Appendix B.

Joint seismic cruises were conducted with the USGS in Years 1, 2, and 3 of the cooperative study. Seismic sections from these cruises were delivered to the Office of Geology for inclusion in the geologic framework analysis. The seismic lines collected during these cruises were located to intersect the core and drillhole locations identified previously to aid in identifying strata on the seismic sections. Additional seismic data were acquired in Year 3 of the study by the Office of Geology utilizing the digital seismic equipment of the Marine Minerals Technology Center deployed on the pontoon work boat built by the Office of Geology Coastal Section.

Dr. Ervin Otvos was contracted in Year 3 of the cooperative study to assist in interpreting seismic sections in the Harrison County portion of the Mississippi Sound and correlating them with core information in the area. Harrison County was chosen because it contained the most core information and the most dense seismic grid. Had the cooperative study continued for the anticipated 5-year duration, Jackson and Hancock counties would have been included in Year 4 to complete the geologic framework interpretation.

Previous Geologic Framework Interpretations

In 1954, Eustis Engineering Company drilled 22 borings in a line from Beauvoir on the mainland Mississippi coast to what is now East Ship Island in anticipation of construction of a causeway to the island. E. H. Rainwater analyzed the drill cuttings and published an interpretation of his findings (Rainwater, 1964) which included a description of the borings' lithologies and a cross-section depicting facies distribution along the line of the borings (Figure 1). While very limited in scope, this interpretation did recognize a Top of Pleistocene horizon based on weathering and several facies variations in the Pleistocene based on foraminifer assemblages. One of the seismic lines collected in Year 3 was oriented to track this old line of borings, and hopefully provide better control for the interpretation.

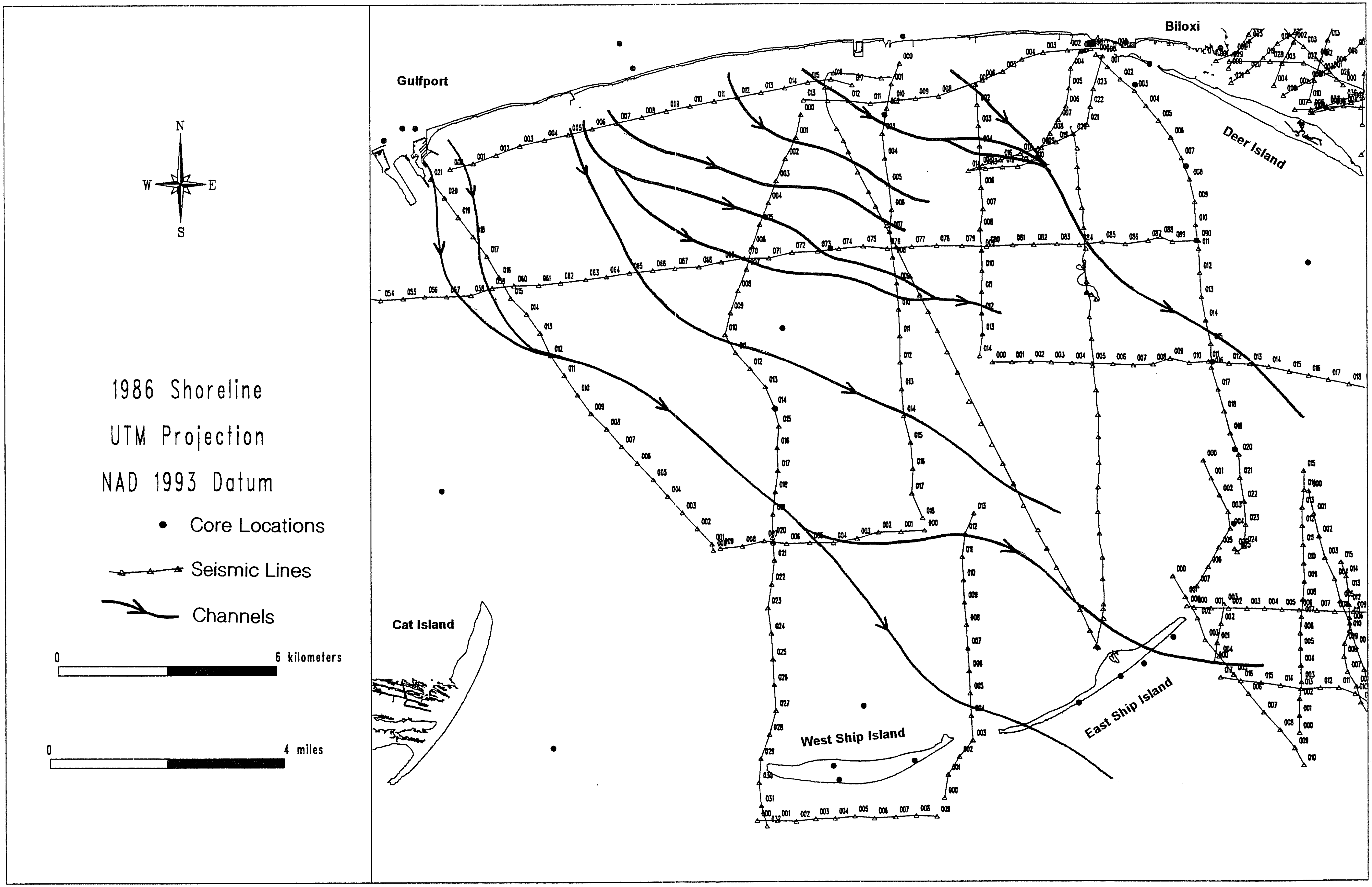

Figure 2. Neogene channel configuration in Harrison County, Mississippi Sound.

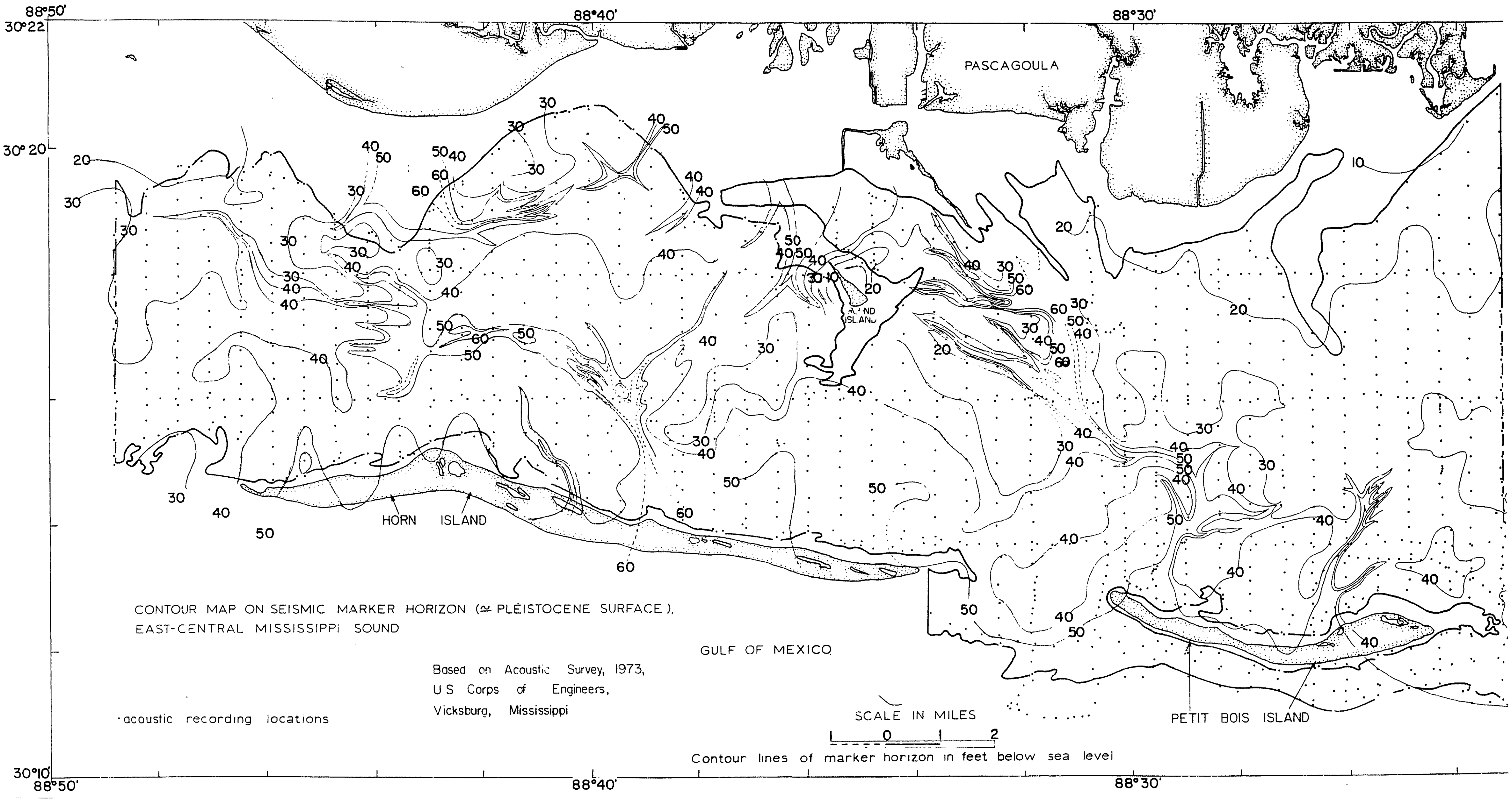

Figure 3. Contour map on Pleistocene marker horizon, East-Central Mississippi Sound (from Otvos, 1976).

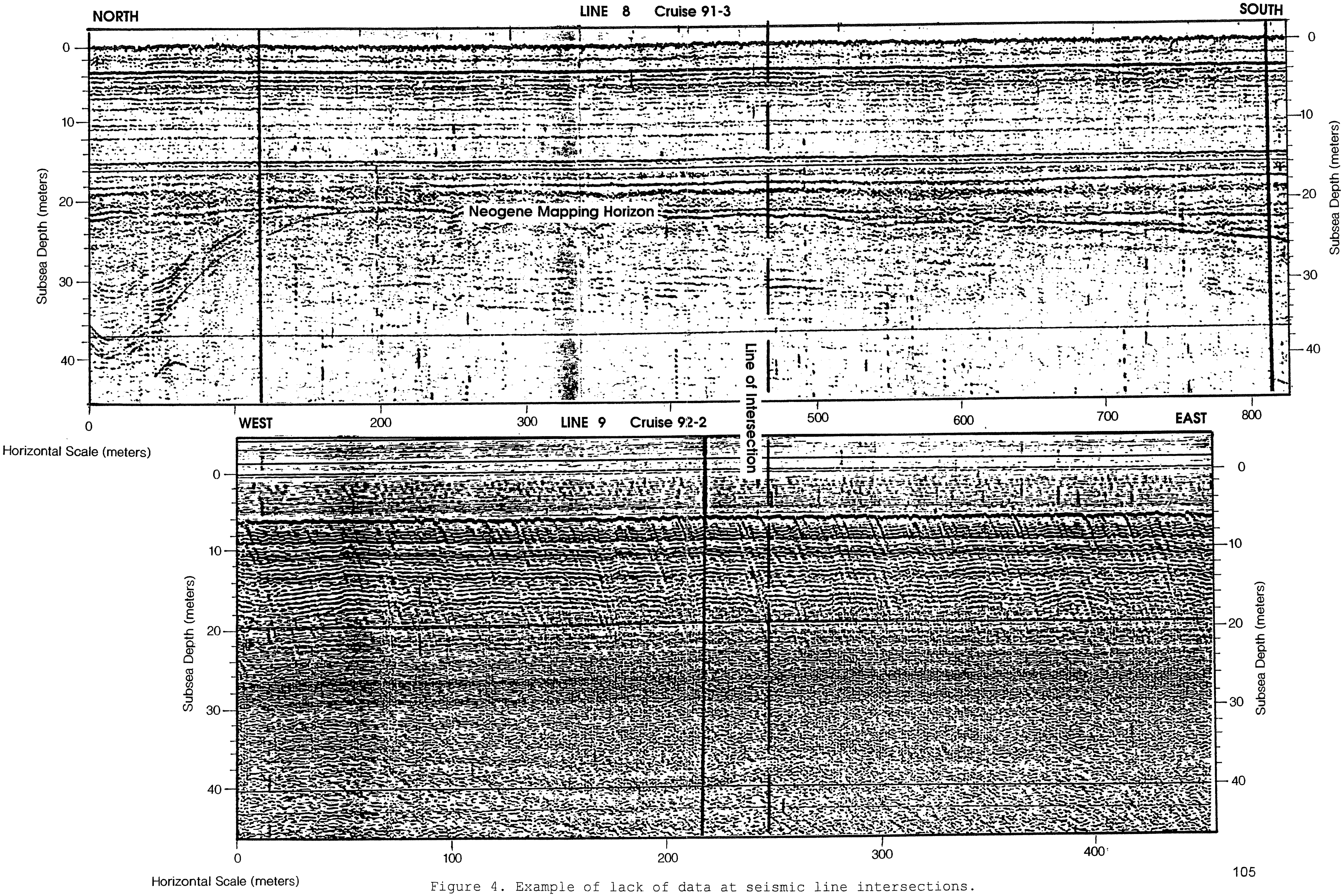

Figure 4. Example of lack of data at seismic line intersections.

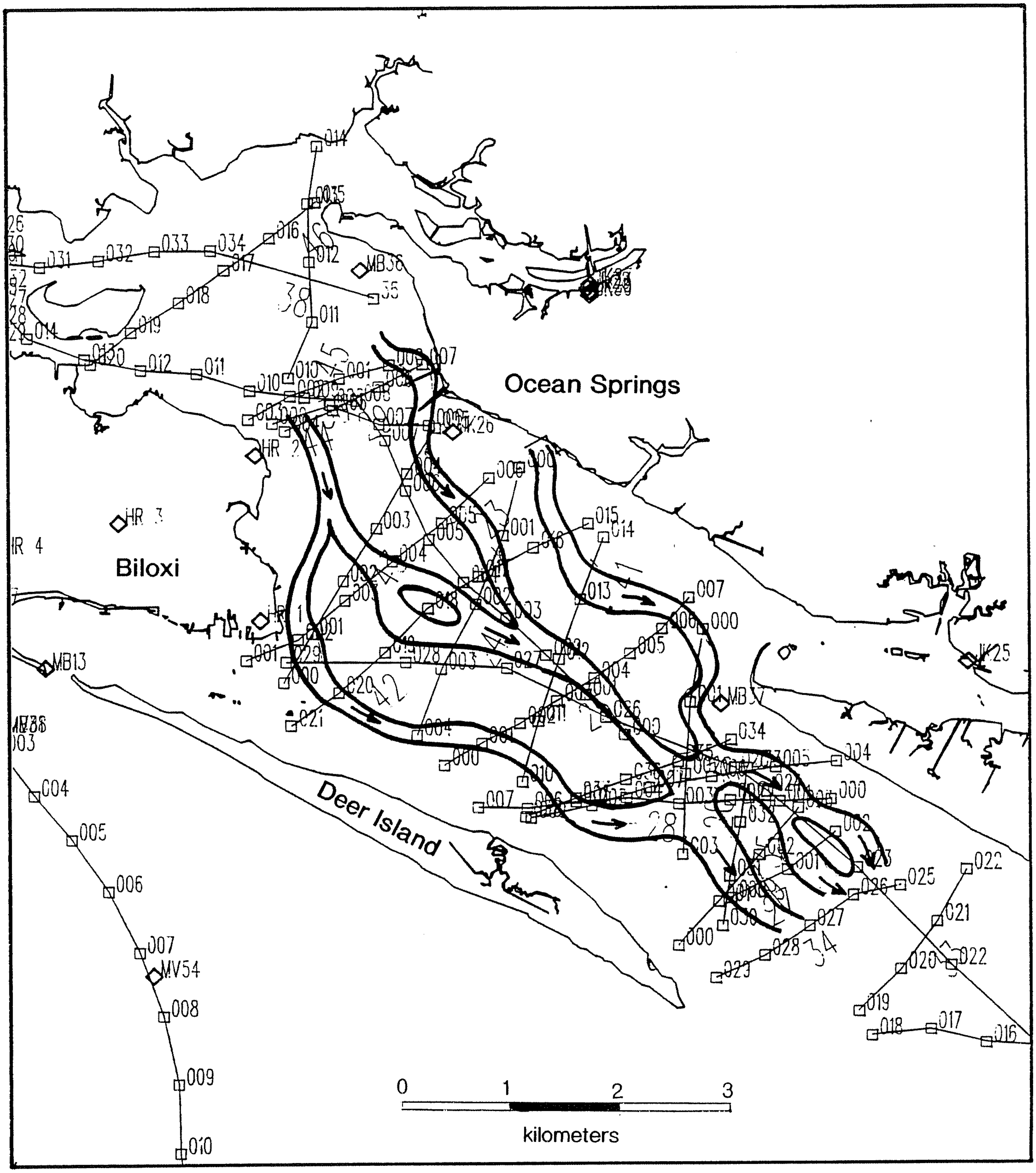

Figure 5. Channel configuration in Upper Pleistocene horizon, Biloxi Bay.

Interpretations and cross-sections involving many of the cores and drillholes included in Appendix B have been done by Ervin Otvos as part of a mineral resources study series for the Mississippi Minerals Resources Institute (Otvos, 1984, 1985a, 1986, 1991, and 1992). Drillhole and core interpretations from that study series were used to aid in the interpretation of seismic data for this report. A general overview of the geologic framework was also done by Otvos (1985b) in a guidebook for the AAPG annual meeting in New Orleans.

Interpretation of New Seismic Data

Seismic data was acquired during the course of this cooperative study in Years 1, 2, and 3 in the Mississippi Sound and the island passes. The data is of varying quality and depth penetration, and is generally not mappable on any single horizon for the entire length of a particular line. The only semi-mappable horizon recognized in the data with any regularity is a probable Neogene horizon which was highly dissected by Neogene fluvial channels during a previous low-stand of sea level. Due to the lack of seismic control density, a continuous map of the Neogene surface could not be made. Instead, a best guess is made as to the orientation of the channels in the Neogene surface and presented as a starting point for further investigations (Figure 2).

A map of the approximate Pleistocene/Holocene surface was done by Otvos (1976) using sparker data recorded by the U. S. Army Corps of Engineers between Horn and Petit Bois islands and the Jackson County mainland shoreline. That interpretation showed the incised fluvial surface resulting from the Biloxi and Pascagoula rivers acting on the Pleistocene exposure surface (Figure 3). A similar interpretation was originally planned for this Harrison County study, however, no reliable Upper Pleistocene marker horizon was found in the current data. That zone is masked by ringing of the data from surface multiples. Future seismic investigations using a weaker source might aid in delineating the Pleistocene surface, which is most likely highly dissected by fluvial activity as in the Neogene. Considering the probable complex nature of the Pleistocene streams in this area, a considerably denser grid would be required to make an accurate interpretation. The Holocene/Pleistocene contact is better recognized in cores and drillholes by its oxidized, exposure-surface appearance.

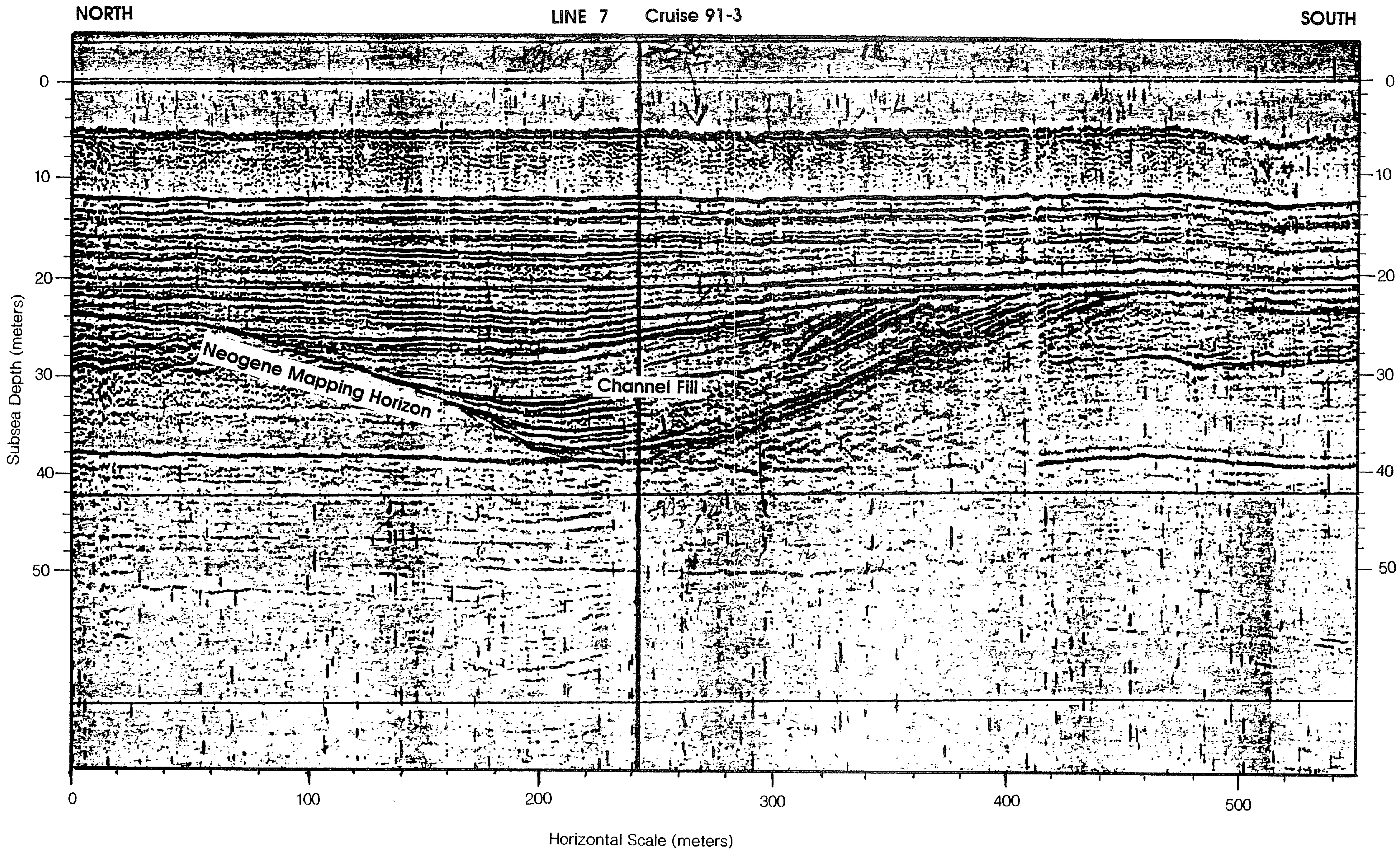

Figure 6. Migrating channel with point-bar fill.

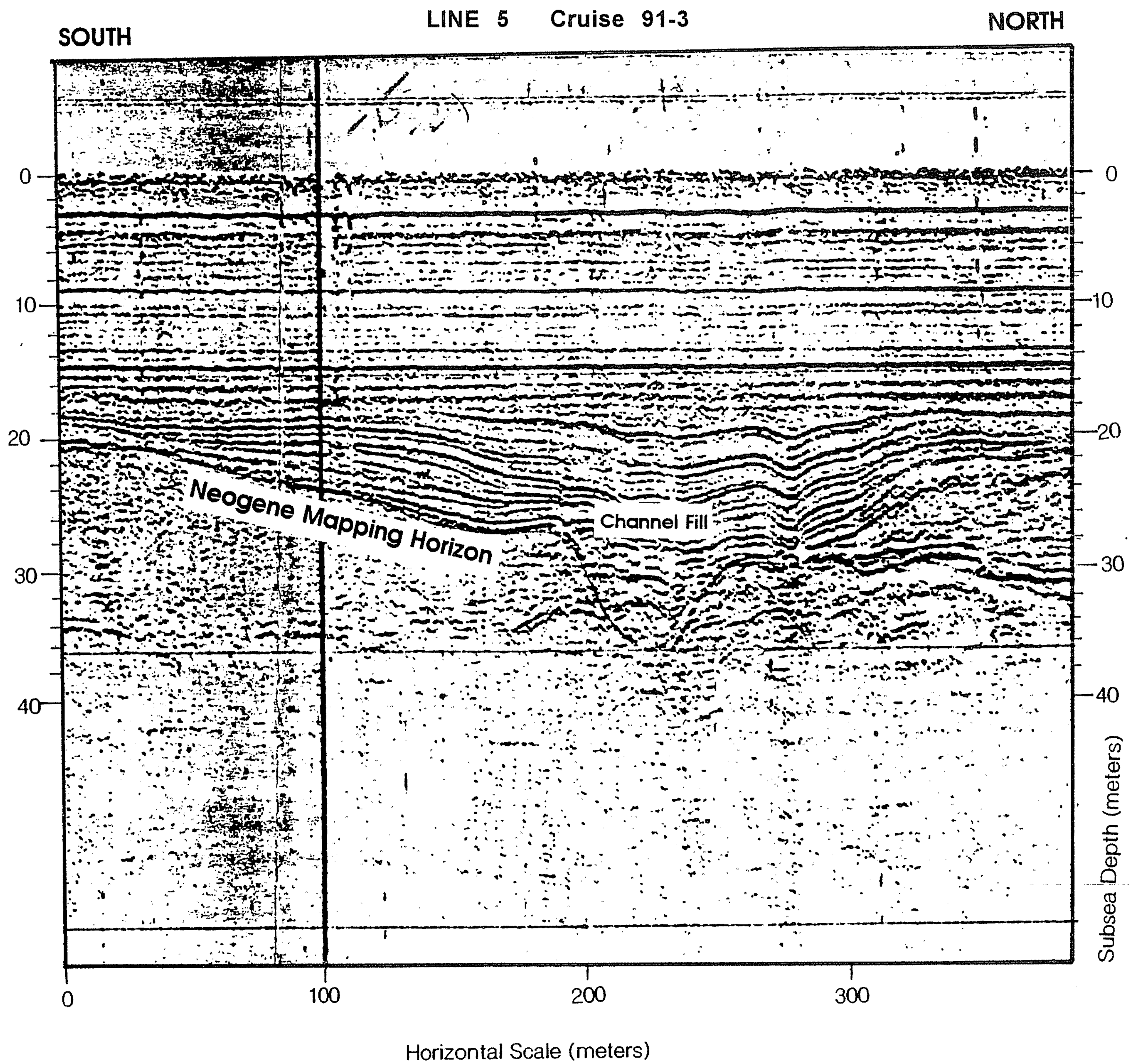

Figure 7. Abandoned channel fill.

The Neogene mapping horizon channel configuration shown in Figure 2 is not necessarily mapped on the same contiguous horizon. At numerous locations there was evidence of several channels cutting through a similar horizon at different times. There was considerable difficulty in tying individual seismic lines together with crossing lines due to poor data quality and discontinuous mapping horizons. An example of this is shown in Figure 4. Where channels are connected together in separate lines on the map, it is done to conform to an anticipated channel direction and pattern based on probable regional surface dip. Only in Biloxi Bay, where the seismic grid is quite dense, could reliable channel configurations be mapped (Figure 5).

Several channel configuration types are noted on the seismic data. The first is a simple, migratory channel cut into a previous surface and filled from one direction, probably by a point-bar system (Figure 6). The second is a deep, incised channel filled with parallel strata, probably as a result of channel abandonment (Figure 7). The third is a probable braided stream configuration, with numerous shallow channels incised in close proximity to each other (Figure 8). The fourth is a multiple, consecutive channel pattern, with several channels of sequential age cut into strata in the same general area (Figure 9). Variations of these patterns in all scales and crossing angles are found throughout the data at the Neogene horizon, adding to the difficulty of interpretation.

Year 3 MMTC Seismic Data

Seismic data were collected in Year 3 using the Marine Minerals Technology Center digital seismic equipment. The equipment was deployed on the pontoon boat built by the Office of Geology Coastal Section to allow data collection in very shallow water. Numerous variations of filtering and source configuration were tried to improve the data quality with no success. Most of the data suffer from the same masking of shallow horizons found in the USGS data. Weather during the seismic cruise was not conducive to operations in the Mississippi Sound during much of the cruise, so several attempts at data acquisition were made in the bays and rivers inland from the coast. These data suffered from side-reflection multiples which could not be overcome in most cases.

The data collected along the line of boreholes described by Rainwater (Figure 1) was not of sufficient quality to permit

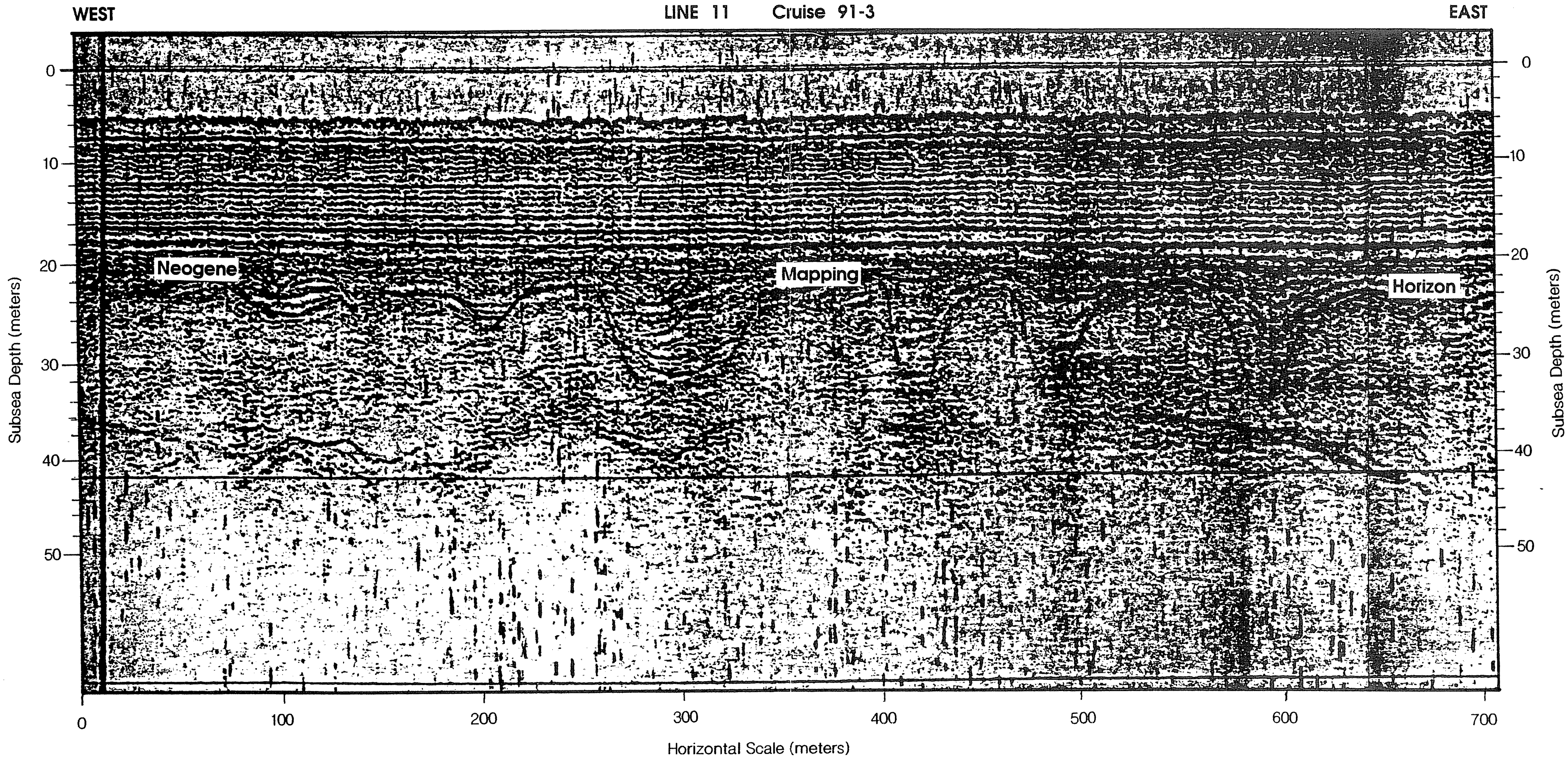

Figure 8. Braided stream channel pattern.

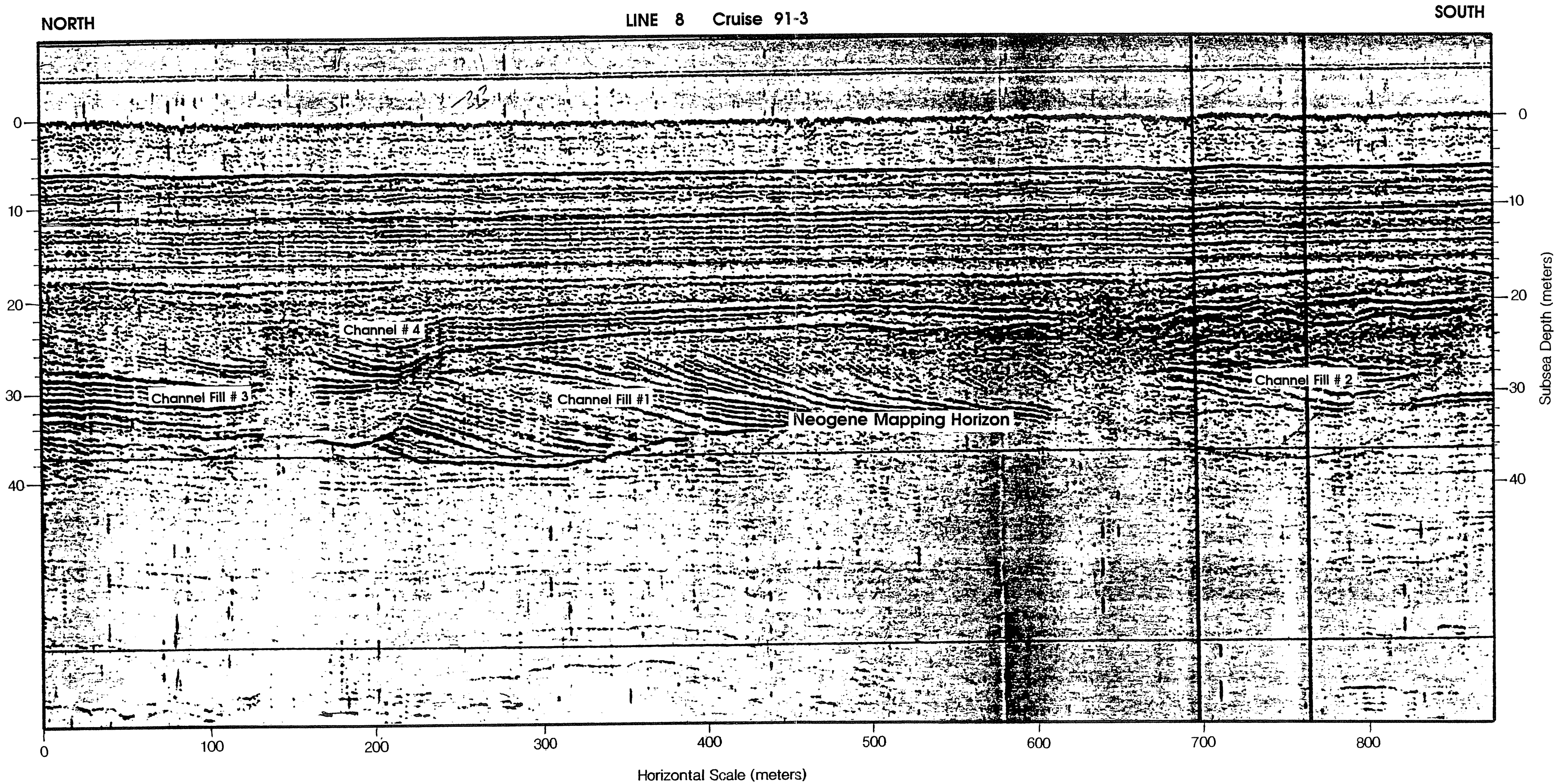

Figure 9. Sequential channel cut-and-fill pattern.

interpretation in the Holocene/Pleistocene horizon. This line did, however, allow interpretation of the channels in the Neogene horizon mapped in the other data.

Suggested Future Investigations

In order to interpret the Pleistocene/Holocene exposure surface and facies changes within the Holocene with seismic data, a better source and collection system is needed in the Mississippi Sound. A sparker source similar to that used by the U.S. Army Corps of Engineers should be tested. A good test for this would be the area just east of the Port of Gulfport as seen on Line 11 of the MS-91-3 cruise. It shows a complex pattern of anastomosing channels in the upper Neogene, which probably would also be present at the Pleistocene/Holocene surface in this area. There are several cores onshore to this area that reached the Pleistocene and would provide good ties to the subsurface data. A dense grid of lines, similar to that collected in Biloxi Bay would be required.

If future funding becomes available, the Office of Geology would welcome a joint project with the USGS to map the Holocene/Pleistocene surface with seismic in the Mississippi Sound.

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MISSISSIPPI SOUND BATHYMETRY

by

Stephen M. Oivanki

INTRODUCTION

Bathymetric data offshore of the Mississippi coast are published by the National Ocean and Atmospheric Administration (NOAA) as navigation charts and aids to mariners. These data are usually general in nature, and are updated infrequently. There is an ongoing program in the Mississippi Sound to dredge the shipping channels and the Intracoastal Waterway in order to maintain minimum navigation depths, and the NOAA charts seldom reflect these changes. The Office of Geology, as part of the storm monitoring segment of the USGS co-operative study, sought a way to efficiently and economically survey the bathymetry of the Mississippi Sound to record changes as a result of storm surge scour of the bottom. Most of the methods employed by NOAA are very costly, and time-consuming, and are more effective in deep water (the Mississippi Sound ranges from 3 to 20 feet deep).

SURVEY METHOD

The method developed for this study is relatively inexpensive, and can be used to survey a large area in a short amount of time. A Lowrance X-16 paper-chart depth recorder is deployed in an outboard work boat. The X-16 can be adjusted for bottom conditions (mud-sand-hard bottoms) and recording scale, and it is very durable in harsh weather conditions. Geographic position is measured with a Trimble Pathfinder GPS unit mounted in the boat. Accurate survey track lines are maintained utilizing a Trimble NavTrac GPS unit with pre-loaded waypoints for navigation. Through trial and error, it was found that reliable depth measurements (+/- 6 inches) could be recorded at a maximum speed of 20 knots with the boat on a plane in calm water.

The survey method measures the depth of water with the X-16 and the geographic position with the Pathfinder GPS. Numbered marks are recorded on the X-16 paper chart at periodic intervals during each survey traverse or any time an unusual depth change is observed, and a corresponding numbered waypoint is recorded on the

Pathfinder GPS. Traverses are made between the mainland and the barrier islands with approximately 1 kilometer between each traverse. Each traverse approaches the shores of the mainland and the barrier islands as close as possible, usually until the water depth reaches 3 feet on the recorder. The boat speed is maintained at 20 knots throughout the survey. Because this method uses a transducer fixed to the bottom of the boat instead of a trailing sonde, calm water is required to obtain a smooth bottom trace on the X-16. Wave heights over one foot have proved too rough for accurate results using this method.

Because the Mississippi shoreline is so accessible and developed, it is fairly easy to find reliable vertical datum marks along the shore, usually on the seawall. The marks are tied to the mean sea level leveling (1929 Vertical Datum) of the seawall by the U.S. Army Corps of Engineers. Permanent marker pilings are located offshore of the mainland Mississippi coast to mark the beginning of deep water as a warning to swimmers. Each of these pilings, located approximately every 500 feet along the shore is numbered for easy identification.

In order to tie each traverse to mean sea level, a base-line traverse is run parallel to the shoreline. The mean sea level bottom depth is surveyed near several of the pilings mentioned previously using a total station set up on Corps of Engineers vertical benchmarks on the seawall. The surveyed pilings are then flagged for maximum visibility. The base-line traverse is surveyed at 20 knots and numbered marks and waypoints are recorded at each marked piling. The location of the base-line traverse is designed to intersect each other traverse made perpendicular to the shore.

The base-line traverse depth is then adjusted to match the measured mean sea level depth at each piling as surveyed from the benchmarks. After all of the data have been transferred to the Office of Geology GIS in Arc/Info a plot is made of the waypoints recorded on the Pathfinder. Accuracy of these points is +/- 2 meters with differential corrections applied. Intersection points between each traverse and the base-line are located and marked on each X-16 paper chart. Each traverse is then adjusted to match the corrected base-line depth at the point of intersection. The corrected traverse depths are then entered into the GIS at the corresponding GPS waypoint to generate a bathymetric map relative to mean sea level.

By tying the entire survey to a mean sea level base-line, it is possible to maintain survey accuracy regardless of the tide level, which is constantly changing throughout the survey period. The base-line can be surveyed at any time prior to or after the main survey. Where there are no permanent pilings for reference, such as in portions of Hancock and Jackson counties, buoys are set and surveyed from shore to run the base-line. Because all of the traverses are tied to known geographic waypoints, the same traverse can be re-surveyed after a major storm to measure in detail any changes that may have occurred. Similarly, individual traverses can be checked periodically to update the survey and determine when a new survey is needed.

The Office of Geology Coastal Section maintains two complete bathymetric survey systems for deployment on the 22-foot and 17-foot Boston Whalers used by the Section. Using both boats, the entire Mississippi Sound can be surveyed in less than two weeks, weather permitting.

BATHYMETRIC SURVEY DATA

Two thirds of the Mississippi Sound have been surveyed at the time of this report. Hancock County and most of Harrison County have been completed. Unfortunately, high wind conditions and high waves throughout the summer field season of 1994 have prevented the completion of this project this year. The Office of Geology plans to complete the project as soon as weather conditions permit, and a bathymetric map of the Mississippi Sound will be delivered to the USGS when this is done.

A STATISTICAL CHARACTERIZATION OF SUSPENDED SEDIMENT IN MISSISSIPPI SOUND USING GRAVIMETRIC AND LIGHT TRANSMISSION INFORMATION

Final Report to the Mississippi Office of Geology

June 24, 1993

by

Scott P. Dinnel, Ph.D.
Center for Marine Science
University of Southern Mississippi

NOTE: This report is copied from the original with no editorial corrections

1. Introduction

Recent applications of satellite data have advanced circulation and transport studies in coastal and estuarine regions. Specifically the application of Advanced Very High Resolution Radiometer (AVHRR) data to quantify surface estuarine and coastal suspended sediment concentrations (Stumpf, 1987). The temporal and spatial resolution of AVHRR data makes it a valuable tool in remotely sensed estuarine research. It is anticipated that AVHRR data will be used in the Mississippi Sound region to produce synoptic quantization of surface suspended sediment concentrations that will allow the distribution, as well as, the fate of suspended sediment to be better understood.

Mississippi Sound is a coastal lagoon that encompasses the entire coastline of Mississippi and a portion of Alabama. It connects with extensive estuarine environments in both adjacent states, Louisiana and Alabama. The Sound is relatively large, approximately 2000 km^2, and shallow, average depth of 3 m. Previous use of satellite data in this region have mostly been descriptions of event forced suspended sediments distributions. Schroeder et al. (1985) describe the spatial extent of suspended sediment associated with cold-fronts in the Mississippi Sound and Mobile Bay regions; Rucker et al. (1990) report on riverine forcing in Mobile Bay; and Abston et al. (1987), and Dinnel et al. (1990), estimate riverine and cold-front derived suspended sediment transport in the Mobile Bay discharge.

To use AVHRR data in a quantitative and effective way in a region such as the Mississippi Sound there is a need for a statistical relationship between the remotely sensed information, such as AVHRR reflectance values, and ground truthed suspended sediment concentrations. Ground truthing suspended sediment concentrations requires spatial and temporal coverage to obtain a sufficient range of suspended sediment conditions. This spatial coverage could be performed by suspended sediment estimates derived from rapidly sampled light transmission data concurrent with AVHRR imagery. Yet before this ground truthing can be performed the statistical relationship between the suspended sediment concentrations and light transmission must be determined. This latter statistical relationship is the subject of this study.

There are four main sources of suspended sediments to the Mississippi Sound. Input via the local rivers, wind-wave resuspension and tidal resuspension of bottom sediments, and the transport from adjacent estuaries or inner shelf. Stumpf (1987) states that a single statistical relationship in a region with multiple suspended sediment sources leads to the greatest error in determining suspended sediment concentrations from satellite reflectance.

The original project objectives were two fold. First, to determine the statistical relationship between gravimetrically derived suspended sediment concentrations and light transmission for the various environmental and source conditions in the Mississippi Sound. And second, to determine if there are different statistical relationships between suspended sediment concentrations and light transmission among the major sources of suspended sediment.

The realized objectives were considerably qualified. A short field season due to funding delays and project duration limits forced a more reduced study than originally proposed. This report summarizes samples taken in the outflow regions of two rivers, the Pearl and the Pascagoula, both with large, direct discharge and sediment loading that affect the suspended sediment concentration distribution in the Mississippi Sound. These are coastal plain rivers that empty into the Sound at different locations, the Pascagoula in the central Sound, and the Pearl in the far western Sound (Figure 1). Each riverine outflow region was characterized to determine their respective suspended sediment concentration signatures during summer low flow conditions. This project does not characterize suspended sediment in Mississippi Sound from the Mobile River via the eastern entrances to the Mississippi Sound, or the suspended sediments resuspended during wind-wave events.

The statistical analysis of the modified field effort, two data acquisition surveys in the Pascagoula River outflow region, and one in the Pearl River outflow region, does allow some conclusions to be drawn. Based on the data collected, there is no statistical difference between the Pearl and the Pascagoula River relationships of light transmission and suspended particulate matter, or between the two surveys within the Pascagoula River outflow region. The limited data does not allow a predictive relationship between light transmission and gravimetrically determined suspended sediment concentration for these two river outflow regions under complete annual cycle river flow conditions as suspended sediment values were lower than those expected for high flow conditions.

2. Methods

Surface transmissometer values and surface water samples were taken at selected locations in two regions of the Mississippi Sound. In addition, transmissometer values were obtained at approximately 0.5 meter intervals through the water column at each station. The sample locations, the water bottle number and the transmissometer reading were recorded (see Appendix). Although suspended sediment concentration are desired, suspended particulate matter is the actual substance determined by the gravimetric procedure. This substance includes the actual suspended sediments and additional particles that would either interrupt light transmission or produce a reflectance. Gravimetric determination of particle concentration involves

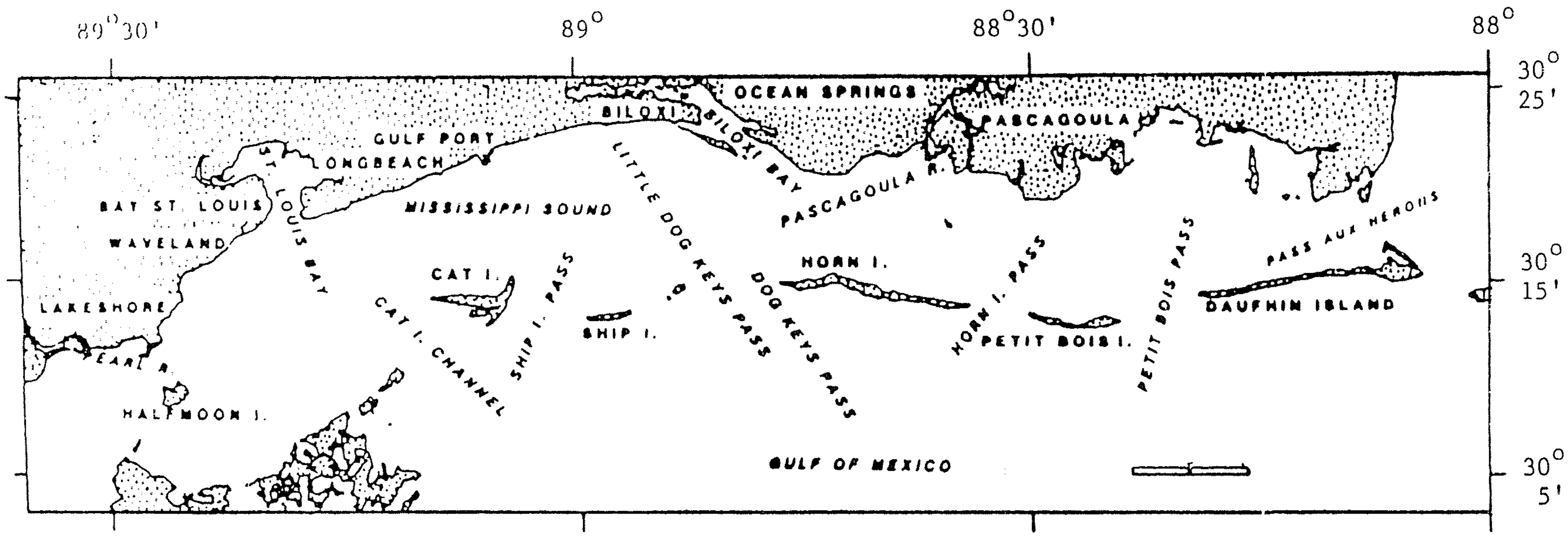

Figure 1. Location map of Mississippi Sound region.

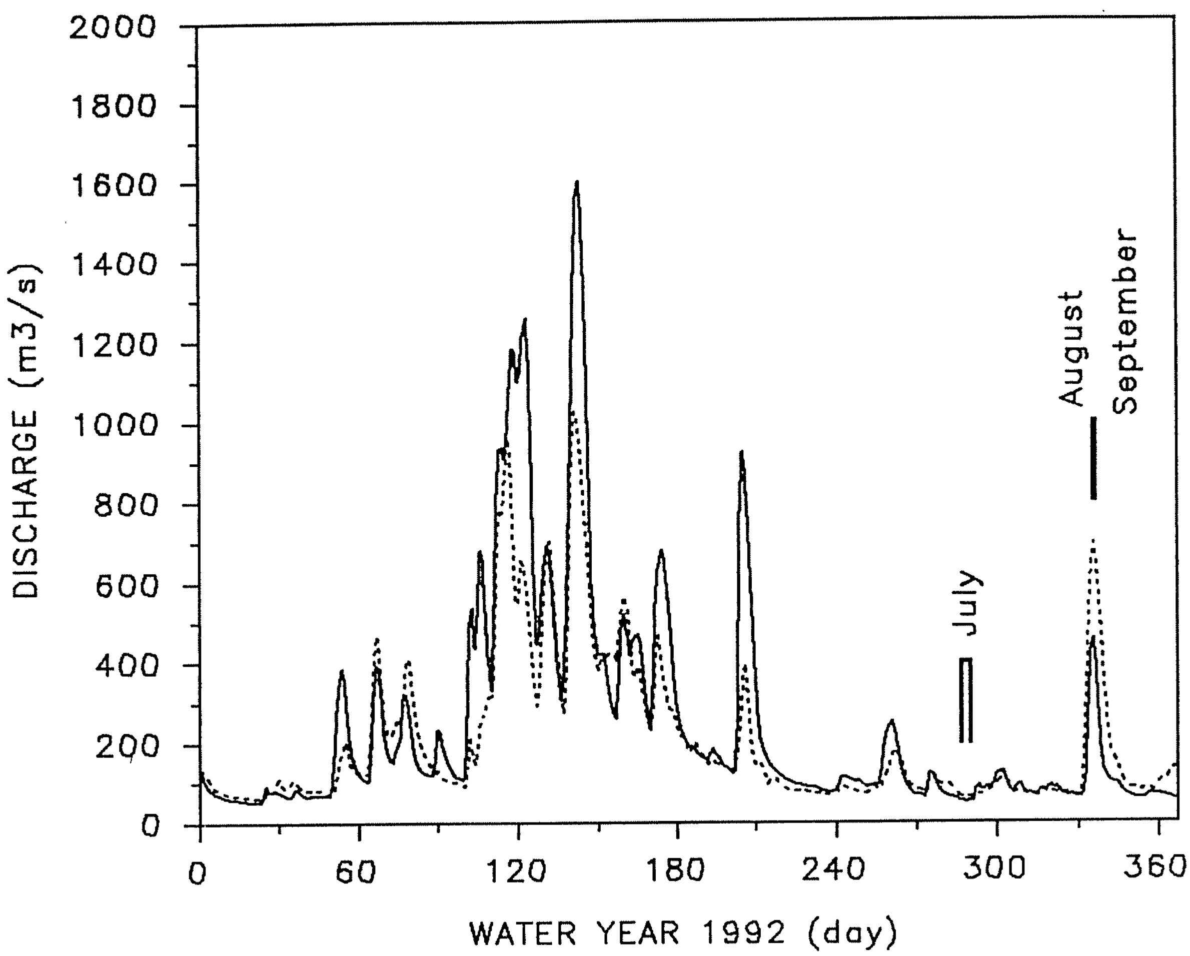

Figure 2. Hydrographs of 1992 water year discharge for Pascagoula River, Merrill MS (*solid line*), U.S. Department of the Interior, 1993a, and the Pearl River, Bogalusa, LA (*dashed line*), U.S. Department of the Interior, 1993b. The survey time periods are identified.

the filtering of the water sample in the laboratory and will be reported as suspended particulate matter (SPM).

Samples were taken during surveys of two river outflow regions. In the Pascagoula River outflow region, samples were taken in the Sound between Dog Keys Pass and Horn Island Pass and across to the mainland around the Pascagoula River mouth. Samples were collected during two periods in the Pascagoula River outflow region, the first period was over 13-16 July, the second period was 1 September. The second sampling region was the Pearl River outflow region. This sampled region covered the Sound from the Pearl River, east towards St. Louis Bay and Cat Island Channel. The Pearl River region was sampled only once, on 31 August.

Field Sampling Procedures

Field work was conducted by the Mississippi Office of Geology and performed using their coastal vessel.

Light transmission values were obtained using a Sea Tech Transmissometer with a 25 cm path length, that was on loan from Dr. Vernon Asper, USM Center for Marine Science, and readings were taken using equipment provided by the project. The transmissometer was deployed over the side of the Office of Geology coastal vessel and held horizontally so as to measure the surface water. The vertical dimension of the instrument and the required total immersion of the instrument, forced sample depths to range from 0.05 to 0.15 meters. These are referred to as surface light transmission sample depths. The light transmission value was read from a digital reading multimeter and recorded. The digital multimeter reading was the direct current voltage (DCV) returned from the transmissometer and is equivalent to the amount of transmitted (650 nm) light that is received by the instrument. This voltage ranges from 0 DCV, equivalent to no light transmission, to the free air value equivalent to 100% light transmission. The transmissometer was cleaned routinely so as to provide consistent free air values.

Surface water samples were obtained by filling 0.95 liter polyethylene bottles by hand at the surface.

The field sampling scheme was arranged so that a range in suspended particulate matter concentrations would be obtained for each field sampling effort. Stations were chosen with the idea that river-borne suspended sediment would be greatest at the surface near the river mouth and decrease in magnitude with distance from the river mouth. The sampling grid was arranged so that surface suspended sediment gradients would be covered.

River Flow conditions

The Pascagoula and Pearl River hydrographs for the 1992 water year are very similar (Figure 2). Spring freshet flow reached over 1000 m^3/s for both rivers, the threshold for flood conditions. Seasonal low flows are approximately 100

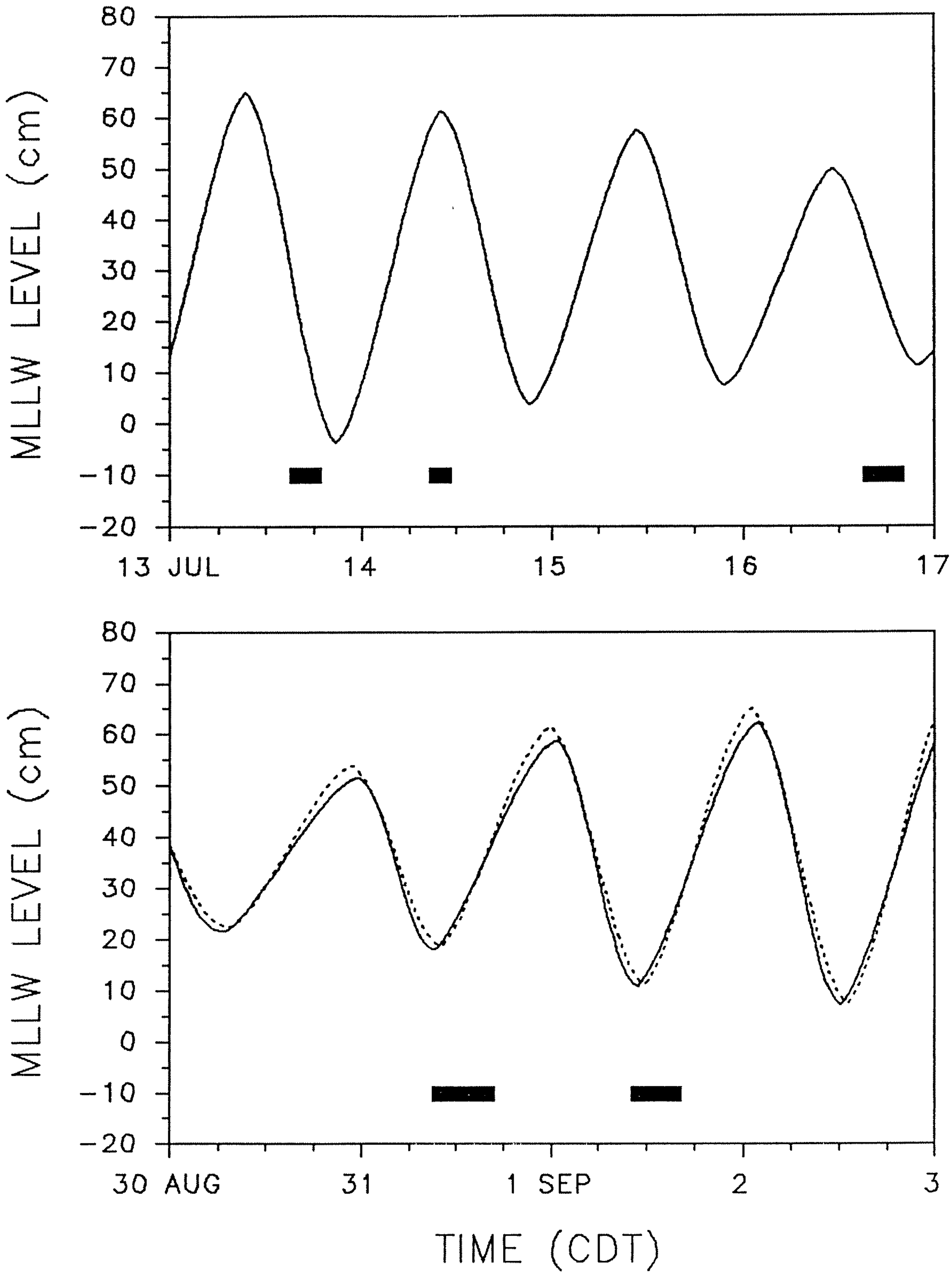

Figure 3. Predicted water level curves for the Mississippi Sound in the Pascagoula River outflow region (*upper*) for July 13-16 1992, and for the Mississippi Sound in the Pascagoula River (*solid line*) and Pearl River (*dashed line*) outflow regions for August 30 through September 2, 1992. The actual times when sampling was underway are identified. Water levels prediceted from U.S. Department of Commerce (1991).

m^3/s. The August/September surveys of the Pearl and the Pascagoula Rivers, respectively, coincided with modest river flow, ~500 m^3/s, runoff from local rain due to the Louisiana landfall of Hurricane Andrew.

Tidal Conditions

The tide in the Mississippi Sound have a low, maximum range, ~1 meter, and are highly diurnal (Seim et al., 1987). Predicted water level curves for time periods bracketing both field efforts are presented in Figure 3. The july survey of the pascagoula River outflow region was spread over four days due to severe thunderstorm activity. Ths samples are not synoptic in the sence of tidal conditions. The later surveys in August and September sampled under more consistent tidal conditions. Both surveys sampled after predicted low water and on the following flood tide.

Laboratory Determinations Procedures

The suspended particulate matter concentrations of each water sample was determined gravimetrically. Known volumes of individual water samples were filtered onto pre-weighed 0.45 micron membrane filters, the filters were then dried and reweighed. The suspended particulate matter concentrations were determined as the ratio of the filtered sediment weight to the volume of sampled filtered. Filters were weighed on a Mettler AE163 Balance; weights were determined to 10^{-5} grams.

Salinity of water samples obtained in August and September were determined using a Guildline benchtop AUTOSAL.

Statistical Analyses

The near logarithmic relationship between suspended particulate matter concentration and light transmission values allowed all the statistical analyses to be conducted between the common logarithm of the suspended particulate matter (LOGSPM) and the light transmission voltage (DCV). Linear regression analyses were performed between survey samples using the general linear model LOGSPM = A + B x DCV. Where B is the slope of the regression line that relates DCV to LOGSPM; this slope is of prime concern in these statistical analyses. The value A is the intercept of the regression line and is unimportant to the analyses as the independent variable has been transformed.

The hypothesis that individual correlation coefficients, r, were equal to zero, H_o:r=0, were evaluated with the student-t test for each sampled region. If the t-statistic falls within the critical region, using α=0.05 and n-2 degrees of freedom (where n is the number of samples), then the slope is not statistically different from zero. This result would not support a linear relationship between DCV

Table 1. Date, time, and station locations for surface suspended particulate matter concentrations (SPM), transmissometer value (DCV), and the common logarithm of the suspended particulate matter (LOGSPM) sampled in the Pascagoula River outflow region in July.

DATE	TIME	LAT	LONG	SPM (mg/l)	DCV (volts)	LOGSPM
7/13/92	1610	30.3307	88.7318	8.38	1.15	0.9232
7/13/92	1620	30.3157	88.7337	3.50	2.22	0.5441
7/13/92	1625	30.2998	88.7332	6.94	2.82	0.8414
7/13/92	1630	30.2823	88.7332	4.88	2.88	0.6884
7/13/92	1638	30.2660	88.7332	5.54	3.55	0.7435
7/13/92	1650	30.2495	88.7332	0.52*	2.88	-0.2840
7/13/92	1700	30.2670	88.6992	3.40	3.68	0.5315
7/13/92	1708	30.2838	88.6832	4.36	3.38	0.6395
7/13/92	1715	30.3007	88.6660	4.02	3.02	0.6042
7/13/92	1725	30.3167	88.6498	3.84	3.00	0.5843
7/13/92	1730	30.3340	88.6323	10.04	0.75	1.0017
7/13/92	1736	30.3465	88.6200	13.93	0.26	1.1440
7/14/92	0955	30.3708	88.6060	15.16	0.37	1.1807
7/14/92	1000	30.3660	88.6048	22.92	0.24	1.3602
7/14/92	1006	30.3535	88.6032	37.24	0.02	1.5710
7/14/92	1012	30.3327	88.5997	18.72	0.23	1.2723
7/14/92	1022	30.3162	88.5998	17.12	0.95	1.2335
7/16/92	1643	30.3335	88.5995	14.08	0.42	1.1486
7/16/92	1653	30.3162	88.6002	24.40	0.17	1.3874
7/16/92	1658	30.2993	88.6002	13.45	0.69	1.1287
7/16/92	1706	30.2827	88.6000	11.12	1.09	1.0461
7/16/92	----	30.2660	88.5998	5.25	1.60	0.7202
7/16/92	1718	30.2492	88.5998	6.26	2.08	0.7966
7/16/92	1725	30.2323	88.6000	3.32	2.27	0.5211
7/16/92	1736	30.2340	88.5488	1.98	2.01	0.2967
7/16/92	1742	30.2505	88.5500	12.24	0.93	1.0878
7/16/92	1747	30.2567	88.5507	8.24	0.94	0.9159
7/16/92	1751	30.2687	88.5500	18.34	0.64	1.2634
7/16/92	1757	30.2835	88.5500	15.95	0.55	1.2028
7/16/92	1802	30.3005	88.5500	28.48	0.26	1.4545
7/16/92	1900	30.3208	88.5593	54.00	0.04	1.7324

* denotes values not included in regression analyses

Table 2. Date, time, and station locations for surface salinity, suspended particulate matter concentrations (SPM), transmissometer value (DCV), and the common logarithm of the suspended particulate matter (LOGSPM) sampled in the Pearl River outflow region in August.

DATE	TIME	LAT	LONG	SALINITY (ppt)	SPM (mg/l)	DCV (volts)	LOGSPM
8/31/92	1049	30.1835	89.5248	1.8	10.75	0.40	1.0314
8/31/92	1101	30.1661	89.5169	4.6	18.77	0.83	1.2734
8/31/92	1106	30.1636	89.5154	5.9	8.03	1.33	0.9049
8/31/92	1111	30.1494	89.5081	8.1	10.04	2.31	1.0017
8/31/92	1118	30.1330	89.4998	9.9	5.30	2.46	0.7243
8/31/92	1124	30.1162	89.4912	10.1	2.94	2.71	0.4683
8/31/92	1130	30.0997	89.4833	12.1	5.98	2.66	0.7767
8/31/92	1139	30.1000	89.4498	12.5	5.06	2.50	0.7042
8/31/92	1147	30.1000	89.4163	12.1	5.14	2.58	0.7110
8/31/92	1155	30.0999	89.3829	12.4	6.76	2.15	0.8299
8/31/92	1205	30.1168	89.3498	13.9	4.80	1.53	0.6812
8/31/92	1217	30.1334	89.3165	14.4	7.70	1.50	0.8865
8/31/92	1227	30.1502	89.2800	15.0	9.40	1.59	0.9731
8/31/92	1308	30.1835	89.3001	14.0	7.00	1.85	0.8451
8/31/92	1316	30.2169	89.3163	12.1	8.42	2.04	0.9253
8/31/92	1323	30.2329	89.3506	11.7	6.96	2.10	0.8426
8/31/92	1329	30.2501	89.3838	12.4	6.06	1.99	0.7825
8/31/92	1339	30.2166	89.4167	11.3	4.32	1.74	0.6355
8/31/92	1349	30.1822	89.4018	9.0	6.55	2.05	0.8162
8/31/92	1400	30.1499	89.3833	12.5	10.02	2.02	1.0009
8/31/92	1410	30.1166	89.3666	12.7	9.04	2.18	0.9562
8/31/92	1419	30.0831	89.3499	13.6	7.56	2.22	0.8785
8/31/92	1445	30.1667	89.2831	15.1	15.84	1.58	1.1998
8/31/92	1453	30.1667	89.3169	13.5	7.76	1.63	0.8899
8/31/92	1459	30.1667	89.3504	12.2	4.70	2.14	0.6721
8/31/92	1505	30.1667	89.3835	11.0	4.96	2.48	0.6955
8/31/92	1513	30.1667	89.4170	10.1	7.82	2.74	0.8932
8/31/92	1520	30.1669	89.4505	7.9	10.06	1.89	1.0026
8/31/92	1528	30.1667	89.4841	6.6	8.09	1.54	0.9079
8/31/92	1534	30.1668	89.5169	2.1	17.04	0.41	1.2315
8/31/92	1542	30.1667	89.5503	7.4	1.74*	1.51	0.2405

* denotes values not included in regression analyses

Table 3. Date, time, and station locations for surface salinity, suspended particulate matter concentrations (SPM), transmissometer value (DCV), and the common logarithm of the suspended particulate matter (LOGSPM) sampled in the Pascagoula River outflow region in September.

DATE	TIME	LAT	LONG	SALINITY (ppt)	SPM (mg/l)	DCV (volts)	LOGSPM
9/1/92	1133	30.3337	88.5505	24.4	8.22	1.47	0.9149
9/1/92	1140	30.3166	88.5501	19.4	21.44	1.44	1.3312
9/1/92	1147	30.2999	88.5501	25.2	28.46	0.58	1.4542
9/1/92	1152	30.2833	88.5500	27.4	14.78	0.50	1.1697
9/1/92	1159	30.2666	88.5501	27.0	13.56	1.75	1.1323
9/1/92	1205	30.2498	88.5502	27.2	12.66	2.10	1.1024
9/1/92	1211	30.2332	88.5499	27.1	13.06	1.33	1.1159
9/1/92	1217	30.2165	88.5501	26.9	15.94	1.24	1.2025
9/1/92	1306	30.2331	88.6004	25.1	9.60	2.86	0.9823
9/1/92	1314	30.2502	88.6000	25.8	13.64	1.33	1.1348
9/1/92	1319	30.2669	88.6001	12.6	18.52	0.92	1.2676
9/1/92	1324	30.2835	88.5999	23.2	14.26	0.82	1.1541
9/1/92	1330	30.3002	88.6000	24.0	8.42	1.00	0.9253
9/1/92	1335	30.3168	88.6002	22.1	11.32	0.80	1.0538
9/1/92	1340	30.3337	88.6000	19.0	13.18	0.79	1.1199
9/1/92	1346	30.3415	88.6012	12.8	14.05	0.64	1.1477
9/1/92	1403	30.3668	88.6051	3.7	5.26*	0.27	0.7207
9/1/92	1410	30.3833	88.6079	1.9	24.27	0.11	1.3850
9/1/92	1427	30.3304	88.6298	22.4	23.64	0.17	1.3736
9/1/92	1441	30.3000	88.6665	23.6	17.34	1.51	1.2390
9/1/92	1434	30.3166	88.6503	21.4	11.84	1.12	1.0734
9/1/92	1448	30.2833	88.6832	25.2	11.38	1.58	1.0561
9/1/92	1455	30.2667	88.6998	26.1	4.88	2.51	0.6884
9/1/92	1505	30.2665	88.7336	26.8	8.60	2.37	0.9345
9/1/92	1511	30.2831	88.7339	25.1	17.60	1.85	1.2455
9/1/92	1517	30.2983	88.7335	22.4	37.88	0.20	1.5784
9/1/92	1522	30.3168	88.7336	19.4	70.71	0.012	1.8495
9/1/92	1528	30.3334	88.7328	19.5	30.13	0.11	1.4789
9/1/92	1537	30.3217	88.7078	17.3	41.10	0.22	1.6138
9/1/92	1540	30.3206	88.7052	17.6	15.12	0.55	1.1796
9/1/92	1548	30.3124	88.6674	21.6	8.78	1.15	0.9435
9/1/92	1556	30.3064	88.6674	23.5	14.64	1.18	1.1655

* denotes values not included in regression analyses

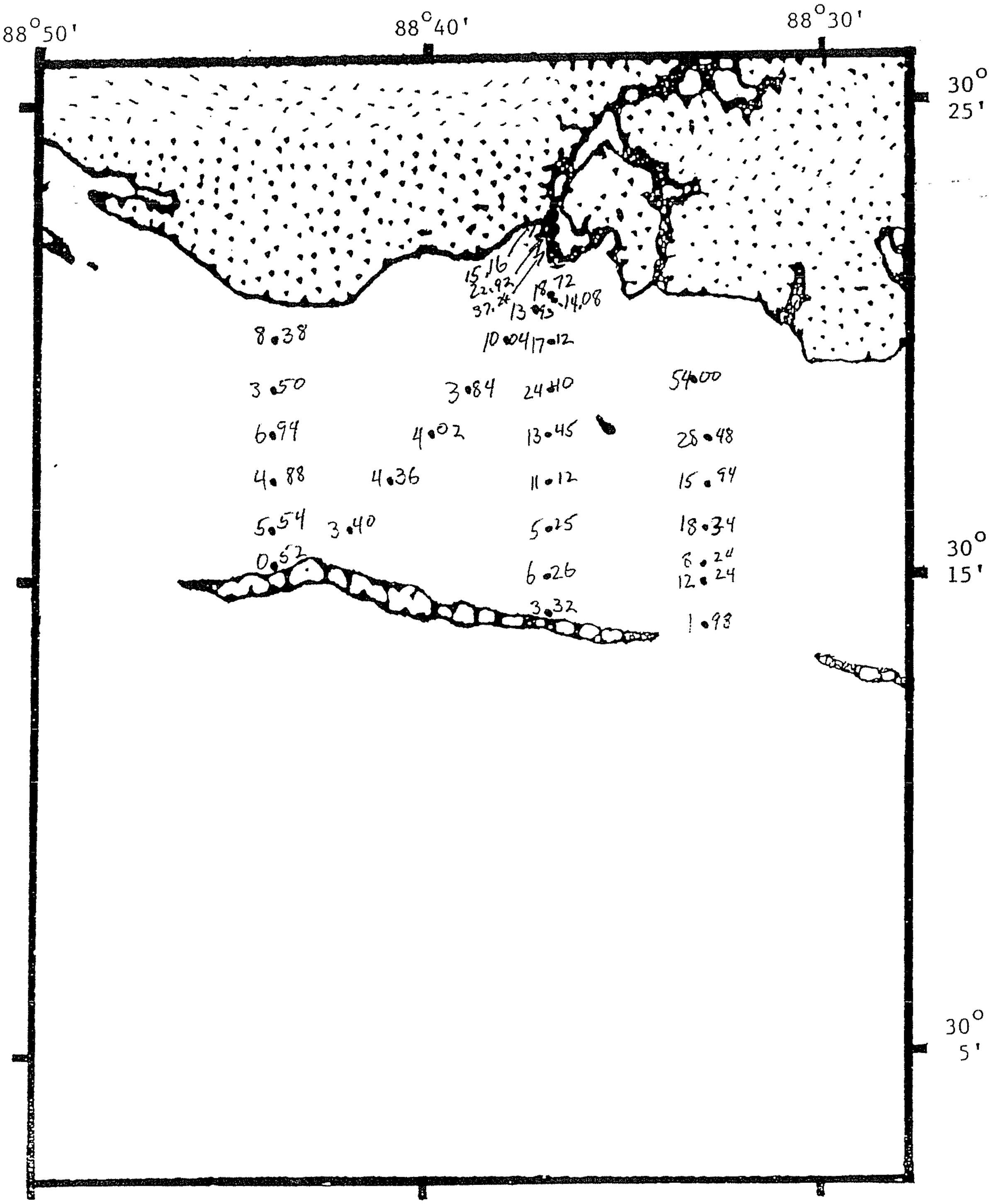

Figure 4. Distribution of surface suspended particulate matter for the July 1992 survey of the Pascagoula River outflow region. Values are in mg/l.

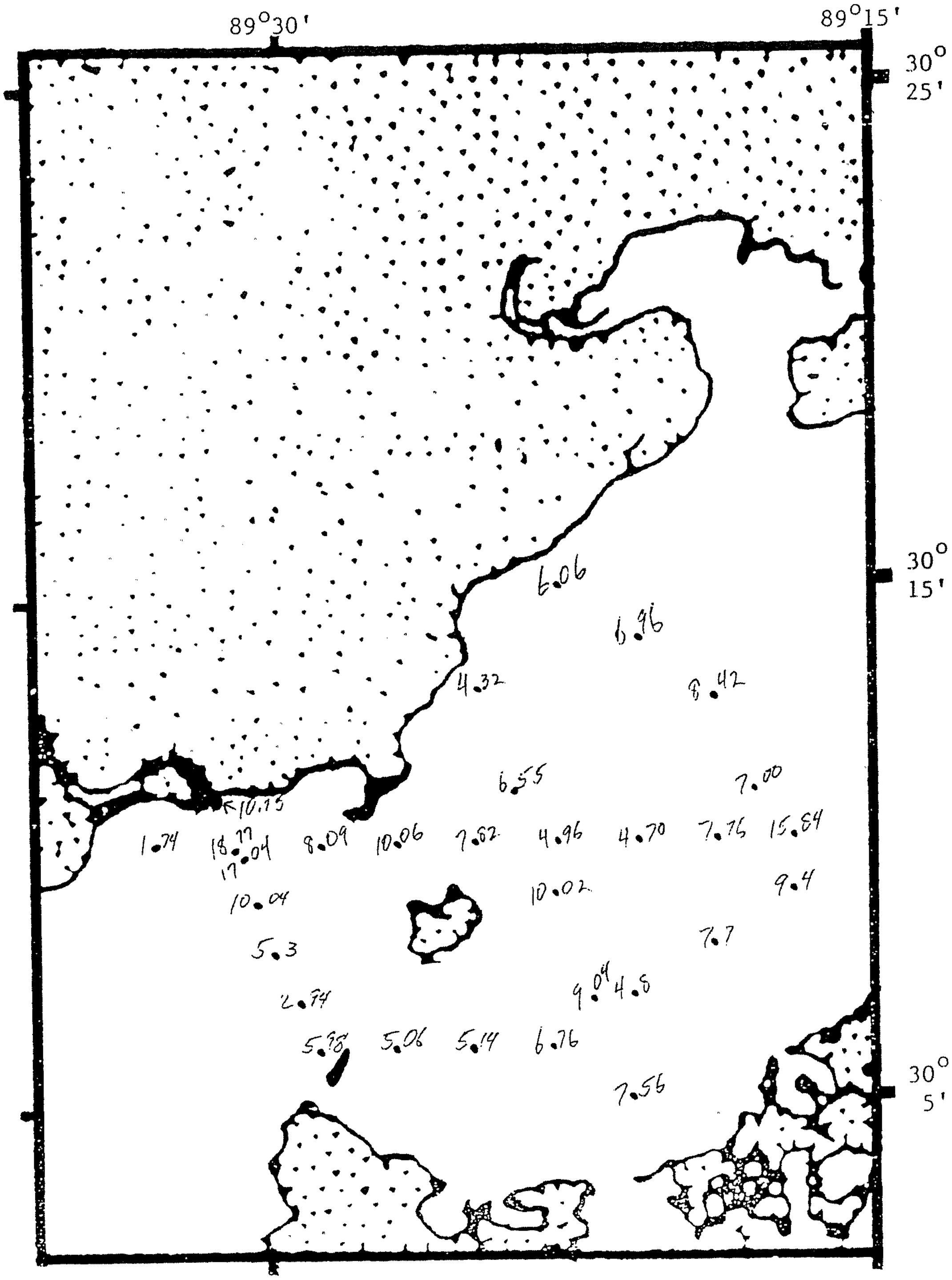

Figure 5. Distribution of surface suspended particulate matter for the August 1992 survey of the Pearl River outflow region. Values are in mg/l.

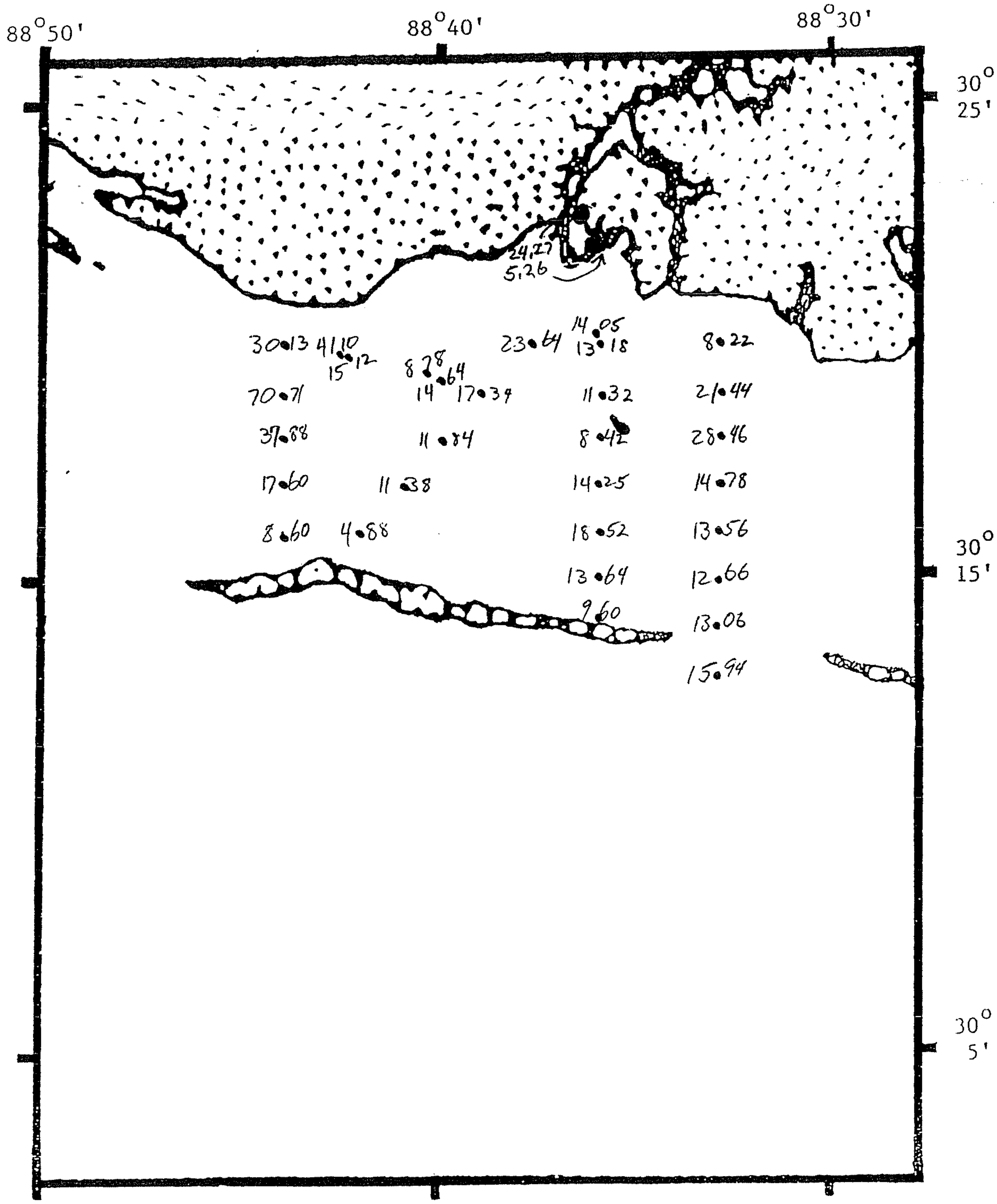

Figure 6. Distribution of surface suspended particulate matter for the September 1992 survey of the Pascagoula River outflow region. Values are in mg/l.

and LOGSPM. It is expected that a relationship does exist, that regression line slopes do not equal zero. If so, the t-statistic will lie outside the critical region.

Pair-wise regression analyses compared regression slopes between individual sampled regions or times. The hypothesis tested is $H_0:B_i-B_j=0$. Where B is the slope of the regression line, and i and j refer to either different regions or survey times. If the slopes are the same, that the relationship between LOGSPM and DCV is the same, the pair-wise student-t statistic would lie within the critical region (at the α=0.05 level). If the relationship is not the same, that there are different slopes, the t-statistic would lie outside the critical region.

Statistical testes followed Steele and Torrie (1980) and were computed at the 95% significance level.

3. Results

Distributions of SPM

Surface suspended particle matter concentrations and transmissometer values are reported in Tables 1-3 for the field samples from the Pascagoula River region in July, the Pearl River region in August and the Pascagoula River region in September, respectively.

Figures 4,5,6, present distribution maps of surface suspended particulate matter concentrations for the field samples from the Pascagoula River region in July, the Pearl River region in August and the Pascagoula River region in September, respectively.

Generally the highest concentrations of surface SPM occurred near the Pascagoula River mouth and between the river mouth and Petit Bois Pass in July (Figure 4). River mouth samples were not substantially higher than individual values sampled in the region. The multiple day collection of these samples does not allow the interpretation of these surface sediment concentrations in a synoptic analysis.

The Pearl River surface SPM distribution also has some of the higher concentrations near the river mouth (Figure 5). Again, individual concentrations at various locations are of the same magnitude. Even though the hydrograph of the Pearl River suggests increased flow, and the associated increased SPM concentrations, there still maybe a lag of a day or two before the peak flow (and peak SPM concentrations) reach the river's mouth from the upriver gauging station.

The September sampling of the Pascagoula River outflow region has higher SPM concentrations than the July sampling period (Figure 6). Although the sampling was performed over one afternoon, the spatial variation of individual SPM values is higher than expected.

Statistical Analyses

Scatter plots of transmission voltage versus SPM, and transmission voltage versus LOGSPM, are presented for the field samples from the Pascagoula River region in July (Figure 7), the Pearl River region in August (Figure 8) and the Pascagoula River region in September (Figure 9). All three surveys show some range of sampled SPM concentrations, yet there are few concentrations above 50 mg/l. The expected concentration range for the Pascagoula and Pearl Rivers is 10 to 100 mg/l over the spectrum of river flow conditions throughout the water year. In all, less than 6% of the sampled values had concentrations above 35 mg/l. This was due to the relatively low flow conditions that prevailed during the surveys.

It is observed that both surveys of the Pascagoula River outflow region had higher SPM concentrations that the Pearl River outflow survey.

Individual survey scatter plots of light transmission versus the log of SPM indicate inverse linear relationships. That, in general, the light transmission decreases as LOGSPM increases, this is expected. In all three surveys a large portion (~50%) of the samples fall outside the 95% confidence interval about the regression lines. This could be the result of a variety of possible errors; spatial or temporal sampling inconsistences between the water sample acquisition and the light transmission determination or as laboratory errors in the weighing or filtering procedures.

In all three surveys the slope of the correlation coefficients are statistically different from zero (Table 4). This means that there is a linear relationship between the light transmission and LOGSPM; if r is different from zero, then this implies that the slopes of the regression lines are statistically different from zero. The correlation coefficient values for all three surveys indicate substantial errors in the relationship. The square of the correlation coefficient is equivalent to the amount of variance describes by the linear relationships. The two Pascagoula River surveys had higher portions of explained variance than the Pearl River survey; only 65% (July) and 50% (September) of the variance in LOGSPM was accounted for by the light transmission, respectively, only 42% of the variance was accounted for in the (August) Pearl River survey.

The test of individual survey relationships (slope of the regression line) between light transmission and LOGSPM was performed between all combinations of survey pairings. Results form the pair-wise t-test are presented in Table 5. This tested the hypothesis that there was not a difference between regression slopes, in each survey pairing this hypothesis was accepted at the 95% confidence level. None of the computed t-statistics fell outside the critical region. This means that at the 95% level there is no difference between the light transmission and LOGSPM relationships

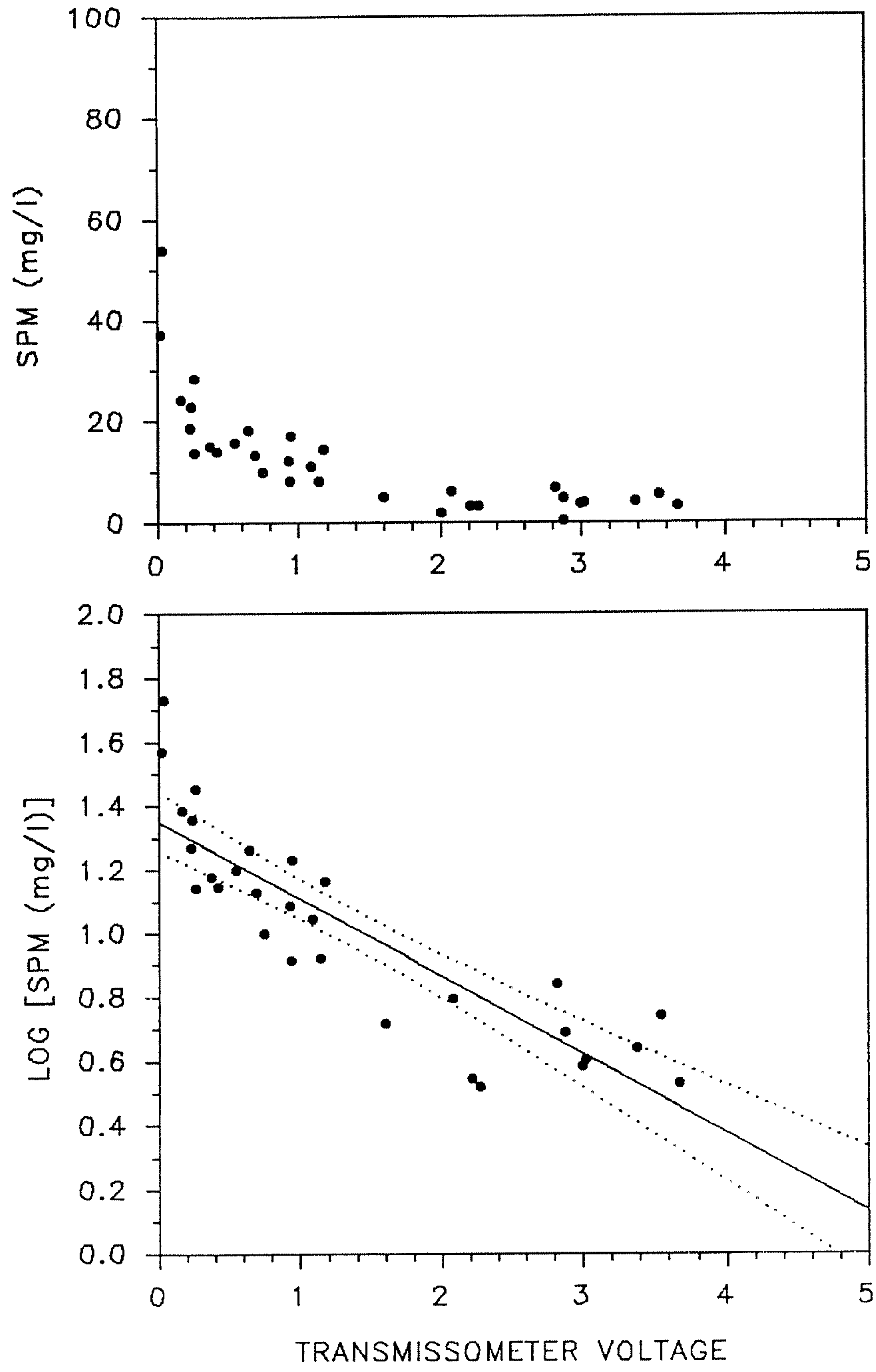

Figure 7. Plot of transmission voltage versus SPM (*upper*), and tranmission voltage versus LOGSPM (*lower*) for the field samples from the Pascagoula River outflow region in July 1992. The regression line, LOGSPM = 1.3504 - 0.2435DCV, the 95% confidence intervals, and the r value of 0.8759 were computed using 30 values.

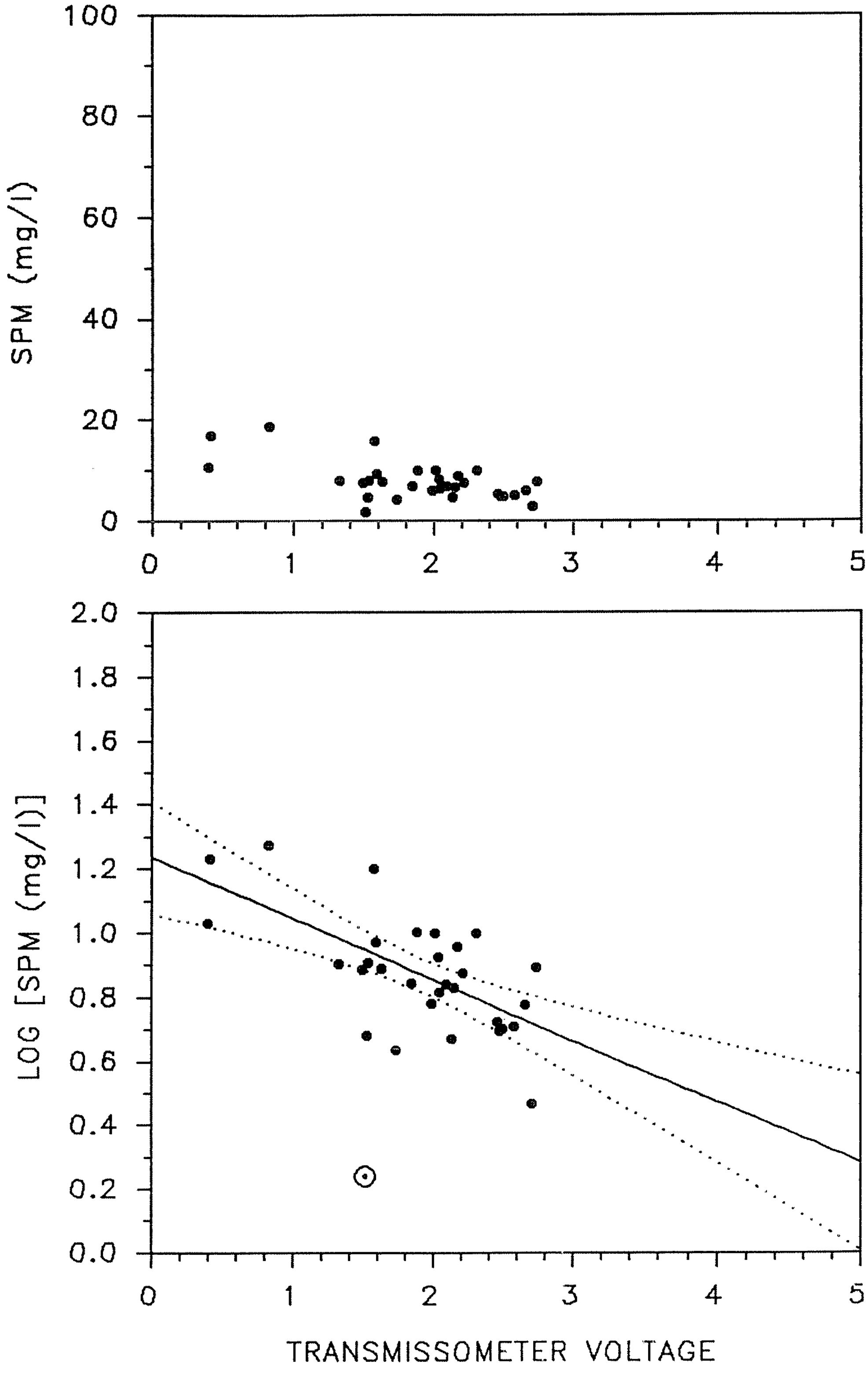

Figure 8. Plot of transmission voltage versus SPM (*upper*), and tranmission voltage versus LOGSPM (*lower*) for the field samples from the Pearl River outflow region in August 1992. The regression line, LOGSPM = 1.2345 - 0.1906DCV, the 95% confidence intervals, and the r value of 0.6475 were computed using 30 values. Data values not used in the regression are identified as ⊙.

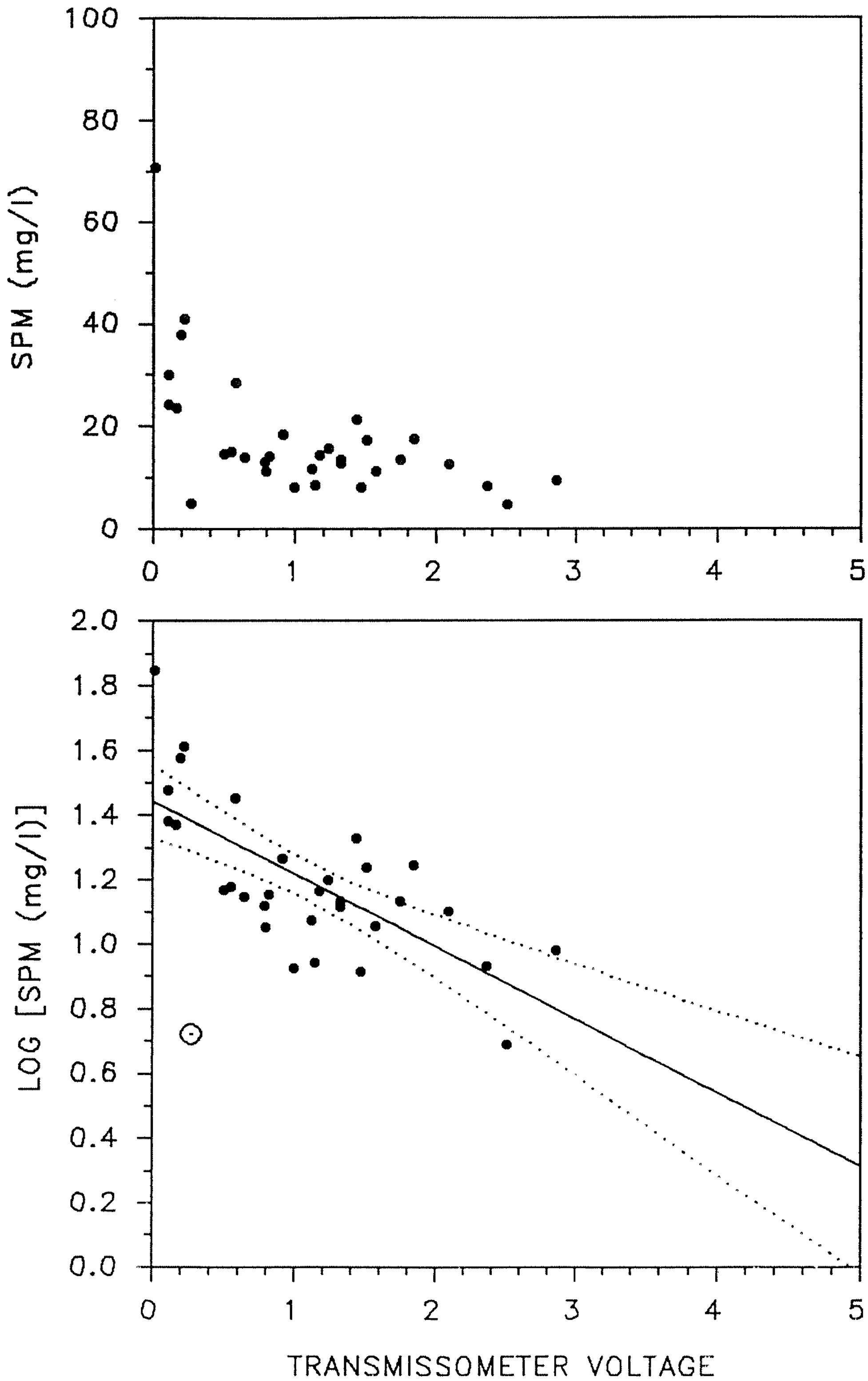

Figure 9. Plot of transmission voltage versus SPM (*upper*), and tranmission voltage versus LOGSPM (*lower*) for the field samples from the Pascagoula River outflow region in September 1992. The regression line, LOGSPM = 1.4432 - 0.2258DCV, the 95% confidence intervals, and the r value of 0.7107 were computed using 31 values. Data values not used in the regression are identified as ⊙.

Table 4. Means, standard deviations (S_d), and standard errors (SE) of concentration of suspended particulate matter determined gravimetrically (SPM), the surface transmissometer reading (DCV), and the common logarithm of the SPM value (LOGSPM). The number of values is n. Correlation coefficients (r) from individual regression analyses using the general linear model LOGSPM = a + b x DCV, where a is the intercept and b is the slope of the regression. The student-t statistic for individual correlation coefficient significance, t_r, tests the hypothesis H_o:r=0. All three t-statistics lie outside the critical region, $t_{critical}$ (with n-2 degrees of freedom). H_o is rejected at the 95% level and the alternative hypothesis, H_1:r=0, that the slope of the regression line is not equal to zero, is accepted.

		Mean	S_d	SE
	Pascagoula River Outflow Region (Jul)			
SPM (mg/l)		13.6587	11.2281	2.0500
DCV (volts)		1.3793	0.1850	0.2163
LOGSPM		1.0145	0.3295	0.0602
n	30			
r	0.8758			
b	-0.2435			
t_r	9.606			
$t_{critical}$	±2.048			
	Pearl River Outflow Region (Aug)			
SPM (mg/l)		8.0956	3.6656	0.6692
DCV (volts)		1.9050	0.6060	0.1106
LOGSPM		0.8714	0.1784	0.0326
n	30			
r	0.6475			
b	-0.1906			
t_r	4.496			
$t_{critical}$	±2.048			
	Pascagoula River Outflow region (Sep)			
SPM (mg/l)		18.3552	12.8481	2.3076
DCV (volts)		1.1036	0.7419	0.1333
LOGSPM		0.1940	0.2357	0.0423
n	31			
r	0.7107			
b	-0.2258			
t_r	5.4403			
$t_{critical}$	±2.045			

Table 5: Results of pair-wise regression analyses. The student-t statistic for pair-wise comparison of regression slopes tests the hypothesis $H_o: b_i - b_j = 0$, that there is no difference between slopes of the regressions. All three t-statistics lie within the critical region so H_o is accepted at the 95% level. Bracketed values indicate number of pooled degrees of freedom. Critical regions for pair-wise t-test are $t < \pm 2.0042$ for df=56, and $t < \pm 2.0032$ for df=57.

i \ j	Pascagoula River (Jul)	Pearl River (Aug)	Pascagoula River (Sep)
Pascagoula River (Jul)	---	-1.0703	-0.3672
Pearl River (Aug)	[56]	---	0.5752
Pascagoula River (Sep)	[57]	[57]	---

between the two Pascagoula River region surveys, or between the Pascagoula and Pearl River region surveys.

When all three regression lines are presented together (Figure 10), it can be seen that there is a similarity between the slopes of the regression lines. That is, there is a similar relationship between light transmission and LOGSPM for all three surveys.

4. Conclusions

Based on the limited field data available there is a logarithmic relationship between light transmission and suspended particulate matter in the Pascagoula and Pearl River outflow regions in the Mississippi Sound. There is no statistical difference in the relationship between light transmission and suspended particulate matter between the Pascagoula and Pearl River outflow regions in the Mississippi Sound at the 95% level. It should be noted that suspended particulate matter concentrations in this study did not attain the magnitudes expected over the annual range of values. Caution should be used when applying the statistical relationships to flow conditions greater than 500 m^3/s for either of the two rivers' outflow regions. Additional field verification is necessary to insure that the statistical relationships presented here hold for sediemnt yields during flood conditions.

This data analysis presents preliminary evidence of a possible single statistical relationship of light transmission and suspended particulate matter from direct river sources for the Mississippi Sound. If this is true, then rapid ground truthing of AVHRR reflectance data as a predictor of suspended particulate matter is feasible. The ground truthing feasibility would be considerably more complicated and the use of AVHRR reflectance information more difficult to use if there are multiple statistical relationships for the various suspended particulate matter inputs to the Mississippi Sound. There is still a great need for field evidence to determine the statistical relationships of wind-wave resuspended material and of river flood material. In addition a difference between the flood condition suspended particulate matter of the Pearl and Pascagoula Rivers is a possibility.

This study supports the contention that there is a single statistical relationship between light transmission and suspended particulate matter in the Pascagoula and Pearl River outflow regions of the Mississippi Sound. But additional study would be necessary to verify this over all river flow conditions and over other suspended particulate matter signals.

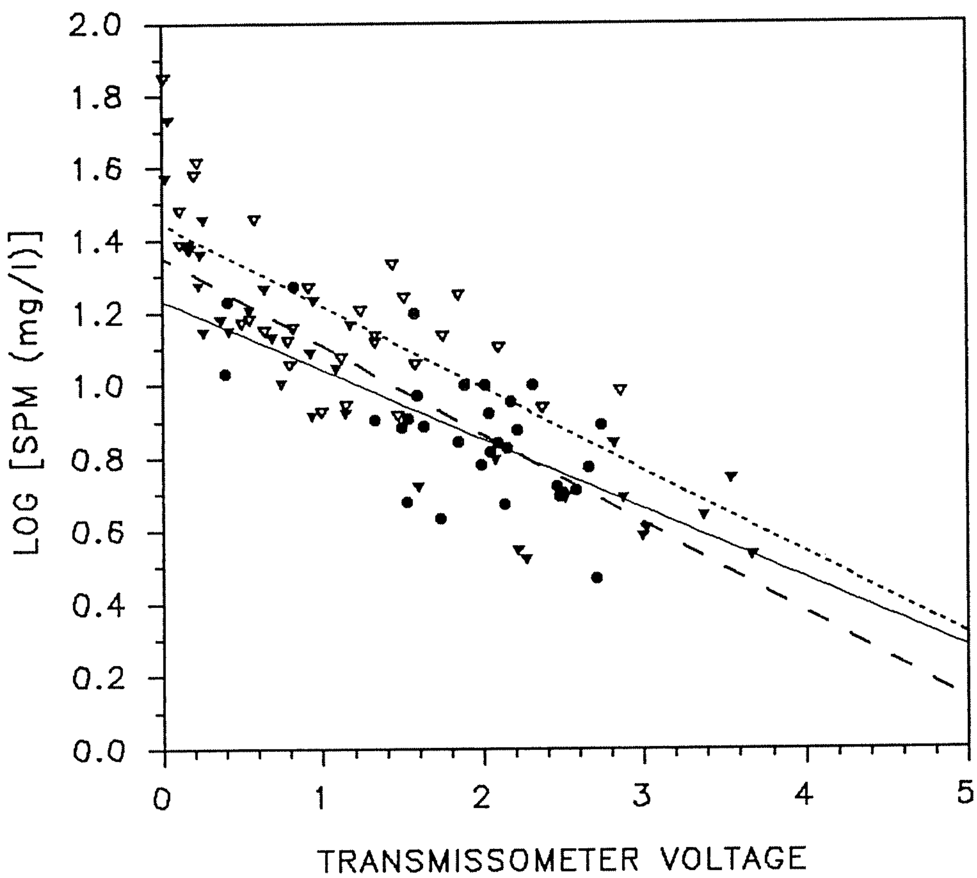

Figure 10. Plot of transmission voltage versus LOGSPM for all three field surveys. Pascagoula River (July) outflow region data values are, ▼, and regression line is, —— ——. Pearl River (August) outflow region data values are, ●, and regression line is, ————. Pascagoula River (September) outflow region data values are, ▽ , and regression line is, - - - - - - -.

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Appendix: All Field Data

Depth indicates estimated sample depth, S indicates surface, B indicates bottom. Suspended sediment concentrations for all surface water samples are reported within report.

DATE	TIME	LATITUDE (deg	LONGITUDE min)	DEPTH (m)	VOLTAGE (DC volts)	SAMPLE BOTTLE
Pascagoula River Outflow						
7/13	1610	30 09.04	88 43.91	S	1.15	A29
7/13	1610	30 09.04	88 43.91	1	1.04	
7/13	1620	30 18.94	88 44.02	S	2.22	A30
7/13	1620	30 18.94	88 44.02	1	2.23	
7/13	1620	30 18.94	88 44.02	1.5(B)	2.16	
7/13	1625	30 17.99	88 43.99	S	2.82	A31
7/13	1625	30 17.99	88 43.99	1	2.92	
7/13	1625	30 17.99	88 43.99	2	2.50	
7/13	1630	30 16.94	88 43.99	S	2.88	A32
7/13	1630	30 16.94	88 43.99	1	3.00	
7/13	1630	30 16.94	88 43.99	2	3.02	
7/13	1630	30 16.94	88 43.99	3	2.43	
7/13	1630	30 16.94	88 43.99	4	3.12	
7/13	1638	30 15.96	88 43.99	S	3.55	A33
7/13	1638	30 15.96	88 43.99	1	3.52	
7/13	1638	30 15.96	88 43.99	2	3.55	
7/13	1638	30 15.96	88 43.99	3	3.60	
7/13	1638	30 15.96	88 43.99	4	3.57	
7/13	1638	30 15.96	88 43.99	B	0.01	
7/13	1650	30 14.97	88 43.99	S	2.88	A34
7/13	1650	30 14.97	88 43.99	1	3.12	
7/13	1650	30 14.97	88 43.99	2	3.32	
7/13	1650	30 14.97	88 43.99	3	3.05	
7/13	1650	30 14.97	88 43.99	4	2.65	
7/13	1650	30 14.97	88 43.99	B	0.50	
7/13	1700	30 16.02	88 41.95	S	3.68	A35
7/13	1700	30 16.02	88 41.95	1	3.65	
7/13	1700	30 16.02	88 41.95	2	3.62	
7/13	1700	30 16.02	88 41.95	3	3.62	
7/13	1700	30 16.02	88 41.95	B	2.70	
7/13	1708	30 17.03	88 40.99	S	3.38	A36
7/13	1708	30 17.03	88 40.99	1	3.30	
7/13	1708	30 17.03	88 40.99	2	3.15	
7/13	1708	30 17.03	88 40.99	3	1.45	
7/13	1708	30 17.03	88 40.99	4	1.60	
7/13	1715	30 18.04	88 39.96	S	3.02	A37
7/13	1715	30 18.04	88 39.96	1	3.04	
7/13	1715	30 18.04	88 39.96	2	2.20	
7/13	1715	30 18.04	88 39.96	3	1.80	
7/13	1715	30 18.04	88 39.96	B	0.50	
7/13	1725	30 19.00	88 38.99	S	3.00	A38
7/13	1725	30 19.00	88 38.99	1	2.60	

Appendix Continued

DATE	TIME	LATITUDE (deg	LONGITUDE min)	DEPTH (m)	VOLTAGE (DC volts)	SAMPLE BOTTLE
Pascagoula River Outflow						
7/13	1725	30 19.00	88 38.99	2	1.70	
7/13	1730	30 20.04	88 37.94	S	0.75	A39
7/13	1730	30 20.04	88 37.94	1	0.73	
7/13	1730	30 20.04	88 37.94	1.5(B)	0.55	
7/13	1736	30 20.79	88 37.20	S	0.26	A40
7/13	1736	30 20.79	88 37.20	0.5(B)	0.32	
7/14	0955	30 22.25	88 36.36	S	0.37	A41
7/14	0955	30 22.25	88 36.36	1	0.29	
7/14	0955	30 22.25	88 36.36	2	0.22	
7/14	0955	30 22.25	88 36.36	3	0.18	
7/14	0955	30 22.25	88 36.36	4	0.12	
7/14	0955	30 22.25	88 36.36	5(B)	0.06	
7/14	1000	30 21.96	88 36.29	S	0.24	A42
7/14	1000	30 21.96	88 36.29	1	0.20	
7/14	1000	30 21.96	88 36.29	2	0.19	
7/14	1000	30 21.96	88 36.29	3	0.12	
7/14	1006	30 21.21	88 36.19	S	0.02	A43
7/14	1006	30 21.21	88 36.19	1	0.01	
7/14	1006	30 21.21	88 36.19	2	0.00	
7/14	1012	30 19.96	88 35.98	S	0.23	A44
7/14	1012	30 19.96	88 35.98	1	0.16	
7/14	1012	30 19.96	88 35.98	2(B)	0.00	
7/14	1022	30 18.97	88 35.99	S	0.95	A45
7/14	1022	30 18.97	88 35.99	1	0.91	
7/14	1022	30 18.97	88 35.99	2	0.80	
7/16	1643	30 20.014	88 35.971	S	0.42	A47
7/16	1643	30 20.014	88 35.971	1(B)	0.02	
7/16	1653	30 18.965	88 36.008	S	0.17	A48
7/16	1653	30 18.965	88 36.008	1	0.18	
7/16	1653	30 18.965	88 36.008	2(B)	0.11	
7/16	1658	30 17.959	88 36.005	S	0.69	?
7/16	1658	30 17.959	88 36.005	1	0.72	
7/16	1658	30 17.959	88 36.005	2	0.22	
7/16	1658	30 17.959	88 36.005	2.5(B)	0.07	
7/16	1706	30 16.956	88 35.998	S	1.09	A46
7/16	1706	30 16.956	88 35.998	1	1.05	
7/16	1706	30 16.956	88 35.998	2	0.41	
7/16	1706	30 16.956	88 35.998	2.5(B)	0.27	
7/16	1713	30 15.959	88 35.992	S	1.60	A56
7/16	1713	30 15.959	88 35.992	1	1.52	
7/16	1713	30 15.959	88 35.992	2	1.43	
7/16	1713	30 15.959	88 35.992	2.5(B)	1.34	
7/16	1718	30 14.954	88 35.987	S	2.08	A54
7/16	1718	30 14.954	88 35.987	1	2.04	
7/16	1718	30 14.954	88 35.987	2	1.87	
7/16	1718	30 14.954	88 35.987	3	1.70	

Appendix Continued

DATE	TIME	LATITUDE (deg	LONGITUDE min)	DEPTH (m)	VOLTAGE (DC volts)	SAMPLE BOTTLE
Pascagoula River Outflow						
7/16	1718	30 14.954	88 35.987	4	1.29	
7/16	1718	30 14.954	88 35.987	5(B)	0.09	
7/16	1725	30 13.944	88 35.997	S	2.27	A53
7/16	1725	30 13.944	88 35.997	1	1.99	
7/16	1725	30 13.944	88 35.997	2(B)	1.53	
7/16	1736	30 14.038	88 32.925	S	2.01	A55
7/16	1736	30 14.038	88 32.925	1	1.90	
7/16	1736	30 14.038	88 32.925	2	1.50	
7/16	1736	30 14.038	88 32.925	3	1.19	
7/16	1736	30 14.038	88 32.925	4(B)	1.06	
7/16	1742	30 15.026	88 33.002	S	0.93	A50
7/16	1742	30 15.026	88 33.002	1	0.80	
7/16	1742	30 15.026	88 33.002	2	0.94	
7/16	1742	30 15.026	88 33.002	3	0.81	
7/16	1742	30 15.026	88 33.002	4	0.38	
7/16	1742	30 15.026	88 33.002	5(B)	1.37	
7/16	1747	30 15.400	88 33.041	S	0.94	A51
7/16	1747	30 15.400	88 33.041	1	0.95	
7/16	1747	30 15.400	88 33.041	2	0.98	
7/16	1747	30 15.400	88 33.041	3	1.01	
7/16	1747	30 15.400	88 33.041	4	0.29	
7/16	1747	30 15.400	88 33.041	5(B)	0.57	
7/16	1751	30 16.117	88 33.001	S	0.64	A52
7/16	1751	30 16.117	88 33.001	1	0.66	
7/16	1751	30 16.117	88 33.001	2	0.63	
7/16	1751	30 16.117	88 33.001	3	0.31	
7/16	1751	30 16.117	88 33.001	4	0.23	
7/16	1751	30 16.117	88 33.001	4.5(B)	0.15	
7/16	1757	30 17.011	88 33.000	S	0.55	A57
7/16	1757	30 17.011	88 33.000	1	0.52	
7/16	1757	30 17.011	88 33.000	2	0.48	
7/16	1757	30 17.011	88 33.000	3	0.13	
7/16	1757	30 17.011	88 33.000	4(B)	0.01	
7/16	1802	30 18.030	88 32.996	S	0.26	A58
7/16	1802	30 18.030	88 32.996	1	0.33	
7/16	1802	30 18.030	88 32.996	2(B)	0.02	
7/16	1900	30 19.245	88 33.563	S	0.04	A99
7/16	1900	30 19.245	88 33.563	0.5(B)	0.03	

Appendix Continued

DATE	TIME	LATITUDE (deg	LONGITUDE min)	DEPTH (m)	VOLTAGE (DC volts)	SAMPLE BOTTLE
Pearl River Outflow						
8/31	1049	30 11.011	89 31.489	S	0.40	A177
8/31	1049	30 11.011	89 31.489	1	0.43	
8/31	1049	30 11.011	89 31.489	2	0.55	
8/31	1049	30 11.011	89 31.489	3	0.55	
8/31	1049	30 11.011	89 31.489	4	0.55	
8/31	1101	30 09.966	89 31.015	S	0.83	A34
8/31	1101	30 09.966	89 31.015	1	1.86	
8/31	1101	30 09.966	89 31.015	2	2.78	
8/31	1106	30 09.815	89 30.921	S	1.33	A29
8/31	1106	30 09.815	89 30.921	1	2.45	
8/31	1111	30 08.962	89 30.485	S	2.32	A152
8/31	1111	30 08.962	89 30.485	1	2.22	
8/31	1111	30 08.962	89 30.485	2	2.00	
8/31	1111	30 08.962	89 30.485	3	0.40	
8/31	1118	30 07.982	89 29.986	S	2.46	A35
8/31	1118	30 07.982	89 29.986	1	2.20	
8/31	1118	30 07.982	89 29.986	2	2.00	
8/31	1118	30 07.982	89 29.986	3	1.91	
8/31	1124	30 06.971	89 29.475	S	2.71	A179
8/31	1124	30 06.971	89 29.475	1	2.90	
8/31	1124	30 06.971	89 29.475	2	2.96	
8/31	1124	30 06.971	89 29.475	3	2.94	
8/31	1130	30 05.986	89 28.998	S	2.66	A148
8/31	1130	30 05.986	89 28.998	1	2.68	
8/31	1130	30 05.986	89 28.998	2	2.67	
8/31	1130	30 05.986	89 28.998	3	2.67	
8/31	1139	30 05.998	89 26.988	S	2.50	A99
8/31	1139	30 05.998	89 26.988	1	2.45	
8/31	1139	30 05.998	89 26.988	2	2.45	
8/31	1147	30 06.001	89 24.978	S	2.58	A33
8/31	1147	30 06.001	89 24.978	1	2.50	
8/31	1147	30 06.001	89 24.978	2	2.42	
8/31	1155	30 05.993	89 22.975	S	2.15	A40
8/31	1155	30 05.993	89 22.975	1	2.10	
8/31	1155	30 05.993	89 22.975	2	1.92	
8/31	1205	30 07.008	89 20.989	S	1.53	A41
8/31	1205	30 07.008	89 20.989	1	1.47	
8/31	1205	30 07.008	89 20.989	2	1.41	
8/31	1205	30 07.008	89 20.989	3	1.01	
8/31	1217	30 08 001	89 18.989	S	1.50	A52
8/31	1217	30 08 001	89 18.989	1	1.47	
8/31	1217	30 08 001	89 18.989	2	1.66	
8/31	1217	30 08 001	89 18.989	3	1.60	
8/31	1227	30 09.011	89 16.979	S	1.59	A42
8/31	1227	30 09.011	89 16.979	1	1.62	
8/31	1227	30 09.011	89 16.979	2	1.52	

Appendix Continued

DATE	TIME	LATITUDE (deg	LONGITUDE min)	DEPTH (m)	VOLTAGE (DC volts)	SAMPLE BOTTLE
Pearl River Outflow						
8/31	1227	30 09.011	89 16.979	3	1.89	
8/31	1308	30 11.011	89 18.003	S	1.85	A60
8/31	1308	30 11.011	89 18.003	1	1.81	
8/31	1308	30 11.011	89 18.003	2	1.45	
8/31	1308	30 11.011	89 18.003	3	1.57	
8/31	1316	30 13.016	89 18.979	S	2.04	A74
8/31	1316	30 13.016	89 18.979	1	2.03	
8/31	1316	30 13.016	89 18.979	2	1.85	
8/31	1316	30 13.016	89 18.979	3	1.92	
8/31	1323	30 13.971	89 21.038	S	2.10	A106
8/31	1323	30 13.971	89 21.038	1	2.10	
8/31	1323	30 13.971	89 21.038	2	2.05	
8/31	1323	30 13.971	89 21.038	3	1.70	
8/31	1329	30 15.008	89 23.027	S	1.99	A59
8/31	1329	30 15.008	89 23.027	1	1.66	
8/31	1329	30 15.008	89 23.027	2	1.89	
8/31	1339	30 12.998	89 25.005	S	1.74	A80
8/31	1339	30 12.998	89 25.005	1	1.55	
8/31	1339	30 12.998	89 25.005	2	1.34	
8/31	1349	30 10.932	89 24.110	S	2.05	A28
8/31	1349	30 10.932	89 24.110	1	2.28	
8/31	1349	30 10.932	89 24.110	2	2.28	
8/31	1349	30 10.932	89 24.110	3	1.35	
8/31	1400	30 08.992	89 22.997	S	2.02	A25
8/31	1400	30 08.992	89 22.997	1	2.02	
8/31	1400	30 08.992	89 22.997	2	2.06	
8/31	1400	30 08.992	89 22.997	3	0.90	
8/31	1410	30 06.994	89 21.996	S	2.18	A26
8/31	1410	30 06.994	89 21.996	1	2.16	
8/31	1410	30 06.994	89 21.996	2	1.90	
8/31	1410	30 06.994	89 21.996	3	0.91	
8/31	1419	30 04.988	89 20.995	S	2.22	A27
8/31	1419	30 04.988	89 20.995	1	2.15	
8/31	1419	30 04.988	89 20.995	2	1.70	
8/31	1445	30 10.000	89 16.988	S	1.58	A71
8/31	1445	30 10.000	89 16.988	1	1.65	
8/31	1445	30 10.000	89 16.988	2	1.60	
8/31	1445	30 10.000	89 16.988	3	1.99	
8/31	1453	30 09.999	89 19.013	S	1.63	A70
8/31	1453	30 09.999	89 19.013	1	1.64	
8/31	1453	30 09.999	89 19.013	2	1.60	
8/31	1453	30 09.999	89 19.013	3	1.58	
8/31	1453	30 09.999	89 19.013	4	0.48	
8/31	1459	30 10.000	89 21.024	S	2.14	A108
8/31	1459	30 10.000	89 21.024	1	2.14	
8/31	1459	30 10.000	89 21.024	2	1.48	

Appendix Continued

DATE	TIME	LATITUDE (deg	LONGITUDE min)	DEPTH (m)	VOLTAGE (DC volts)	SAMPLE BOTTLE
Pearl River Outflow						
8/31	1459	30 10.000	89 21.024	3	0.92	
8/31	1505	30 10.000	89 23.009	S	2.48	A188
8/31	1505	30 10.000	89 23.009	1	2.48	
8/31	1505	30 10.000	89 23.009	2	2.39	
8/31	1505	30 10.000	89 23.009	3	0.70	
8/31	1513	30 10.000	89 25.018	S	2.74	A88
8/31	1513	30 10.000	89 25.018	1	2.95	
8/31	1513	30 10.000	89 25.018	2	2.91	
8/31	1520	30 10.013	89 27.031	S	1.89	A85
8/31	1520	30 10.013	89 27.031	1	2.07	
8/31	1520	30 10.013	89 27.031	2	1.88	
8/31	1520	30 10.013	89 27.031	3	1.56	
8/31	1528	30 10.004	89 29.047	S	1.54	A87
8/31	1528	30 10.004	89 29.047	1	2.00	
8/31	1528	30 10.004	89 29.047	2	1.89	
8/31	1528	30 10.004	89 29.047	3	1.84	
8/31	1528	30 10.004	89 29.047	4	1.45	
8/31	1534	30 10.006	89 31.017	S	0.41	A92
8/31	1534	30 10.006	89 31.017	1	0.78	
8/31	1534	30 10.006	89 31.017	2	3.07	
8/31	1542	30 10.002	89 33.016	S	1.51	A89
8/31	1542	30 10.002	89 33.016	1	1.42	
8/31	1542	30 10.002	89 33.016	2	1.19	
Pascagoula River Outflow						
9/01	1133	30 20.019	88 33.030	S	1.47	A158
9/01	1133	30 20.019	88 33.030	1	1.25	
9/01	1133	30 20.019	88 33.030	2	0.23	
9/01	1140	30 18.995	88 33.004	S	1.44	A128
9/01	1140	30 18.995	88 33.004	1	0.10	
9/01	1147	30 17.991	88 33.007	S	0.58	A113
9/01	1147	30 17.991	88 33.007	1	0.36	
9/01	1147	30 17.991	88 33.007	2	0.02	
9/01	1152	30 16.995	88 33.002	S	0.50	A151
9/01	1152	30 16.995	88 33.002	1	0.45	
9/01	1152	30 16.995	88 33.002	2	0.47	
9/01	1152	30 16.995	88 33.002	3	0.10	
9/01	1159	30 15.994	88 33.007	S	1.75	A174
9/01	1159	30 15.994	88 33.007	1	1.74	
9/01	1159	30 15.994	88 33.007	2	1.66	
9/01	1159	30 15.994	88 33.007	3	1.62	
9/01	1159	30 15.994	88 33.007	4	0.15	
9/01	1205	30 14.985	88 33.014	S	2.10	A120

Appendix Continued

DATE	TIME	LATITUDE (deg	LONGITUDE min)	DEPTH (m)	VOLTAGE (DC volts)	SAMPLE BOTTLE
Pascagoula River Outflow						
9/01	1205	30 14.985	88 33.014	1	2.10	
9/01	1205	30 14.985	88 33.014	2	2.00	
9/01	1205	30 14.985	88 33.014	3	1.79	
9/01	1205	30 14.985	88 33.014	4	1.00	
9/01	1211	30 13.991	88 32.995	S	1.33	A119
9/01	1211	30 13.991	88 32.995	1	1.30	
9/01	1211	30 13.991	88 32.995	2	1.31	
9/01	1211	30 13.991	88 32.995	3	1.01	
9/01	1217	30 12.989	88 33.005	S	1.24	A145
9/01	1217	30 12.989	88 33.005	1	1.19	
9/01	1217	30 12.989	88 33.005	2	1.09	
9/01	1217	30 12.989	88 33.005	3	0.98	
9/01	1306	30 13.988	88 36.024	S	2.86	A117
9/01	1306	30 13.988	88 36.024	1	2.70	
9/01	1306	30 13.988	88 36.024	2	2.63	
9/01	1306	30 13.988	88 36.024	3	2.47	
9/01	1306	30 13.988	88 36.024	4	0.45	
9/01	1314	30 15.009	88 36.000	S	1.33	A149
9/01	1314	30 15.009	88 36.000	1	1.23	
9/01	1314	30 15.009	88 36.000	2	0.78	
9/01	1314	30 15.009	88 36.000	3	0.40	
9/01	1314	30 15.009	88 36.000	4	0.29	
9/01	1319	30 16.014	88 36.003	S	0.92	A144
9/01	1319	30 16.014	88 36.003	1	0.93	
9/01	1319	30 16.014	88 36.003	2	0.90	
9/01	1324	30 17.011	88 35.991	S	0.82	A178
9/01	1324	30 17.011	88 35.991	1	0.71	
9/01	1324	30 17.011	88 35.991	2	0.38	
9/01	1330	30 18.011	88 36.002	S	1.00	A53
9/01	1330	30 18.011	88 36.002	1	0.52	
9/01	1330	30 18.011	88 36.002	2	0.09	
9/01	1335	30 19.010	88 36.011	S	0.80	A101
9/01	1335	30 19.010	88 36.011	1	0.39	
9/01	1335	30 19.010	88 36.011	2	0.13	
9/01	1340	30 20.022	88 36.000	S	0.79	A102
9/01	1340	30 20.022	88 36.000	1	0.10	
9/01	1346	30 20.190	88 36.072	S	0.64	A155
9/01	1403	30 22.007	88 36.306	S	0.27	A98
9/01	1403	30 22.007	88 36.306	1	0.30	
9/01	1403	30 22.007	88 36.306	2	0.47	
9/01	1410	30 22.999	88 36.472	S	0.11	A126
9/01	1410	30 22.999	88 36.472	1	0.15	
9/01	1410	30 22.999	88 36.472	2	0.19	
9/01	1410	30 22.999	88 36.472	3	0.21	
9/01	1410	30 22.999	88 36.472	4	0.44	
9/01	1410	30 22.999	88 36.472	5	0.56	

Appendix Continued

DATE	TIME	LATITUDE (deg	LONGITUDE min)	DEPTH (m)	VOLTAGE (DC volts)	SAMPLE BOTTLE
Pascagoula River Outflow						
9/01	1410	30 22.999	88 36.472	6	0.57	
9/01	1427	30 19.824	88 37.787	S	0.17	A103
9/01	1427	30 19.824	88 37.787	1	0.15	
9/01	1427	30 19.824	88 37.787	2	0.07	
9/01	1434	30 18.994	88 39.018	S	1.12	A104
9/01	1434	30 18.994	88 39.018	1	1.00	
9/01	1434	30 18.994	88 39.018	2	0.30	
9/01	1441	30 17.998	88 39.992	S	1.51	A97
9/01	1441	30 17.998	88 39.992	1	1.46	
9/01	1441	30 17.998	88 39.992	2	1.26	
9/01	1441	30 17.998	88 39.992	3	0.48	
9/01	1448	30 16.995	88 40.993	S	1.58	A100
9/01	1448	30 16.995	88 40.993	1	1.56	
9/01	1448	30 16.995	88 40.993	2	1.25	
9/01	1448	30 16.995	88 40.993	3	0.78	
9/01	1448	30 16.995	88 40.993	4	0.14	
9/01	1455	30 15.999	88 41.987	S	2.51	A171
9/01	1455	30 15.999	88 41.987	1	2.54	
9/01	1455	30 15.999	88 41.987	2	2.08	
9/01	1455	30 15.999	88 41.987	3	0.98	
9/01	1455	30 15.999	88 41.987	4	0.27	
9/01	1505	30 15.988	88 44.017	S	2.37	A153
9/01	1505	30 15.988	88 44.017	1	2.36	
9/01	1505	30 15.988	88 44.017	2	2.29	
9/01	1505	30 15.988	88 44.017	3	2.32	
9/01	1505	30 15.988	88 44.017	4	2.26	
9/01	1511	30 16.985	88 44.035	S	1.85	A156
9/01	1511	30 16.985	88 44.035	1	1.88	
9/01	1511	30 16.985	88 44.035	2	1.71	
9/01	1511	30 16.985	88 44.035	3	1.38	
9/01	1511	30 16.985	88 44.035	4	0.39	
9/01	1517	30 17.900	88 44.010	S	0.20	A123
9/01	1517	30 17.900	88 44.010	1	0.20	
9/01	1517	30 17.900	88 44.010	2	0.10	
9/01	1522	30 19.009	88 44.016	S	0.01	A180
9/01	1522	30 19.009	88 44.016	1	0.00	
9/01	1528	30 20.001	88 43.967	S	0.11	A185
9/01	1528	30 20.001	88 43.967	1	0.01	
9/01	1537	30 19.300	88 42.467	S	0.22	A170
9/01	1537	30 19.300	88 42.467	1	0.08	
9/01	1540	30 19.235	88 42.311	S	0.55	A157
9/01	1540	30 19.235	88 42.311	1	0.54	
9/01	1548	30 18.745	88 40.221	S	1.15	A10
9/01	1556	30 18.383	88 40.042	S	1.18	A131

HISTORICAL HUMAN MODIFICATION OF MISSISSIPPI'S MAINLAND SHORELINE

by

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Introduction

The Mississippi Gulf Coast may be described as one of the most engineered shorelines of the United States (Canis et al., 1985). Most of Hancock and Harrison counties are fronted by a combination seawall/artificial beach, and two reaches of Jackson County (Ocean Springs and Pascagoula) have been similarly modified. The remaining shoreline reaches of the mainland are subject to (mostly) storm-induced erosion (short-term average retreat rates vary from 2 to 3 m/yr), and vacation home owners in Jackson County are petitioning the state to do something to retard loss of their beachfront properties. Based upon a research methodology that is mostly archival, this summary report represents a preliminary effort in describing the impacts of humans as geomorphic agents along the mainland beaches of the Mississippi coastal zone.

Acknowledgments

Assistance in the compilation of the accompanying photographs was generously provided by Ms. Murella Hebert Powell of the Biloxi Public Library, Ms. Kat Bergeron of The Sun-Herald, and the Public Relations office of the U.S. Army Corps of Engineers, Mobile District.

Research Methods

To investigate historical impacts upon the mainland shoreline of Mississippi, considerable library and archival research (literary, map, and photographic) was conducted. Notable institutions at which research was conducted include the Mississippi Office of Geology (Jackson), Department of Archives and History (Jackson), Mississippi State University (Starkville), U.S. Army Corps of Engineers libraries (Vicksburg and Mobile), Biloxi Public Library (Biloxi), The Sun-Herald library (Biloxi), Louisiana

State University (Baton Rouge), Louisiana Geological Survey (Baton Rouge), New Orleans Public Library (New Orleans), and the Historic New Orleans Collection (New Orleans). Although much historical information on the Mississippi Coast was found to be available, only a portion of it specifically addressed coastal impact issues. The accumulation of data was facilitated by several mid-1980s publications (notably Scholtes and Scholtes, 1985; Sullivan, 1985; and Sullivan et al., 1985), and excellent archives at the Biloxi Public Library (notably the James Stevens collection made available by archivist Ms. Murella Hebert Powell). Ms. Kat Bergeron, historian at The Sun-Herald, made available numerous personal files.

As might be expected, it was found that an inverse relationship existed between volume of historical sources and time before present. In regard to direct shoreline impacts, very little written information predates the Civil War, but the twentieth-century record is fairly well documented. Accurate maps date to about 1850, and several were consulted during the data-gathering process. (However, since mapping of historical shoreline changes was being conducted for the MS Office of Geology by the Louisiana Geological Survey, this aspect of human impacts was not quantified during the course of this study.) The photographic record was also found to be somewhat spotty, especially for the late 19th- and early 20th-centuries when shoreline impacts began to increase rapidly.

Although an accurate and detailed documentation of historical shoreline impacts along the mainland of Mississippi would require a longer monograph than is presented here, the present report is intended to provide a framework for understanding the evolution of human impacts. Most of the discussion pertains to present-day Harrison County, which contains the longest reach of developed shoreline and was best documented in the historical literature. Information on Hancock and Jackson counties was of a more spotty nature, and more in-depth research at local libraries and historical societies may be required to accurately document human modification of the shoreline.

Preliminary results from this research project have been presented at meetings of the Mississippi Academy of Sciences (Jackson, MS, Feb. 23-24, 1991) (Meyer-Arendt, 1991c) and the Association of American Geographers (Miami, FL, April 13-17, 1991)

(Meyer-Arendt, 1991a). A more comprehensive overview of the research was presented at the Gulf Coast Section, Society of Economic Paleontologists and Mineralogists Foundation research conference in Houston, TX, Dec. 8-11, 1991 (Meyer-Arendt, 1991b).

Geologic Setting

The geomorphic features that formed during previous high stands of sea level strongly influence the present-day distribution of beaches, wetlands, and islands of the Mississippi coast (Meyer-Arendt and Gazzier, 1990). Narrow eroding beaches formerly fronted the Pleistocene barrier complex of Harrison County as well as Pleistocene headlands in Hancock and Jackson counties (Otvos, 1985c). Although these have been substantially modified by human action, remnants remain in coastal reaches such as along the northern shore of St. Louis Bay. Tidal wetlands are found in and near the bayhead deltas of modern drainage systems. These areas include the Pascagoula River delta and protected low-energy bays and deltas of Back Bay of Biloxi and St. Louis Bay (Meyer-Arendt, 1989). Delta progradation and aggradation are still active in the sheltered bays, but the Pascagoula bayhead delta has prograded into Mississippi Sound to a point where erosion and deposition are nearly balanced. In addition to bayhead delta marshes, extensive marshes formed in southern Hancock County as a result of the Mississippi River St. Bernard delta deposition and in eastern Jackson County marshes as a result of Pascagoula River fluvio-deltaic sedimentation into what is now known as the Bayou Cumbest delta complex (Gazzier, 1977; Kramer, 1990; Meyer-Arendt and Kramer, 1991). The barrier islands--Petit Bois, Horn, Ship, and Cat Islands--formed via a combination of shoal emergence and modification of existing Pleistocene-Holocene beach-barrier complexes and are highly dynamic--i.e. transgressive as well as westward-migrating (Kwon, 1969; Waller and Malbrough, 1976; Shabica et al., 1984; Otvos, 1979; Rucker and Snowden, 1990).

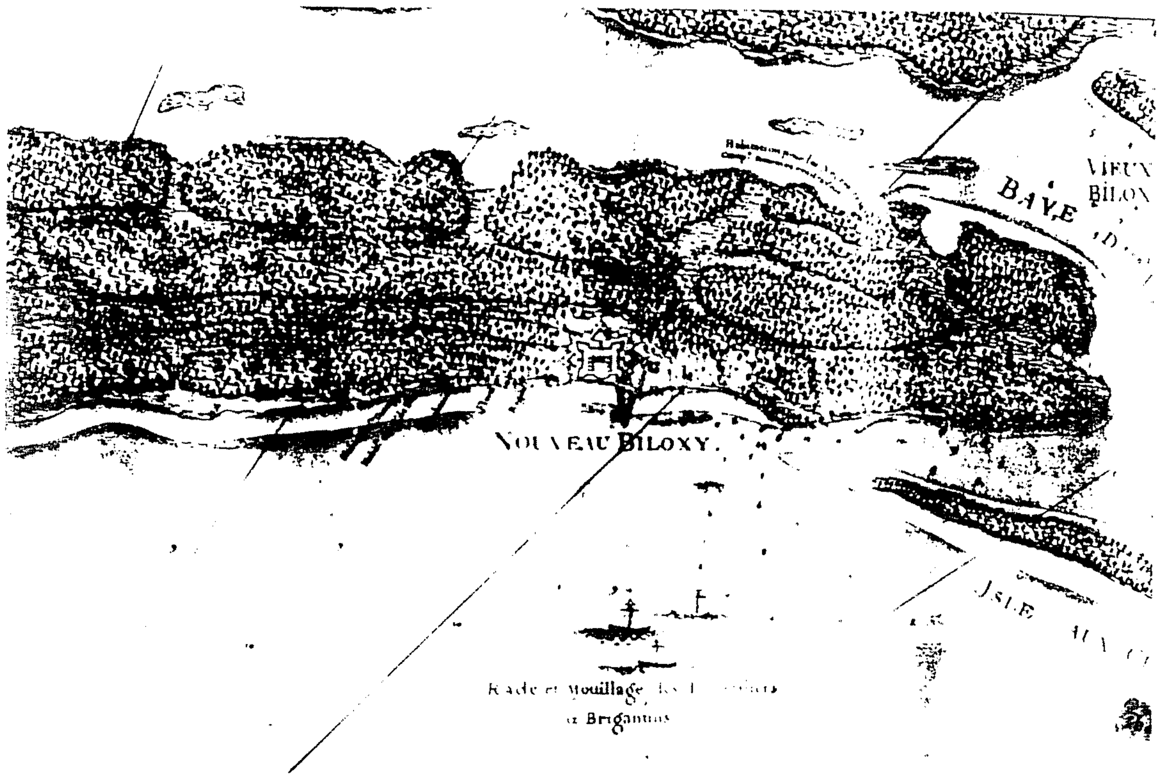
The Pre-American Period, 1699-1811

Since arrival of the French in 1699, the mainland Mississippi Gulf Coast has been a popular locus for settlement. Sheltered from high wave energy by the barrier islands and a shallow Mississippi Sound, the mainland coast was perceived to be somewhat more protected from devastating hurricanes. Although the initial site of French settlement was at the junction of Fort Bayou and Biloxi

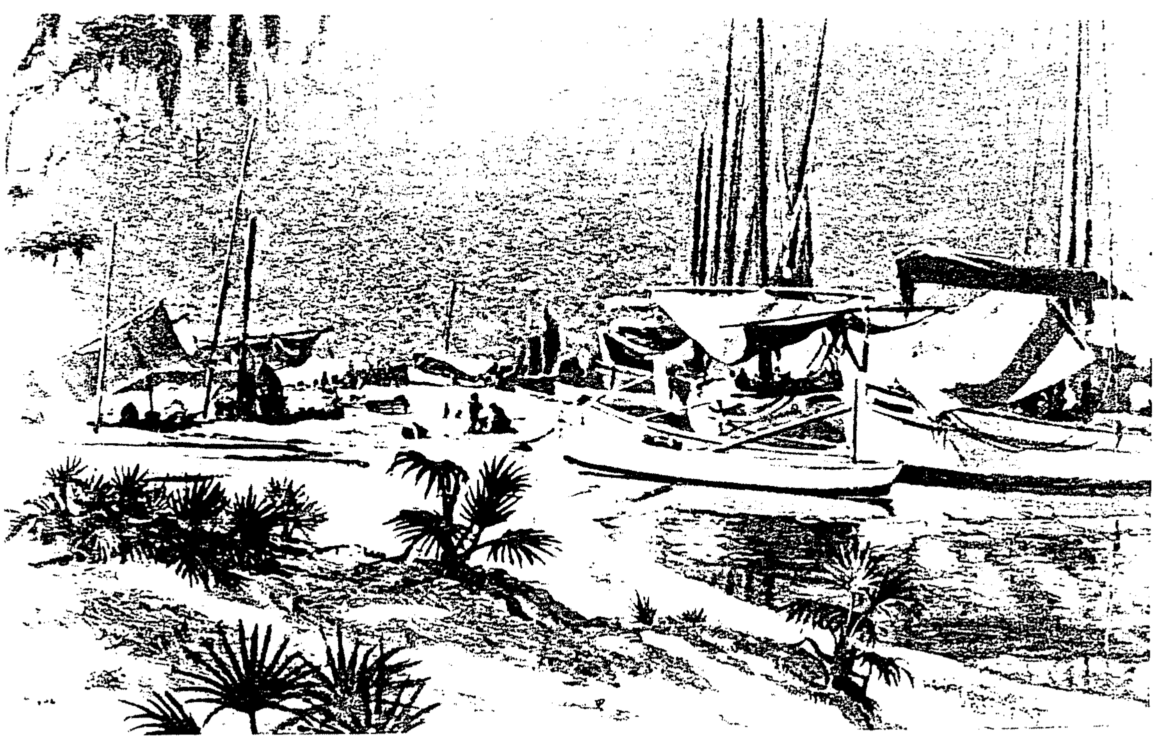
Bay (Old Biloxi, in what is now Ocean Springs), the settlement was moved to the north side of the Biloxi peninsula in 1720 (Prior, 1947). Although indicated on old maps (Figure 1), no fort was ever constructed along the beach (Sullivan et al., 1985). The importance of this French outpost waned quickly, as first Mobile and later New Orleans were deemed to be more strategically situated in terms of commerce and territorial control. Throughout the 18th century, the few, mostly French-descended coastal inhabitants were engaged in fishing, farming, stock-raising, exploiting pine resources, and trading with the urban center of New Orleans (Alexander, 1980; Scholtes and Sholtes, 1985; Sullivan et al., 1985). Periodic incursion by marauding Indians drove the settlers to the barrier islands (especially Cat Island and Deer Island), and periodic hurricanes drove the surviving settlers back to the mainland (Sullivan et al., 1985). The population was relatively low at the time the American flag was raised in coastal Mississippi in 1811 (the census listed a total of 770 inhabitants), and--according to the little information available--human impacts along the shorefront remained relatively insignificant (Sullivan et al., 1985).

The Antebellum Period, 1811-1861

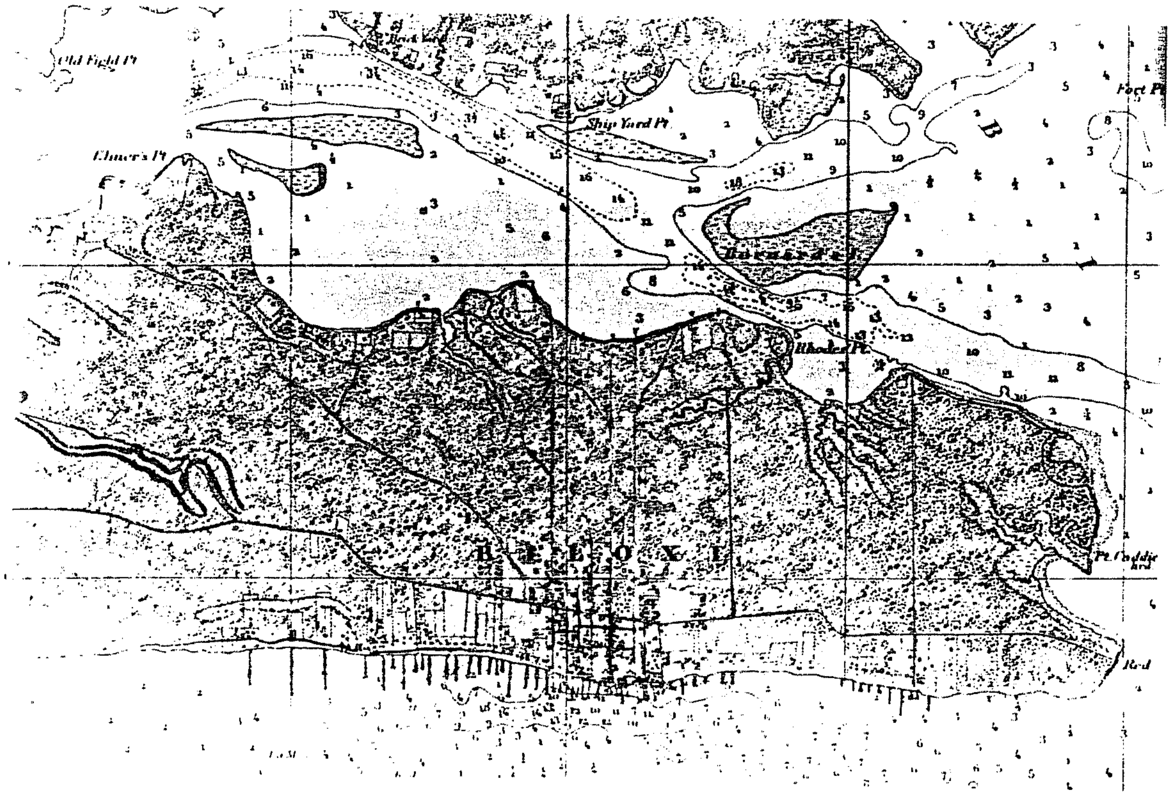
The economic patterns established during the 18th century--farming, stock-raising, lumbering, and fishing--continued into the 19th century as increasing numbers of Anglo settlers moved into the region, but a new form of economic activity--recreation and tourism--rapidly gained in importance. Even before admission into the United States in 1811, New Orleans sojourners made their way to the narrow natural beaches of Hancock County (Claiborne, 1876), and following statehood in 1817, summer sojourns at the coast increased in popularity (anon., 1958; Hayden, 1950). Whereas the primary mode of transport in the early decades of the century was sail-powered lugger (Figure 2), the advent of the steam engine in the late 1820s was soon followed by the introduction of steamboat service between New Orleans and Mobile. This development led to ever-increasing volumes of trade and tourism in coastal Mississippi (Hayden, 1950). The late antebellum period of the 1840s and 1850s was characterized by increased visitation--by New Orleans residents fleeing summertime yellow fever outbreaks and by Mississippi plantation owners and their families--and increased hotel and summer home construction (Smedes, 1965). Biloxi, historically the largest city as well as the most important



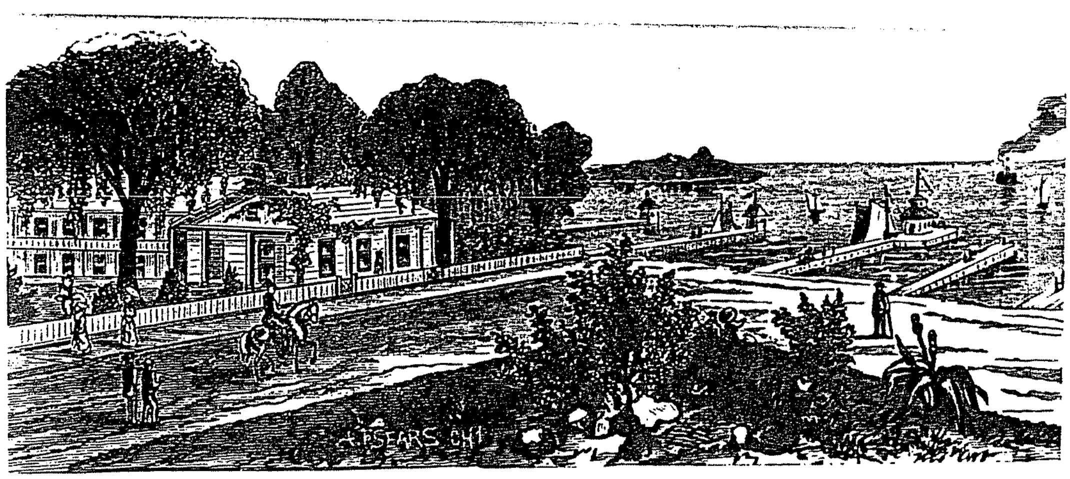
1. Map of Biloxi, 1720. (courtesy Ms. Murella Hebert Powell, Biloxi Public Library [BPL)



2. Lugger camp at Biloxi, mid 1800s. (courtesy Ms. Murella Hebert Powell, BPL)



3. Map of Biloxi, 1850s.



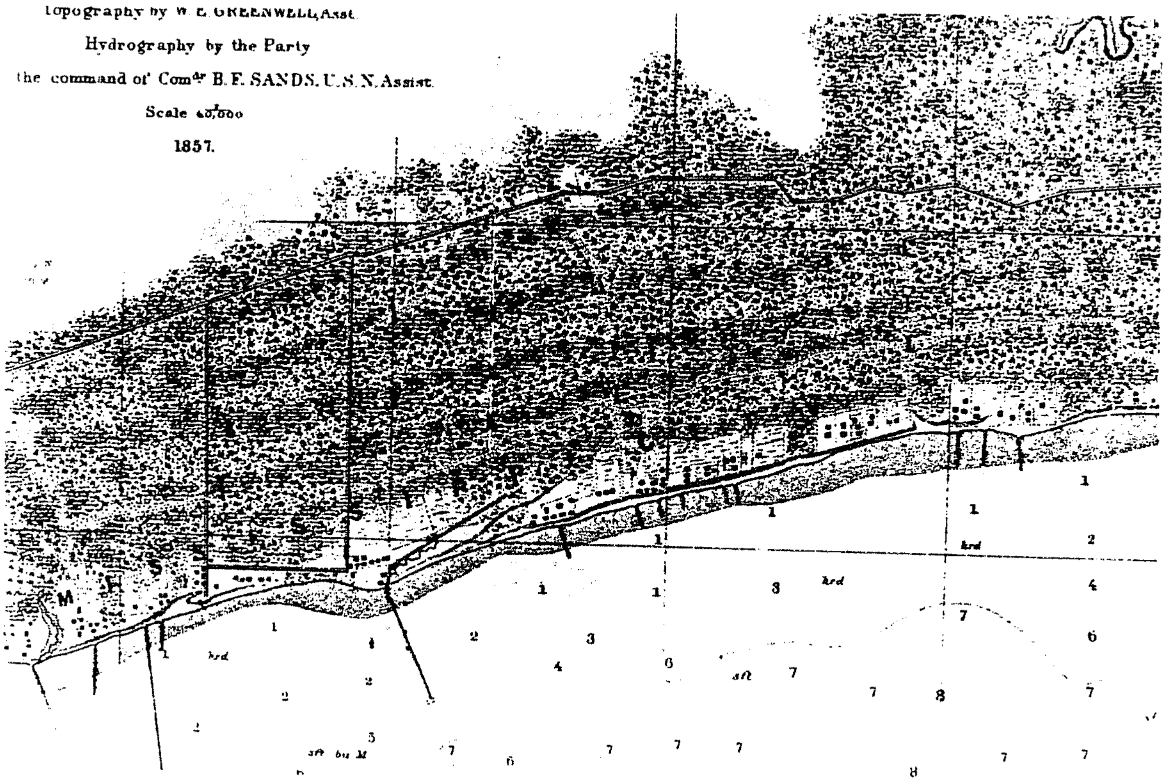
BILOXI, MISS. VIEW ON THE GULF OF MEXICO.

4. The Biloxi waterfront, circa 1850. (courtesy Ms. Murella Hebert Powell, BPL)

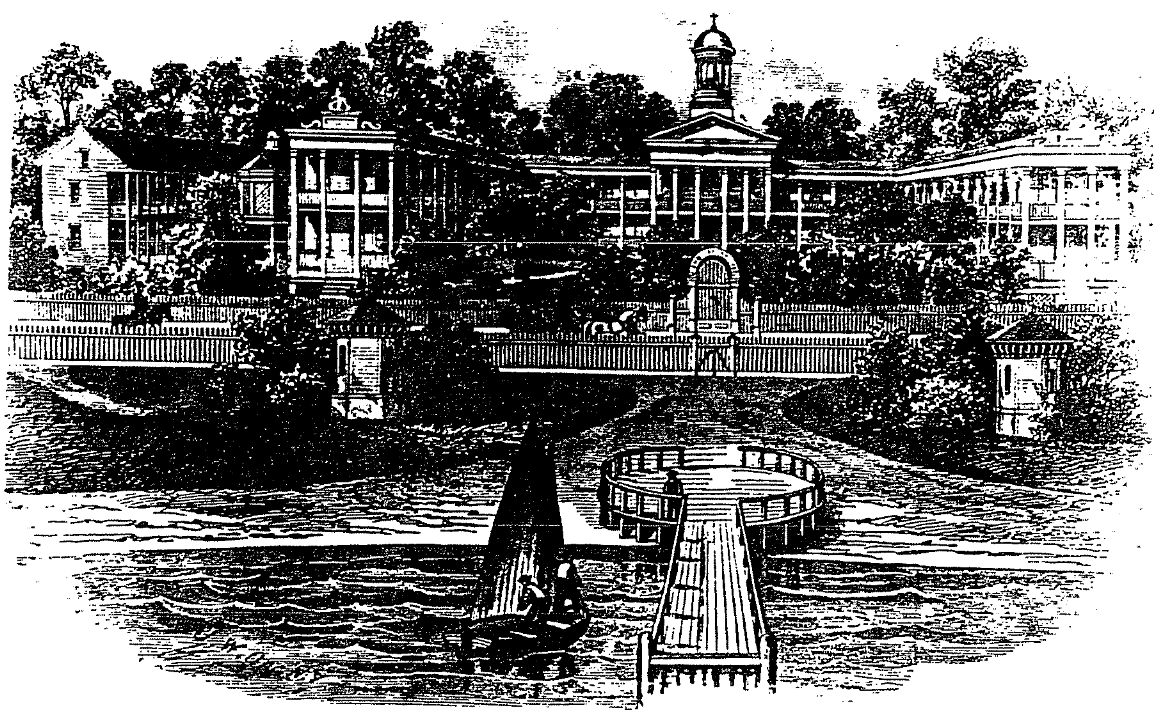
commercial center on the coast (Figure 3), received tourists from both New Orleans and Mobile, and several hotels were built, including the Magnolia Hotel--renovated and still standing. The Biloxi waterfront was characterized by numerous wharves where the steamships and sailing vessels docked (Figure 4). In the 1840s, a new city--named Mississippi City--was platted and it became the seat of the newly created Harrison County (Figure 5).

Mississippi City was intended to become a major urban center and the southern terminus of a rail line which would link the coast with Jackson, but these plans were never realized for a variety of financial reasons (Sullivan et al., 1985). Pass Christian, with its New Orleans connection, became a resort "equal to White Sulphur Springs, Saratoga, and Newport" and boasted of the oldest yacht club in the South (Hayden, 1950). The building of "Grand Hotels" began in Pass Christian as early as the 1840s (Figure 6), and continued in the postbellum 19th century (Figures 7 and 8). Because of a virtual absence of a sand beach, however, it has been suggested that it was not the attraction of the environment that led to tourist development but rather the annual summertime evacuation of disease-prone New Orleans (Hayden, 1950; Sullivan et al., 1985). Bay St. Louis and Waveland also benefited from tourism development because of the relative proximity to New Orleans. The shell-strewn muddy tidal flats of Pascagoula attracted wealthy summer refugees from Mobile.

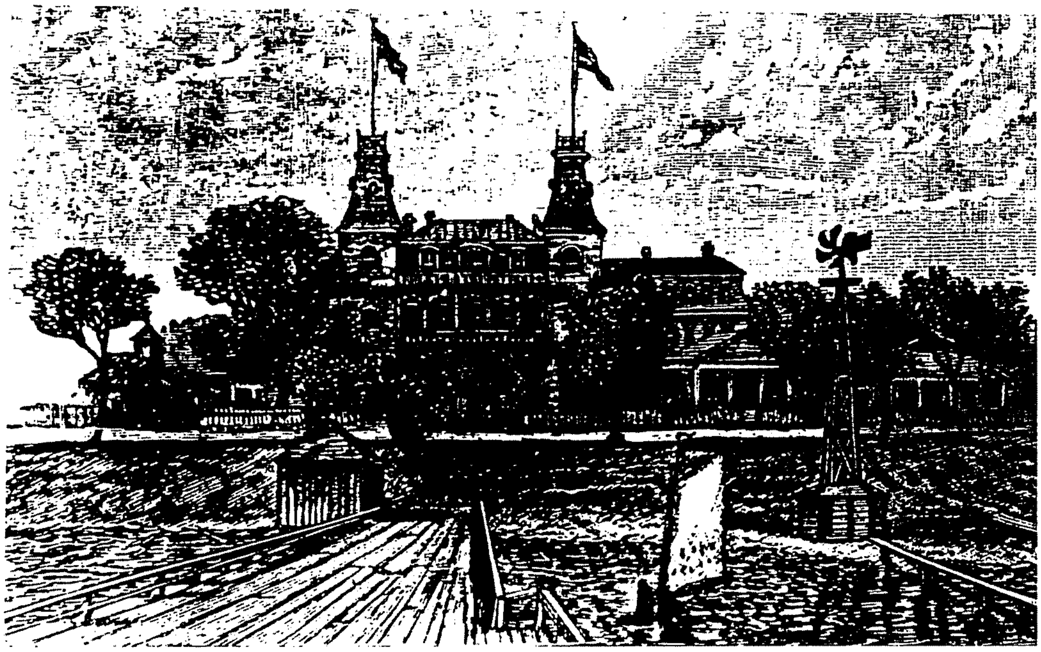
With increasing coastal urbanization in the late antebellum period, the extent of human impacts upon the shore zone began to slowly increase. In the nearshore were wharves (for boat docking) and private piers, often with pavilions (for fishing and bathing) (see Figures 3 and 5). The shore zone (especially in Harrison County) typically consisted of a narrow sand beach backed by a vegetated (grassy) backshore which extended inland to a low scarp which apparently reflected past, probably storm-induced, wave-cutting activity at the seaward edge of the Pleistocene barrier. Although there were lower-elevation coastal reaches where pine flats or marshes approached the shoreline, the preferred locus of settlement was where the live oak (*Quercus virginiana*) covered Pleistocene dune ridges approached the shoreline (and the beach/scarp profile dominated). For the most part, structures and buggy roads were constructed above the scarp line (as clearly seen on the 1850s coastal charts for the entire Mississippi coast [Figure 5 is an example]).



5. Map of Mississippi City, 1857.

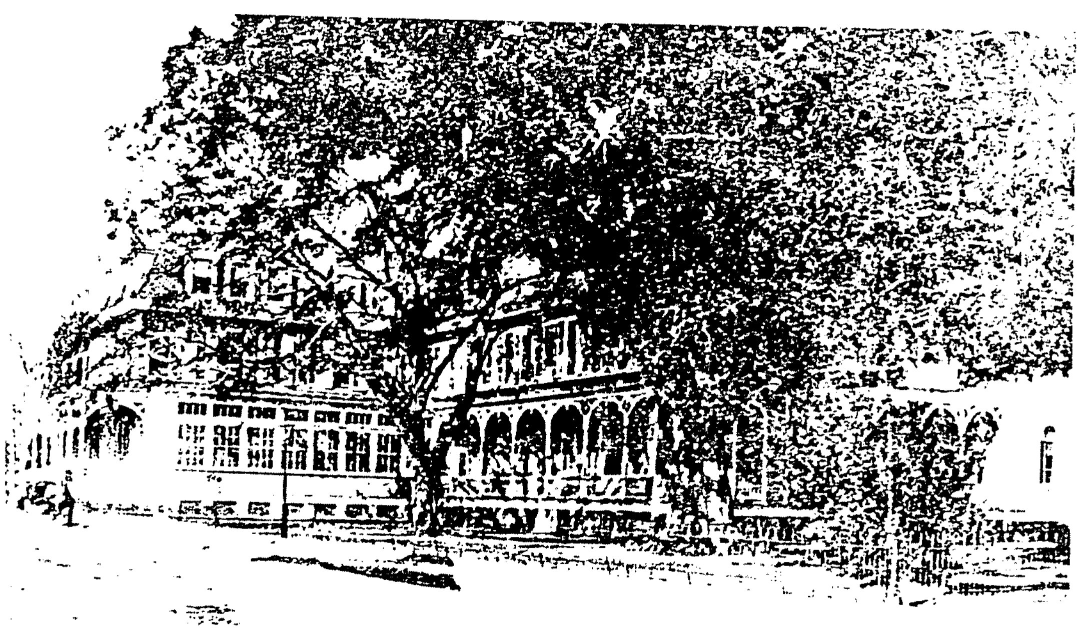


6. Christian Brothers College (former Pass Christian Hotel), 1866. (courtesy Ms. Dottie Cooper and Ms. Murella Hebert Powell, BPL)



7. Mexican Gulf Hotel, Pass Christian, built in 1883. (courtesy Ms. Murella Hebert Powell, BPL)

The spacious Mexican Gulf Hotel in Pass Christian around the turn of the century during the city's tourist boom. (Courtesy Mary Ellen Alexander)



8. Mexican Gulf Hotel, Pass Christian, ca. 1900. (courtesy Ms. Mary Ellen Alexander in source????)

Although the beach was occasionally used by horses and horses-and-buggies, no true "road" was built on the beach, and buggies often became mired in the sand. The building of structures (homes and commercial establishments) seaward of the scarp was relatively rare, although the commercial wharf zones of Pass Christian and Biloxi displayed this trend. The natural scarp also became "smoothed" by the construction of shore-normal roads and urbanization in general, and was no longer evident at Biloxi by the 1850s (see Figures 3 and 4).

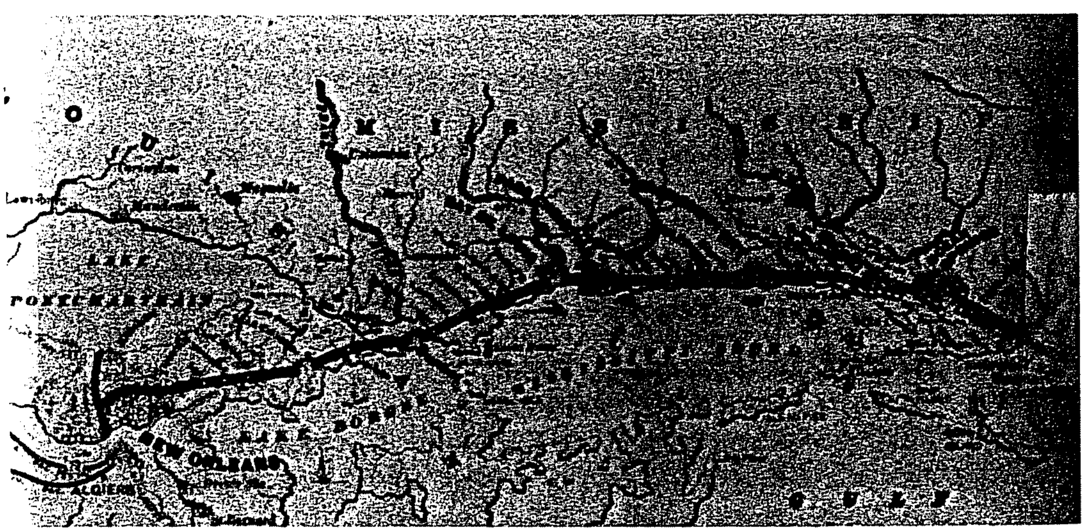
The Postbellum Period (The Gilded Age), 1865-1905

The incipient tourism boom was interrupted by the Civil War (see Sullivan et al., 1985, for a discussion of coastal Mississippi in the Civil War arena), and although most of the South entered a turbulent time of Reconstruction, the Mississippi Coast benefited from the Gilded Age affluence that characterized much of the rest of the nation. Hotels re-opened following the war, and steam packets from New Orleans again deposited tourists at the beachfront wharves (Figure 9). The opening of a rail line between New Orleans and Mobile in 1870 stimulated a new tourism boom by not only facilitating ease of access but also by expanding the touristic hinterland to the rest of the nation. The rail link to Northern and Midwestern markets inaugurated a phase of 'winter recreation' in Mississippi, which benefited the hotel industry by filling rooms that historically remained vacant during the local off-season. (The destination of migrating "snowbirds" shifted to more optimal climes as railroads expanded the winter recreation zone to southern California and ever southward into Florida, and the wintertime appeal of the Mississippi coast gradually diminished [Hayden, 1950].)

Summer tourism remained dominant, and the new east-west Mobile-New Orleans run of the Louisville & Nashville railroad did a booming business (Figures 10 and 11). Railroad trestles were built across St. Louis and Biloxi bays (Figure 12), and more hotels--ranging from modest to grand--were built in response to touristic demand (anon., 1885) (Figure 13). Because of their more aesthetic (and sandy) shorelines, Biloxi and Pass Christian remained the touristic centers along the Mississippi coast (Figure 14), although even beachless towns such as Pascagoula and Ocean Springs became sites of summer home construction (Figures 15 and 16). Non-beach attractions at Ocean Springs were the natural

Early tourists came to Ocean Springs and Jackson County in steamboats. Passengers had to be assured of safety from Indians before the turn of the century. (Courtesy M. James Stevens)

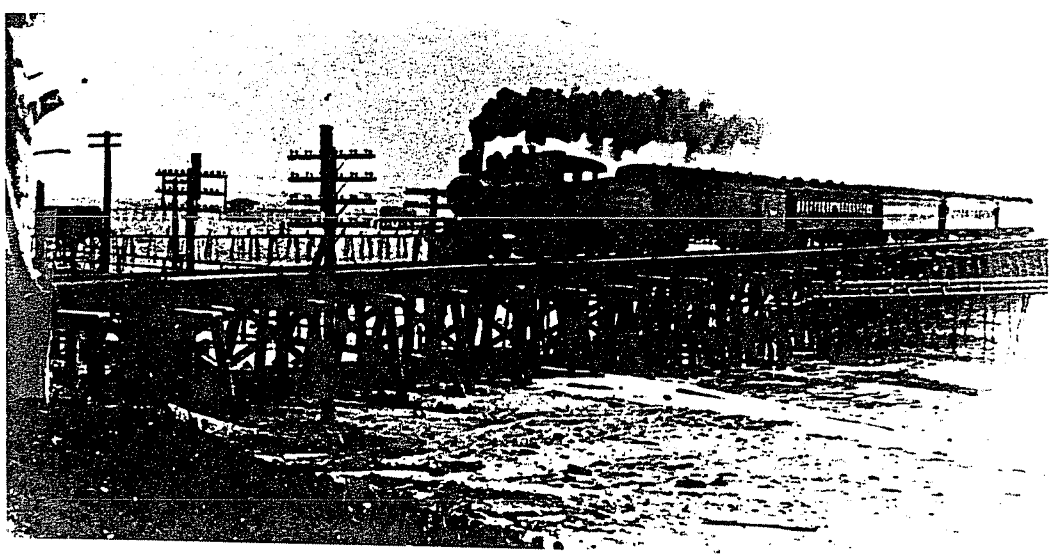
9. Steam packet advertisement, circa 1850s. (courtesy Ms. Murella Hebert Powell, BPL)



10. Louisville & Nashville Railroad map, late 19th century. (courtesy Ms. Murella Hebert Powell, BPL)

The Louisville and Nashville Depot, at New Orleans, La.

11. Louisville & Nashville Railroad depot, New Orleans, 1895. (courtesy Ms. Murella Hebert Powell, BPL)



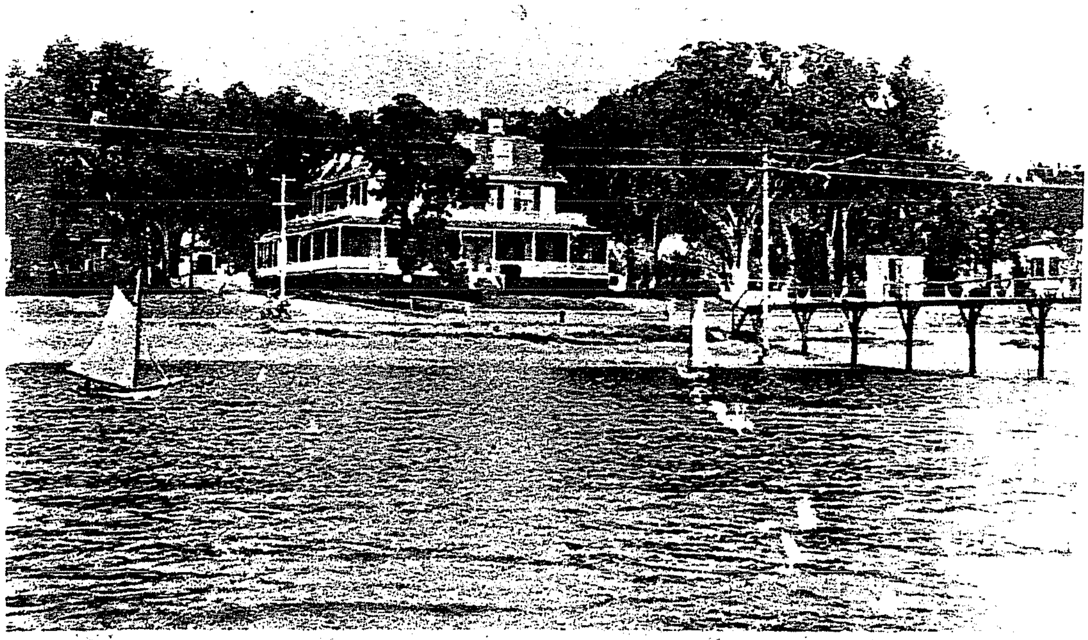
12. Mobile-New Orleans coast excursion train crossing Bay St. Louis bridge, 1904 (courtesy MS Department of Archives and History)

"health" springs (no longer flowing because of lowered groundwater tables) which appealed to "thermalists" and thus triggered a hotel-building boom.

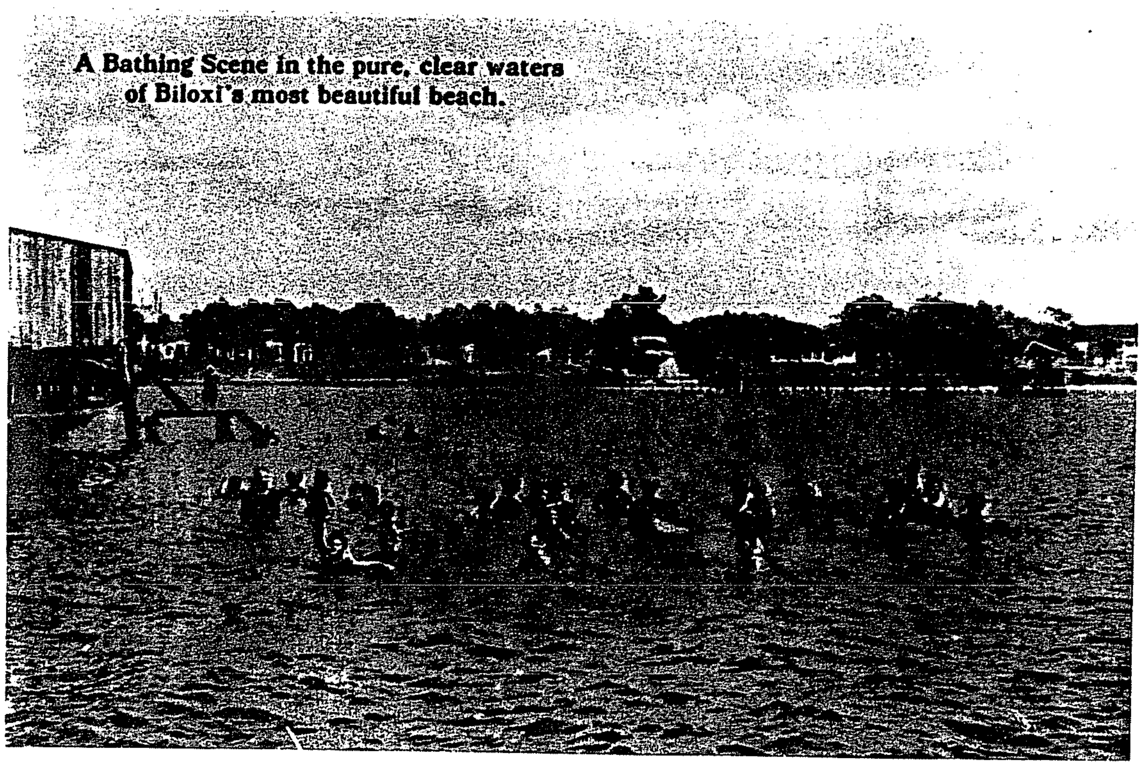
All of these events led to a greater coastal population and an increasingly complex coastal infrastructure. Prior to the 1870s, there was no formal "road" along the beach. The historic connection from east to west was along the Pass Christian-Port Cadet Road (Pass Road) which ran along the spine of the Pleistocene barrier. The 1870 Louisville & Nashville Railroad was built a short distance closer to the Sound. The beach became popular for strolling and buggy riding in the 1870s, although the latter often became mired in wet sand (Lang, 1936).

At about the same time, however, Biloxi became the center of a new seafood-canning industry, and previously underutilized resources such as shrimp and oysters became important commodities (Figure 17). The booming oyster industry produced a valuable byproduct--shells--which was first used for land reclamation of the Biloxi waterfront (Figures 18 and 19). These shells, crushed, also served as a suitable roadbed material and a partially shell-filled discontinuous beach road soon took on the name of 'old shell road' (Black, 1986; Sullivan et al., 1985) (Figures 20, 21, and 22). In places this shell road was built upon the backshore of the beach, yet in other places the road followed a course amidst the live oaks and above the scarp. In spite of a serious hurricane in 1893 which caused significant damage and shoreline erosion (Sullivan, 1985), the segments of the Shell Road gradually became extended. By the turn of the century, the beachfront contained telegraph poles and boardwalks and longer reaches of the Shell Road. Although another hurricane in 1901 caused extensive damage to the beachfront, plans for building a trolley line along the beach were not interrupted (Sullivan, 1985; Sullivan et al., 1985) (Figures 23, 24, and 26).

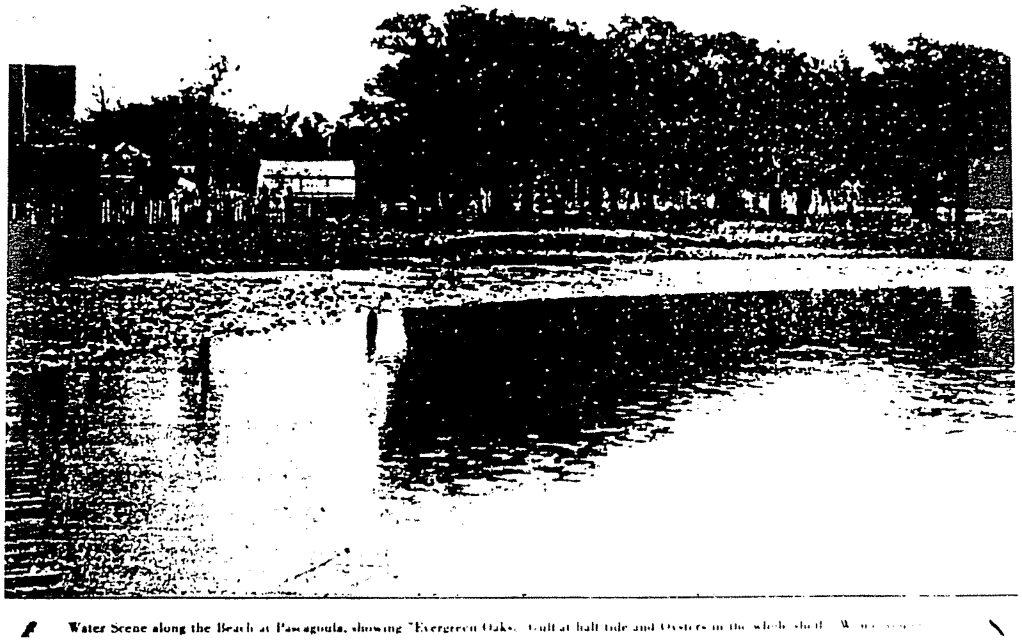
Also, a direct link with the interior of Mississippi finally was realized with the southward expansion of rail lines from Hattiesburg in the late 1880s (Black, 1986). The 1893 hurricane called attention to the need for a safer harbor (Alexander, 1980), and by the mid-1890s, a new port--incorporated as Gulfport in 1898--was built. An artificial harbor was created jutting out into Mississippi Sound, and a channel was dredged to Ship Island. The former Ship Island anchorage became obsolete, as ships could now dock directly at the end of the rail line (Black, 1986). Almost as



13. Memphis Hotel, Biloxi, n.d. [no date]. (courtesy Ms. Murella Hebert Powell, BPL)



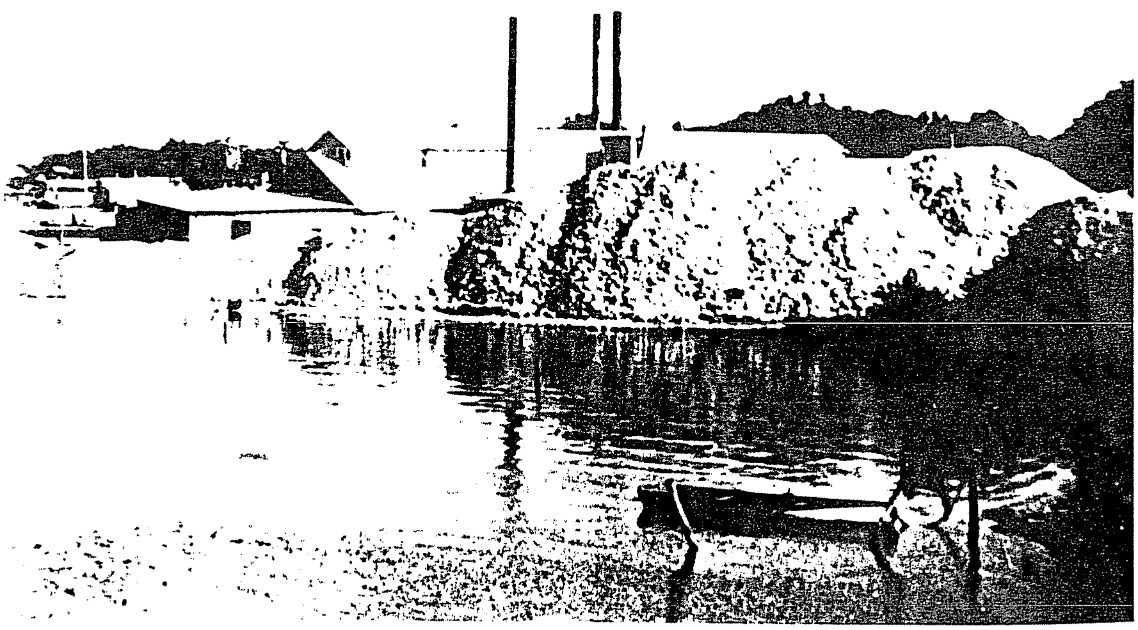
14. Biloxi bathhouse, early 1930s? (courtesy Ms. Kat Bergeron, The Sun Herald)



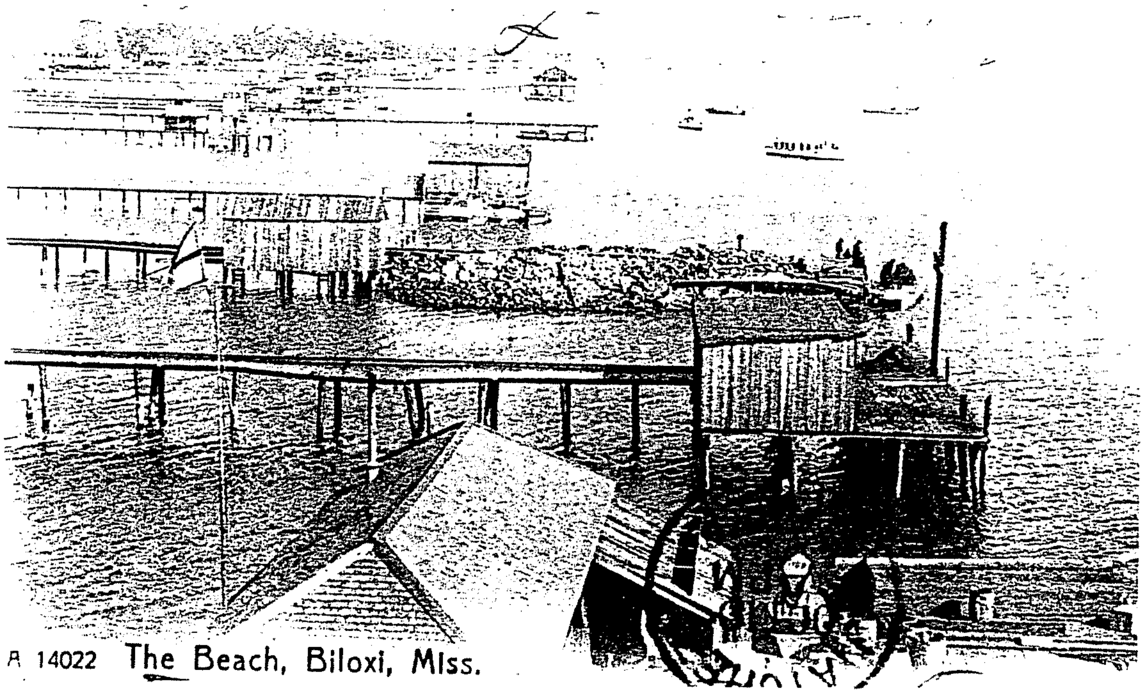
15. Pascagoula "beach" at half-tide, 1900. (courtesy The Sun Herald)

16. Ocean Springs waterfront, 1914. (courtesy The Sun Herald)

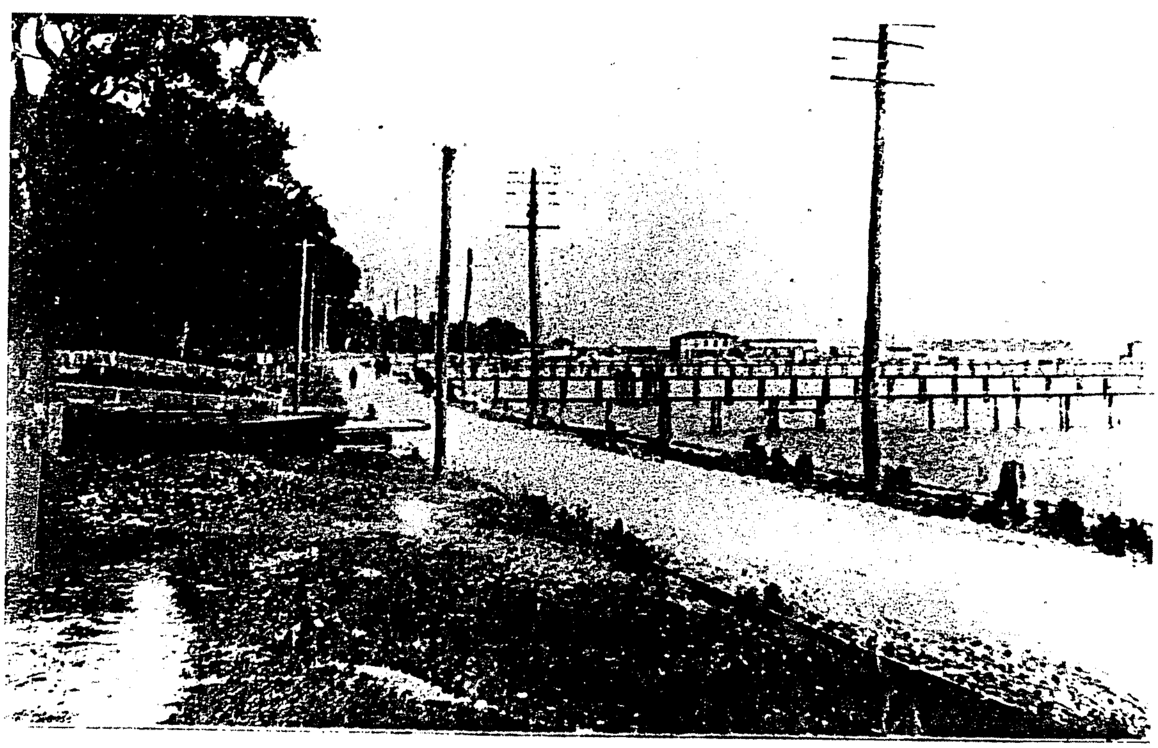
17. Shoveling oyster shells, 1930s. (courtesy Ms. Murella Hebert Powell, BPL)



18. Oyster shell mounds, East End, Biloxi, n.d. (courtesy Mr. George Ziz and Ms. Murella Hebert Powell, BPL)

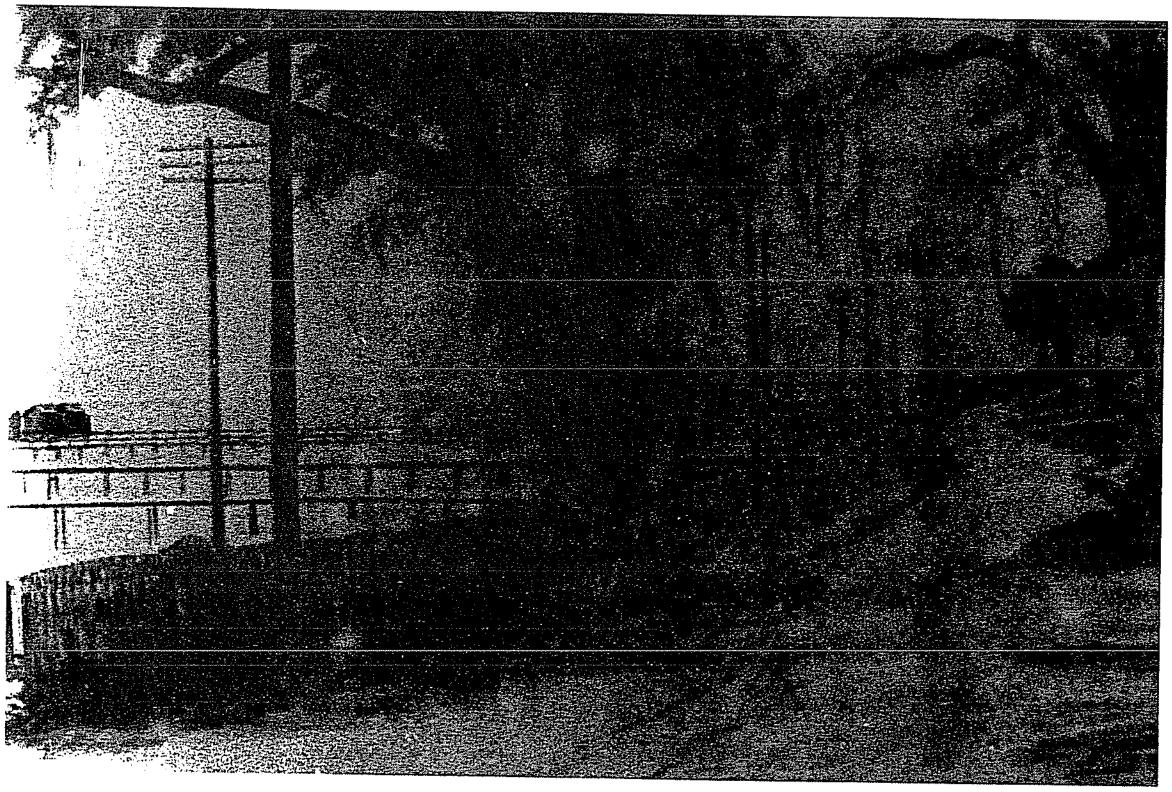


19. Oyster shell filling, Biloxi, 1907. (courtesy Ms. Murella Hebert Powell, BPL)

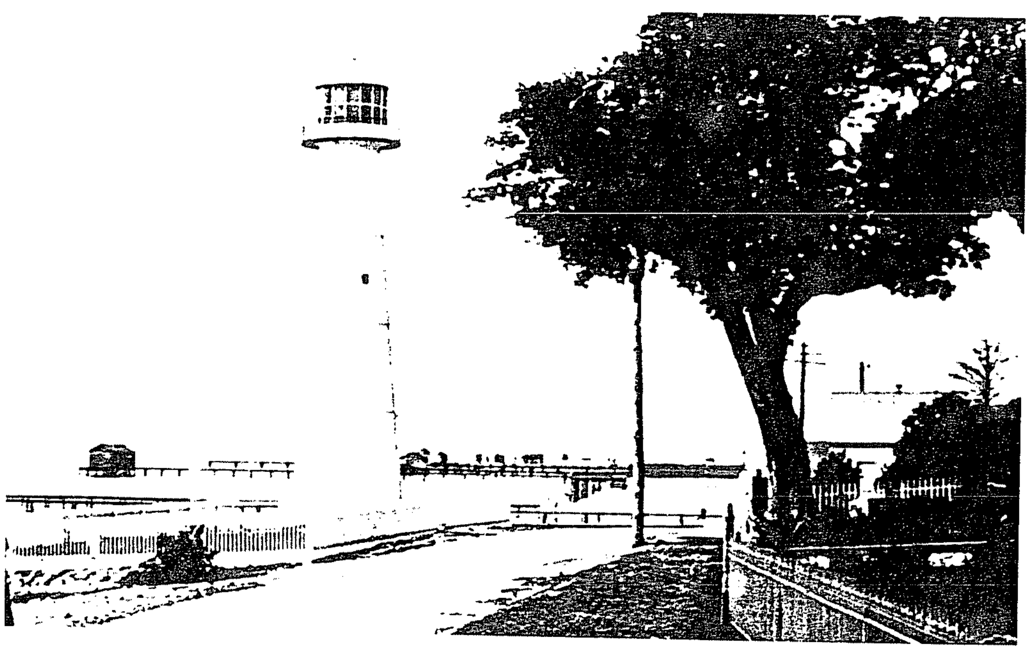


SHELL DRIVEWAY ALONG BILOXI BAY.

20. Shell road, Biloxi, 1905. (courtesy Ms. Kat Bergeron, The Sun Herald)



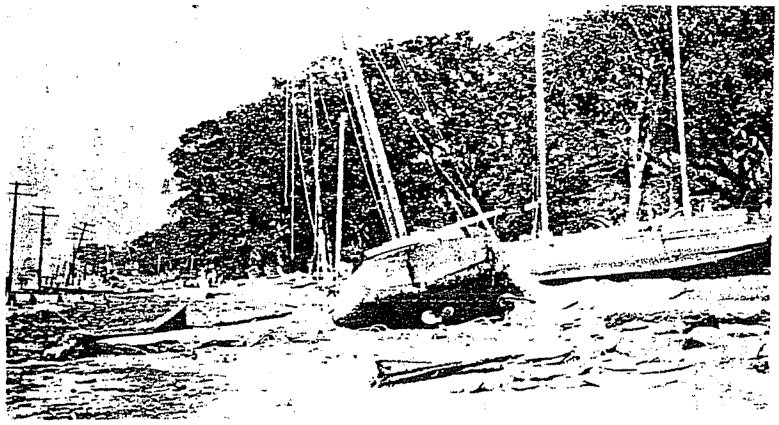
21. Shell road, Biloxi, 1890s [drawing by M. Scholtes Cramer]. (courtesy Ms. Kat Bergeron, The Sun Herald)



22. Shell road and Biloxi lighthouse, circa 1892. (courtesy Ms. Murella Hebert Powell, BPL)

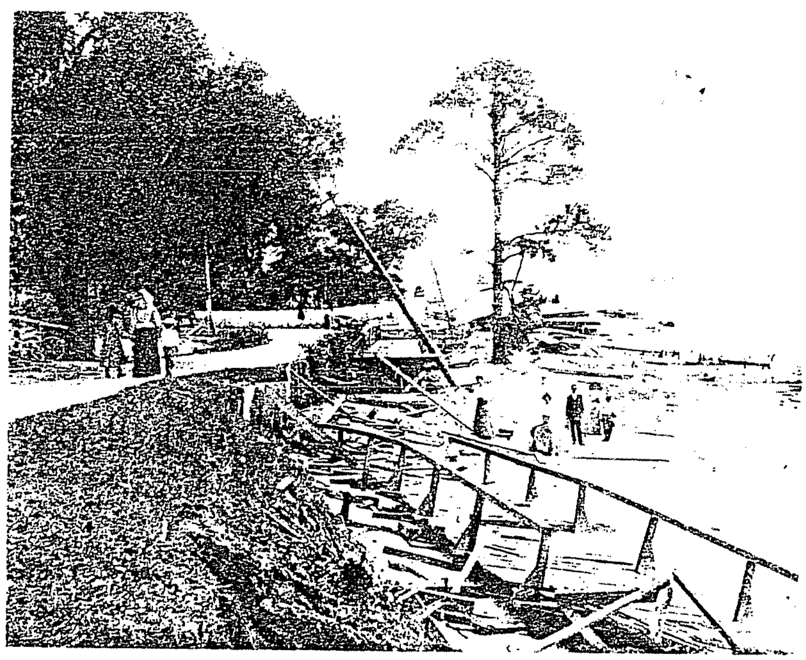
23. The trolley on West Beach, Biloxi, circa 1905. (courtesy Ms. Kat Bergeron, The Sun Herald)

24. Biloxi in the aftermath of the Aug. 15, 1901 hurricane. (courtesy Ms. Murella Hebert Powell, BPL)



Schooners block the shell road normally used by buggies and an occasional automobile in 1909. (Courtesy: O.M. 'Jac' Smith, Jr.)

25. Biloxi in the aftermath of the 1909 hurricane. (xeroxed from Sullivan 1985).



People out surveying the damage the morning after the 1901 storm found their beachfront drastically altered. Beach erosion was evident, and a boardwalk had fallen victim to the high waters. Faintly, the Biloxi Lighthouse rears like an apparition behind the tree at the center of the photo. (Courtesy: O.M. 'Jac' Smith)

26. Biloxi in the aftermath of the 1901 hurricane. (xeroxed from Sullivan 1985).

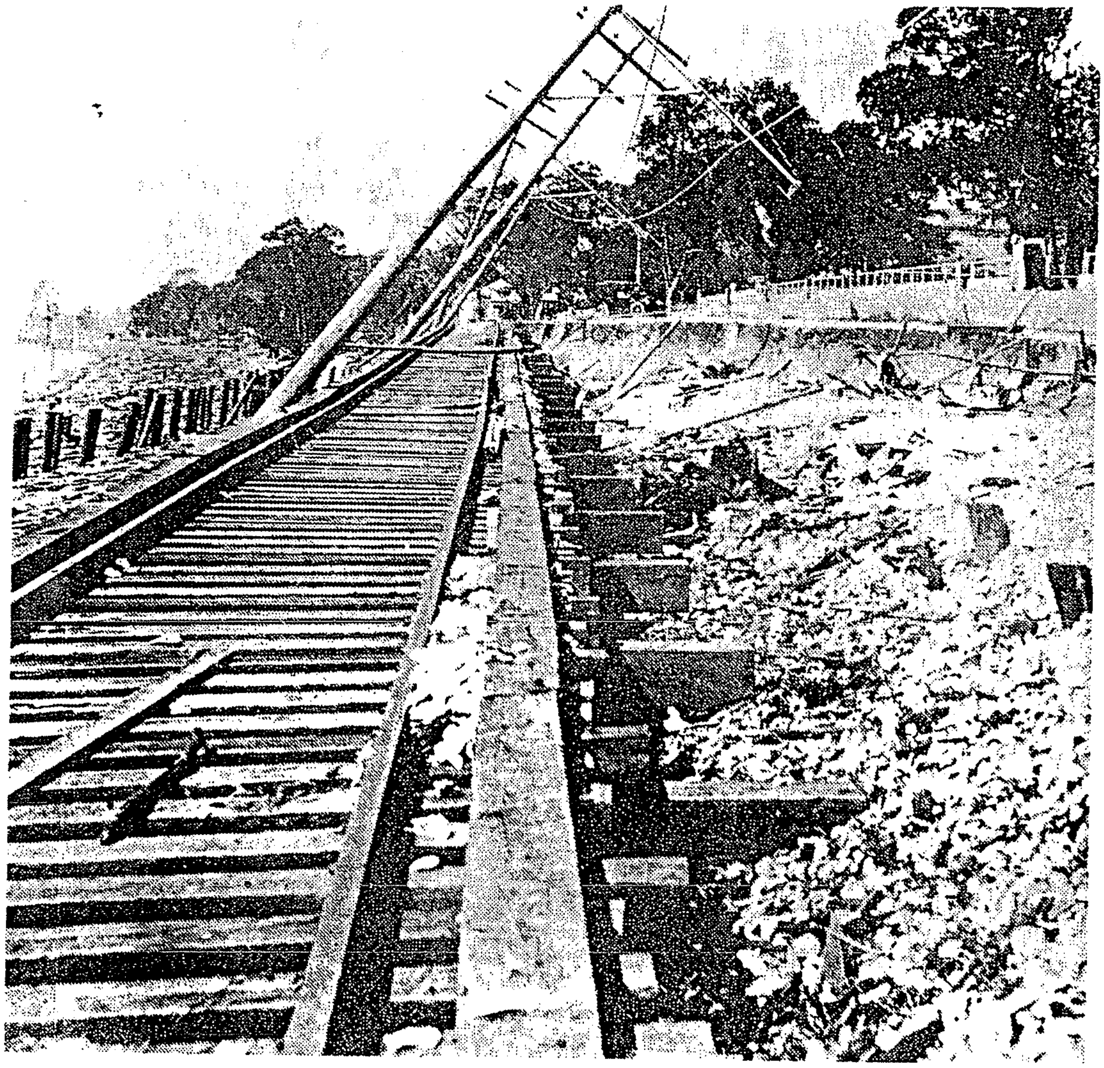
if to epitomize the opulent affluence of the Gilded Age, the grandest beach hotel along the Mississippi coast--the Great Southern Hotel--was built in 1903, the same year that the Gulfport Yacht Club and bathing pavilion opened (Black, 1986). Electricity came to the coast, the trolley connected Gulfport with Biloxi, tourism continued to increase, and human encroachment upon the beachfront increased as well.

Taming the Mississippi Shoreline, 1905-1951

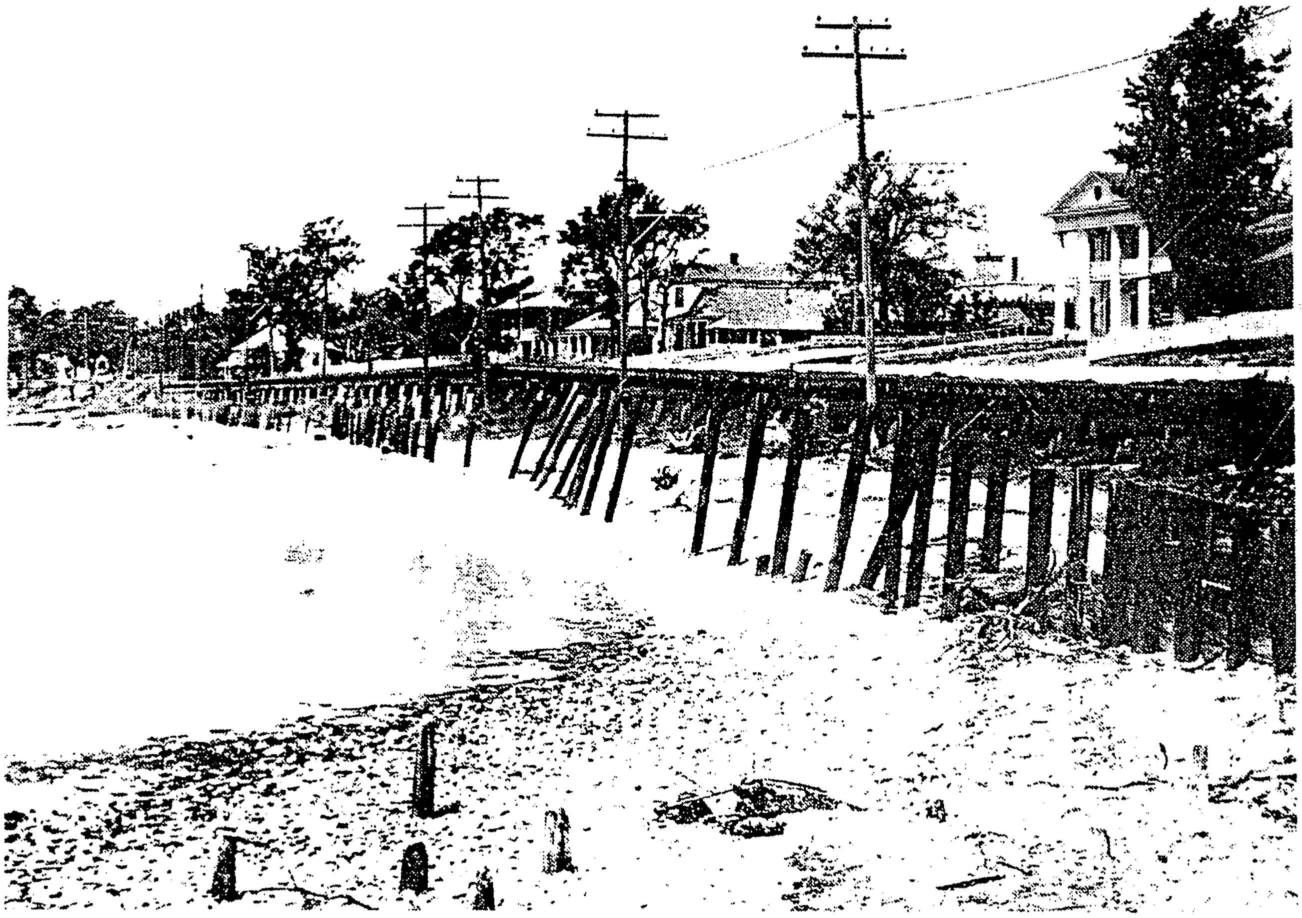
The dynamicism of the physical environment came to be more negatively perceived with this increasing human encroachment on the shorefront, particularly during storm events. When a 1909 hurricane caused serious damage to the shell highway and new interurban trolley (Figures 25, 27, and 28), petitioning for state involvement in erosion control began. A more severe hurricane in 1915 destroyed 50% of the beach roadway which was by then nearly continuous along Harrison County (Figure 29), and in the following year the Mississippi legislature passed a law committing the state to protect the beach "highway" (anon., 1930). Partly to ensure that the state commitment would be honored, the Harrison County communities linked and improved the old Shell Road and in 1918 rechristened it the "Old Spanish Trail" as part of a national tourism promotion effort (Figure 30). Rights-of-way were obtained, low areas were filled, and the road was graded and partially paved, a vast improvement over the oyster shells, according to Model T drivers (Bergeron, 1991). The route of the highway and the old trolley tracks appear on a 1916-17 coastal chart (Figure 31).

The 1916-17 coastal chart of the entire Mississippi coast, although not very detailed, does provide an idea of the variability of the beach environment at the time. Large sections of sea-fronting marsh are shown several miles west of Biloxi (not shown on Figure 31), and beach widths (which provide clues as to potential storm damages) also varied along the coast (Figures 32 and 33).

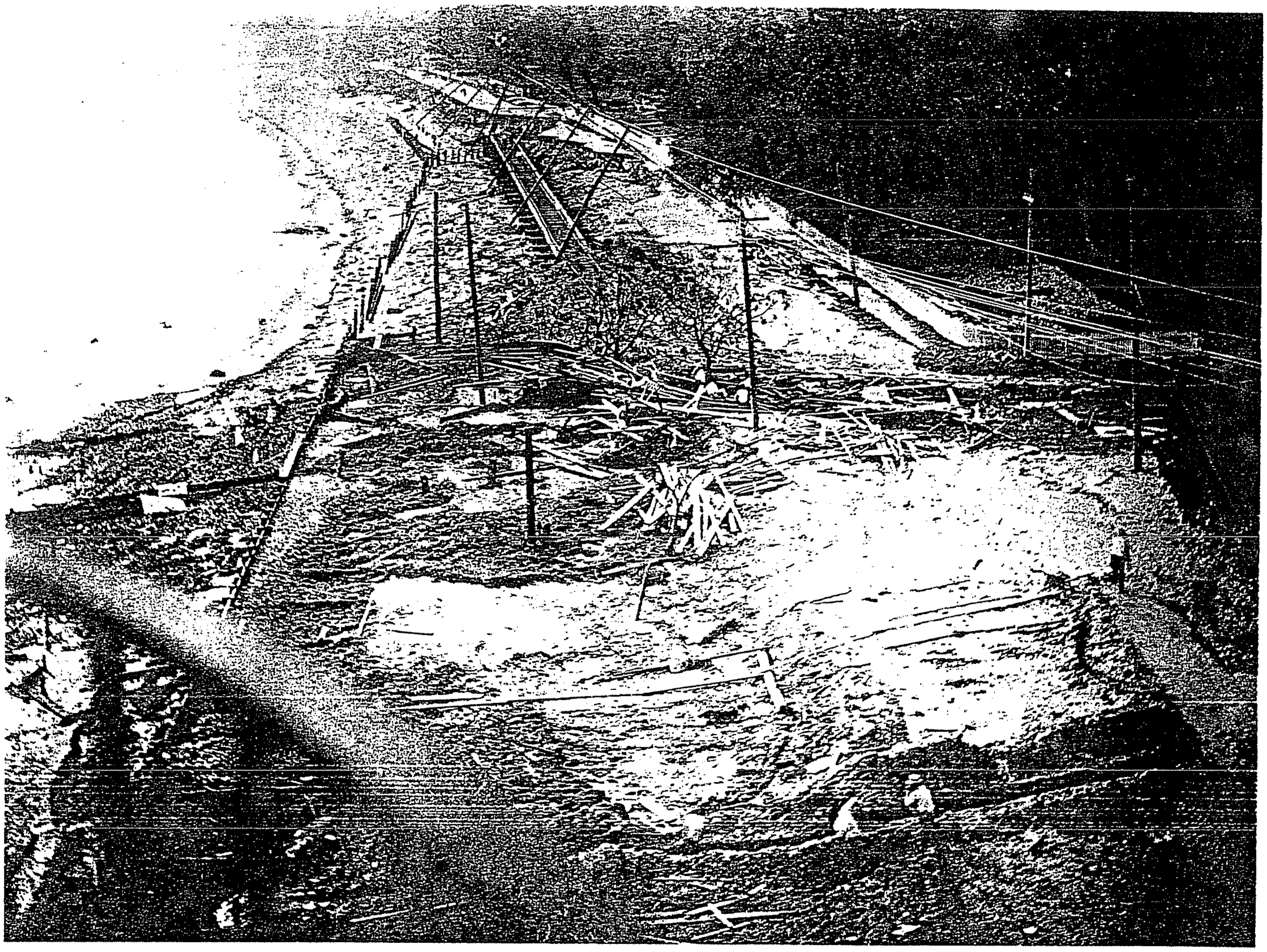
The 1915 storm directly stimulated seawall construction along the Mississippi coast. The greatest feat of all was the construction of the 42-km seawall fronting Harrison County, allegedly the second longest seawall in the world (Davis, 1988; Mississippi Department of Wildlife Conservation, 1986). Funded by a state tax on gasoline, the seawall was built between 1924 and



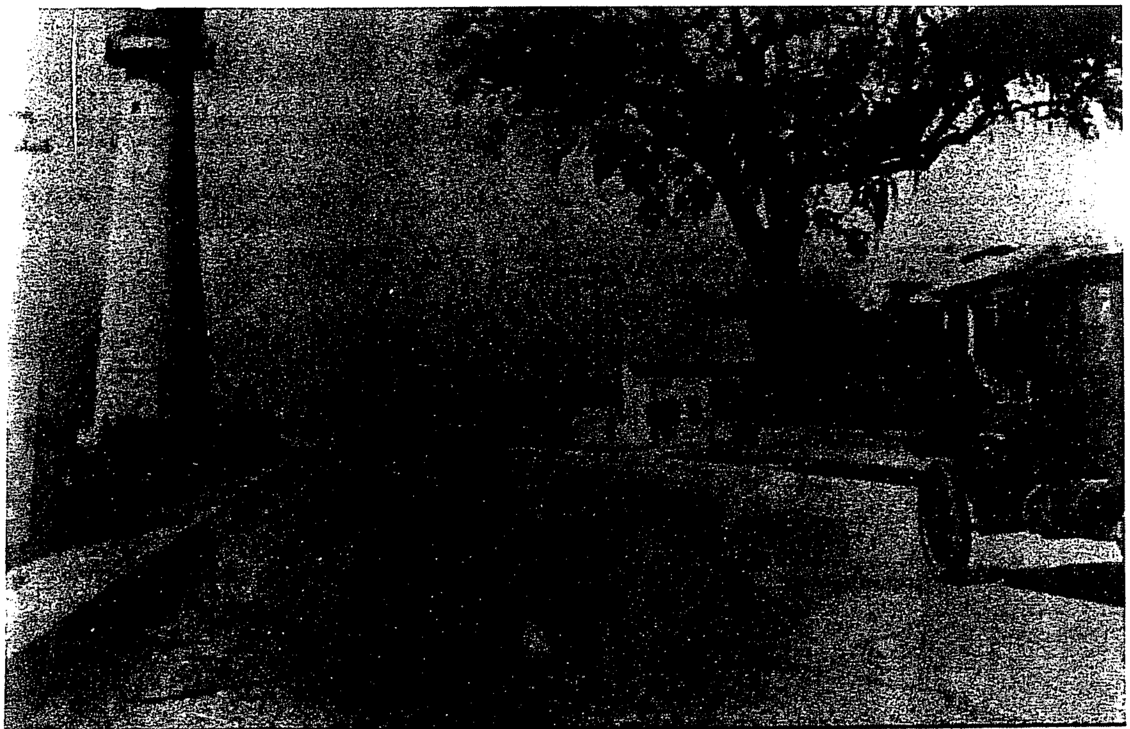
27. Interurban trolley track damage, Biloxi, 1909 (?). (xeroxed from Sullivan 1985).



28. Interurban trolley track damage, Biloxi, 1909 (?). (xeroxed from Sullivan 1985).

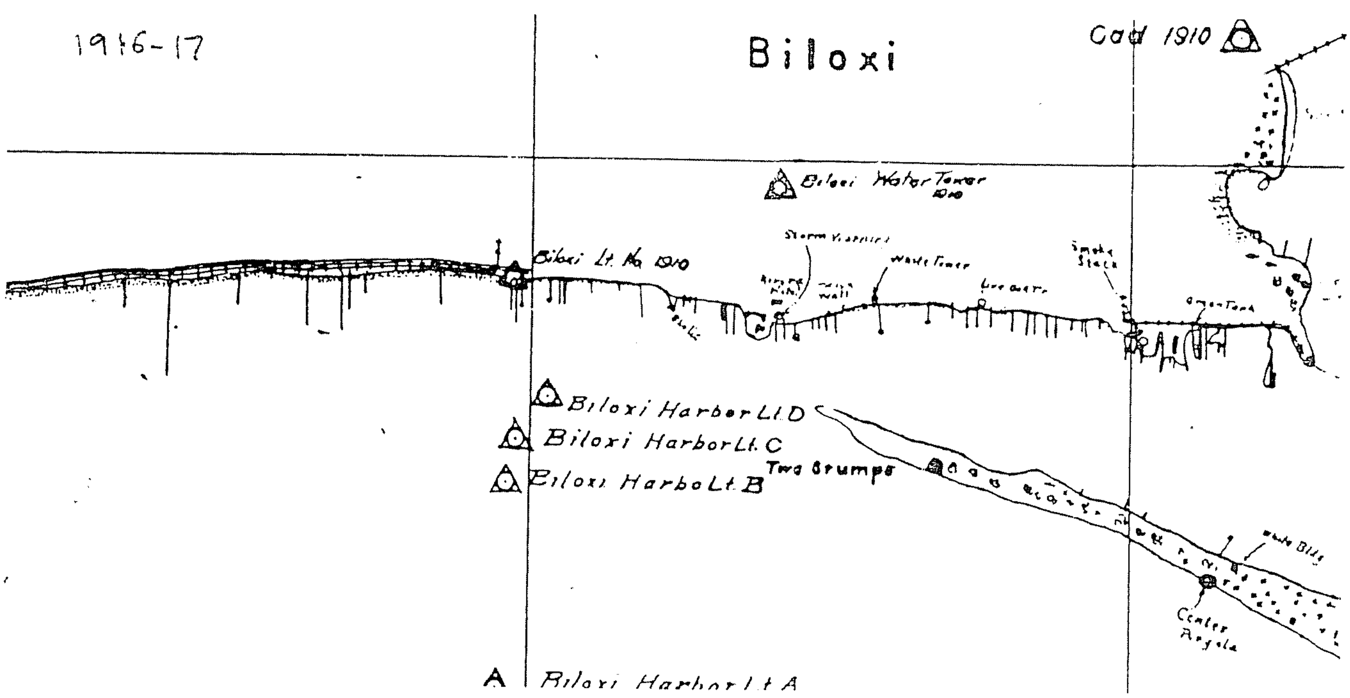

The view of West Beach photographed from the top of the Biloxi Lighthouse looking west shows how the angry seas of 1915 undermined the trolley tracks, fences, utility poles and beach. (Courtesy: Mae Henley)

29. Interurban trolley track damage, Biloxi, 1915. (xeroxed from Sullivan 1985).

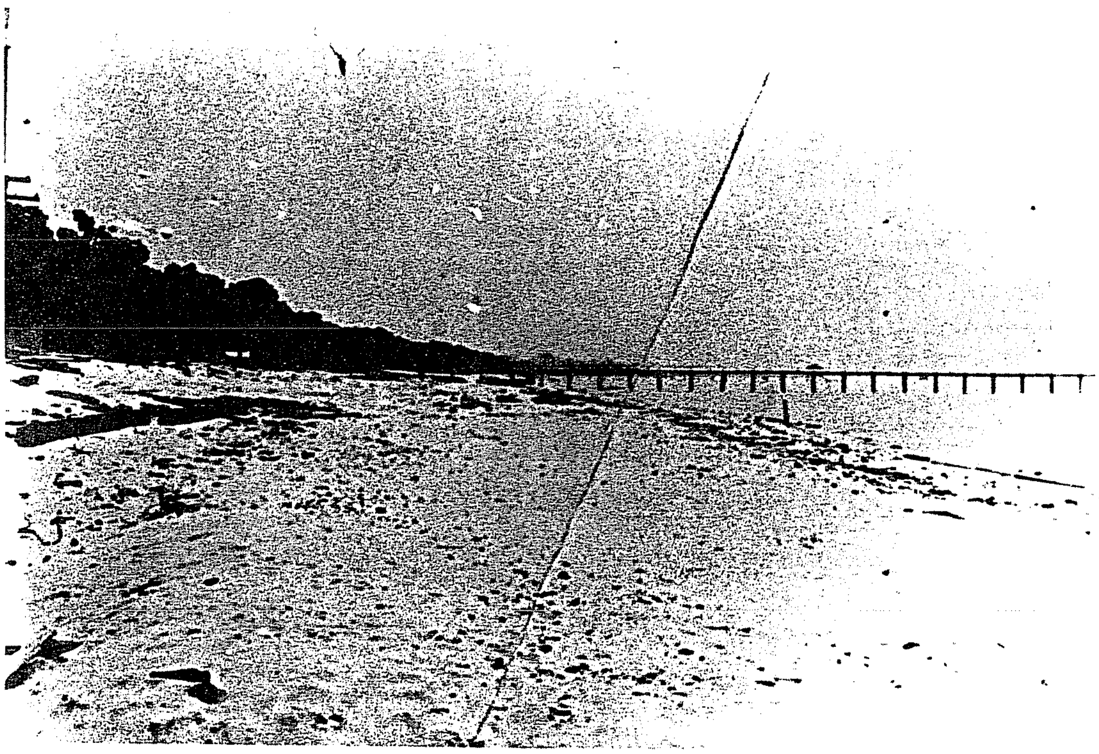


A Model T tools down the forerunner to U.S. 90 in Biloxi, circa 1918. In January 1916, prisoners graded the roadwa

30. New motor road and Biloxi lighthouse, 1918. (courtesy Ms. Kat Bergeron, The Sun Herald)

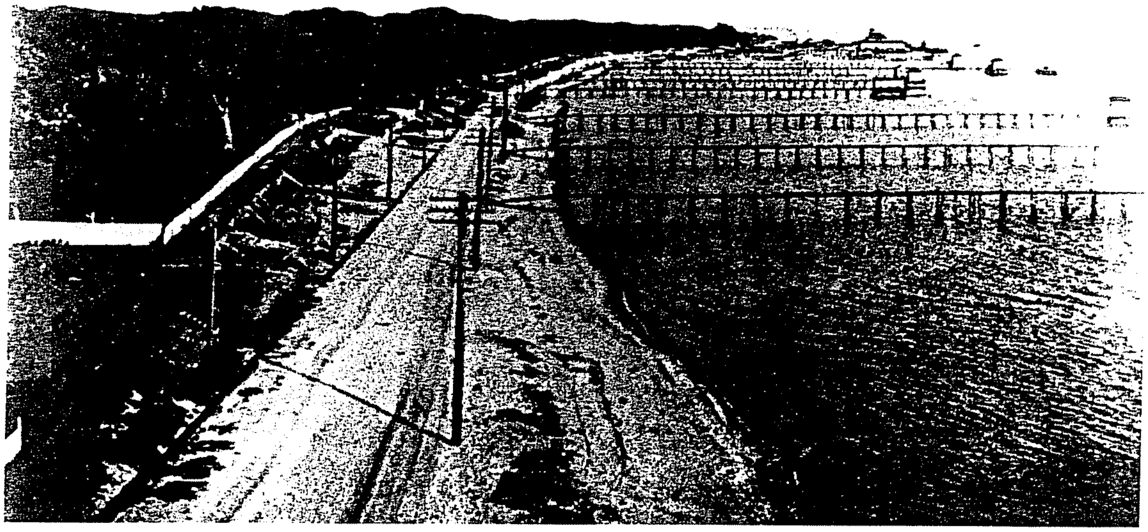


31. Map of Biloxi, 1916-17.

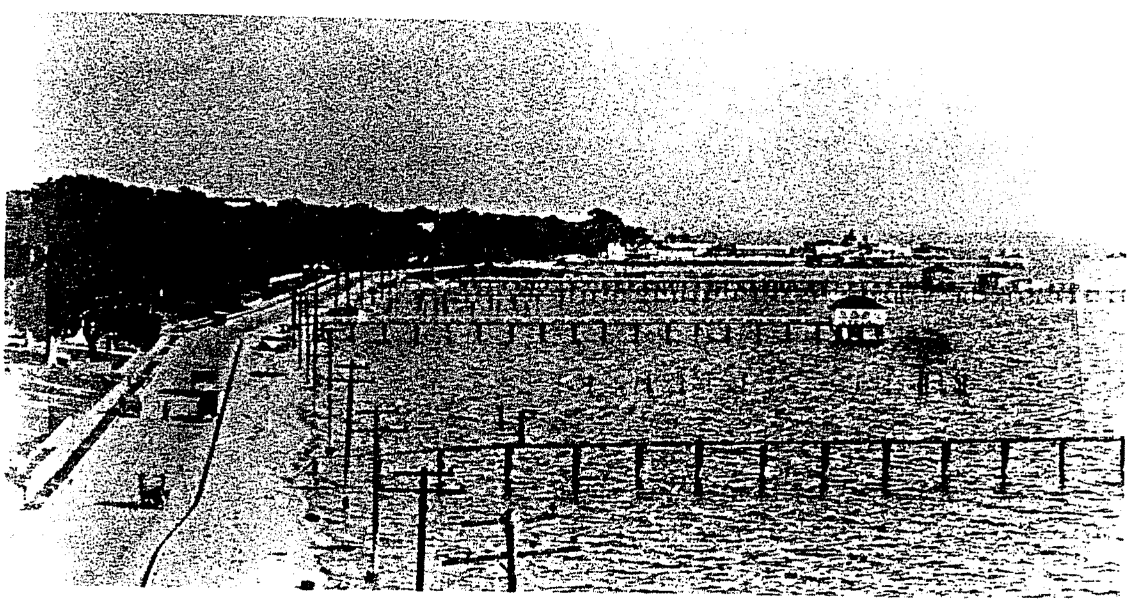


32. West Beach, Biloxi, 1920s (?). (courtesy Ms. Murella Hebert Powell, BPL)

33. Beach fronting Great Southern Golf Club, Gulfport, 1920s. (courtesy The Sun Herald)

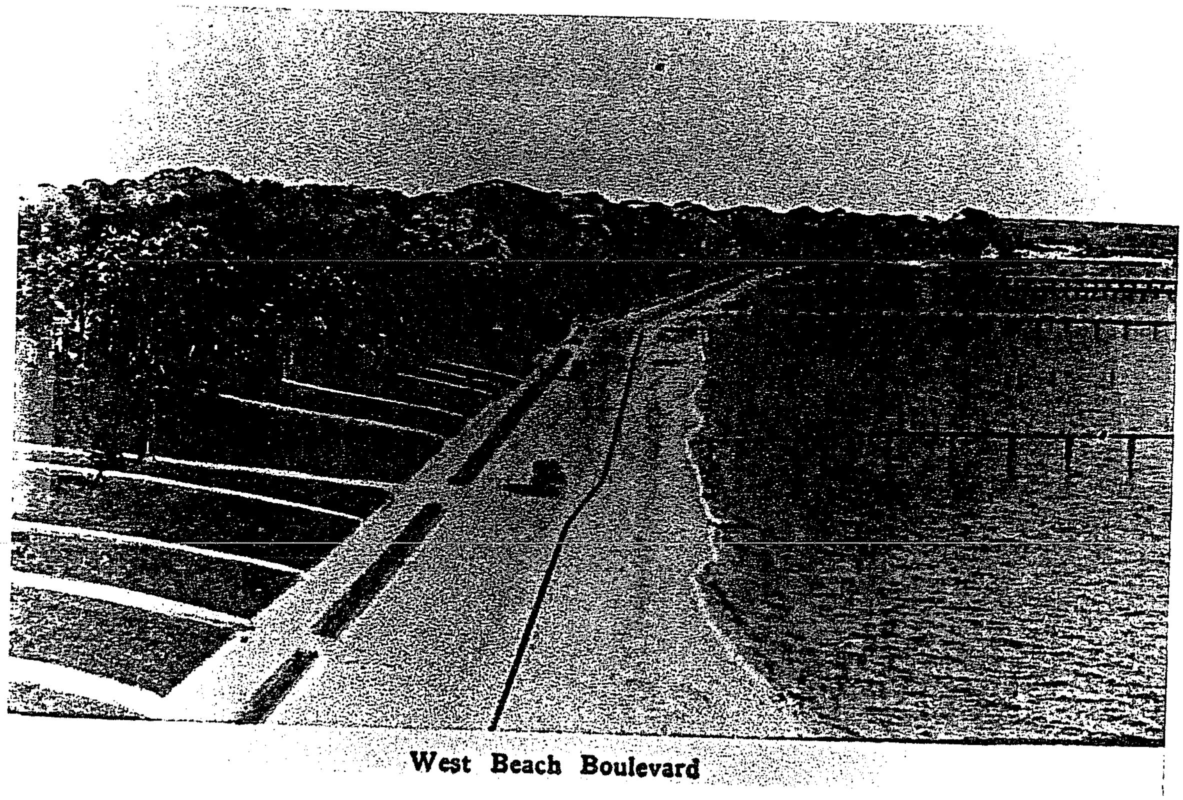


34. West Beach, Biloxi from lighthouse, 1909-1911. (courtesy Ms. Murella Hebert Powell, BPL)

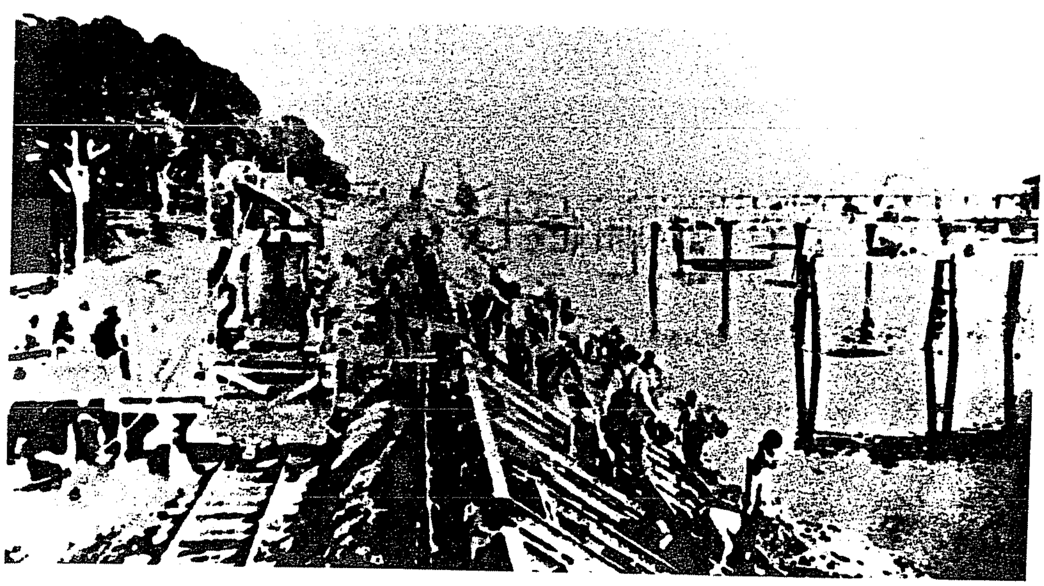


Looking east on Biloxi's West Beach Boulevard in the 1920s. (Courtesy Dixie Press)

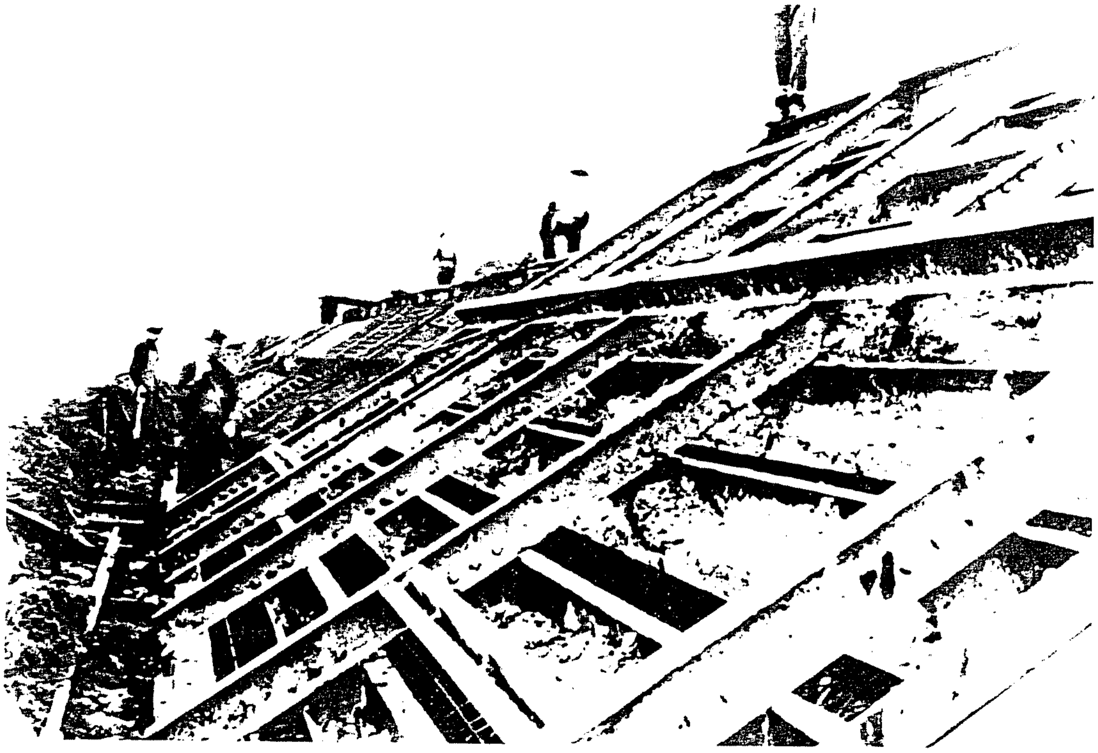
35. West Beach, Biloxi from lighthouse, early 1920s. (courtesy Ms. Murella Hebert Powell, BPL)



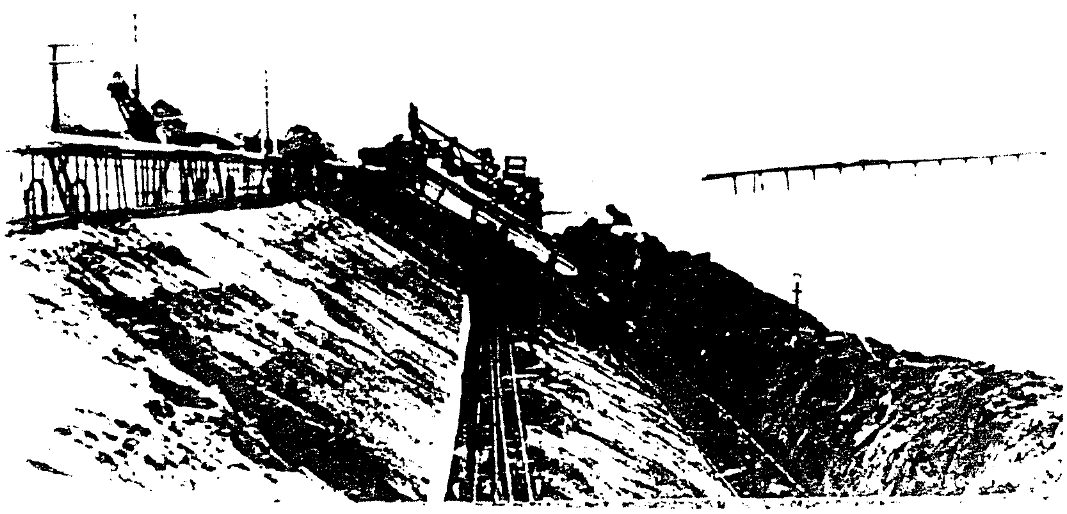
36. West Beach, Biloxi from lighthouse, late 1920s. (courtesy Ms. Kat Bergeron, The Sun Herald)



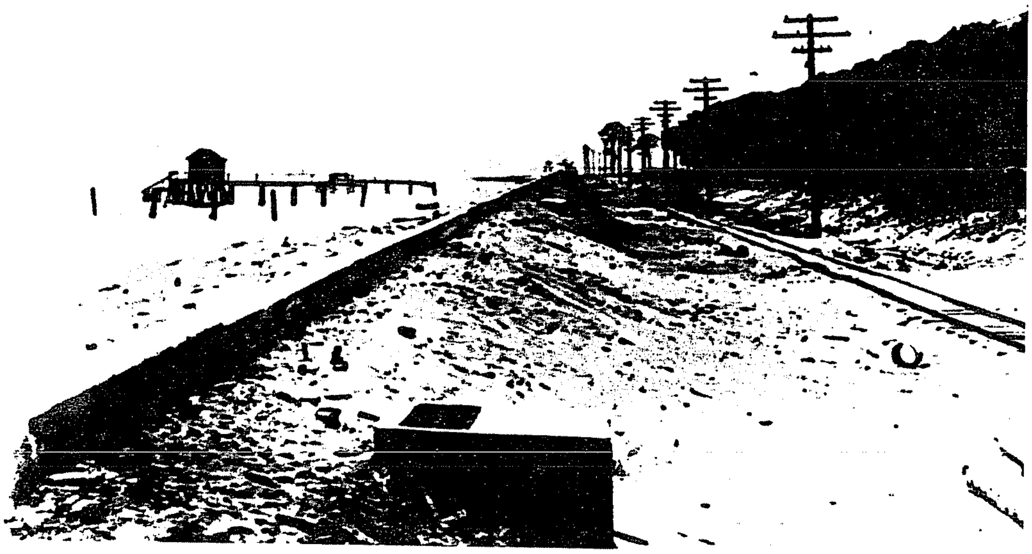
37. Construction of Harrison County seawall, 1924. (courtesy Ms. Murella Hebert Powell, BPL)



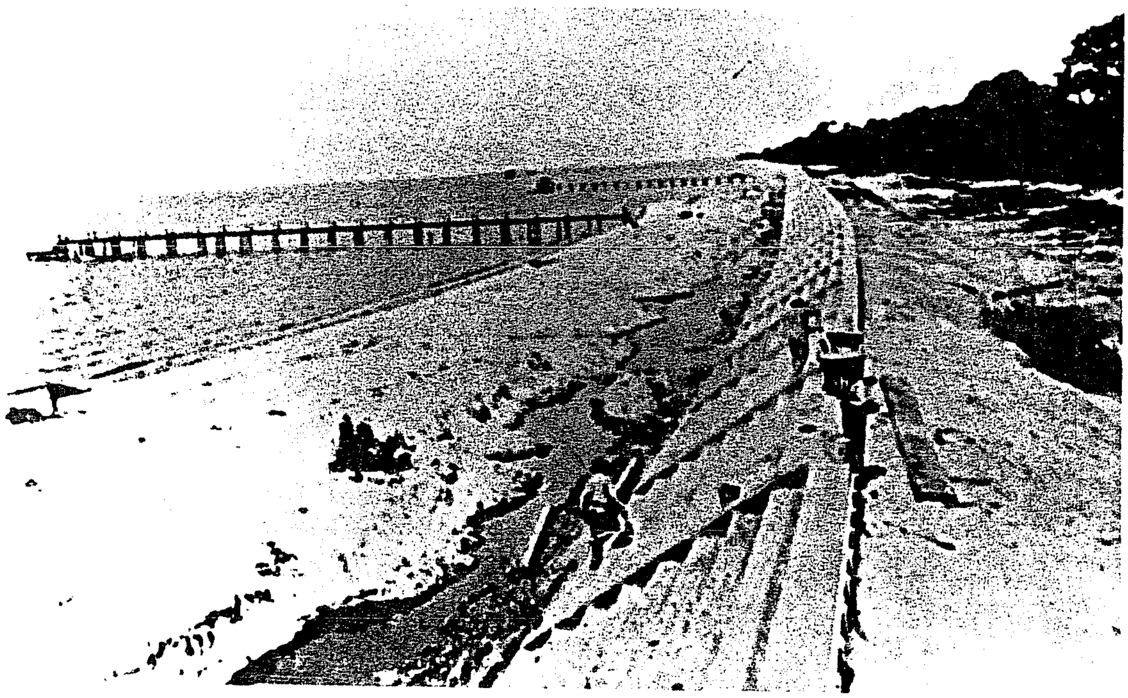
38. Construction of Harrison County seawall, 1920s. (courtesy Library of Congress and Ms. Murella Hebert Powell, BPL)



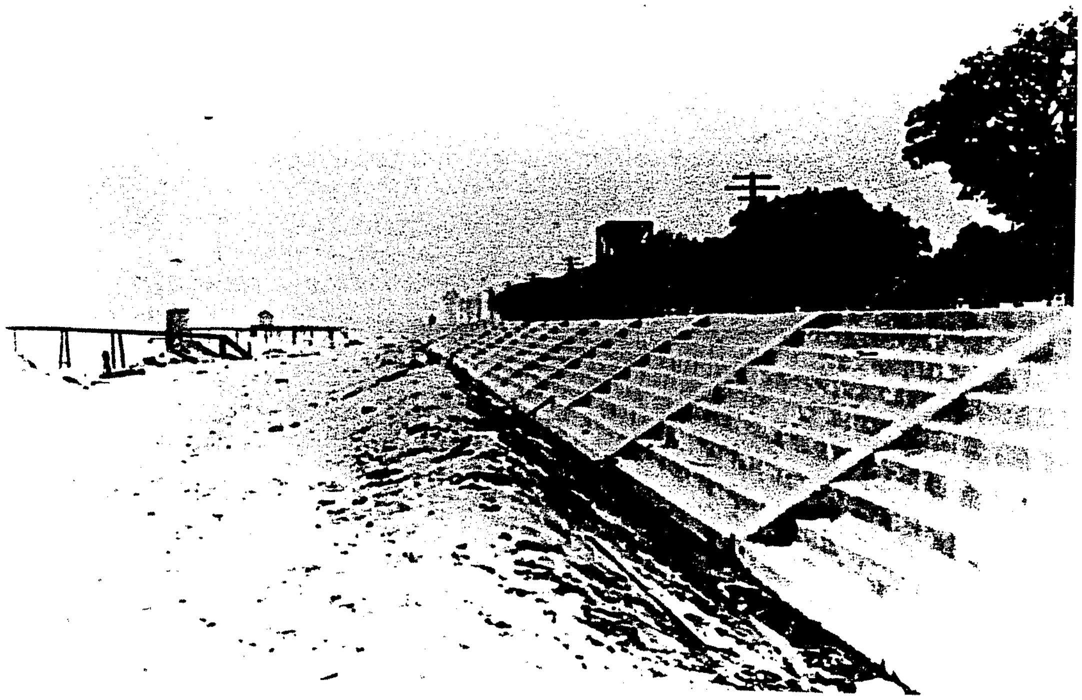
39. Construction of Harrison County seawall, 1920s. (courtesy Library of Congress and Ms. Murella Hebert Powell, BPL)



40. Construction of Harrison County seawall, 1920s. (courtesy Library of Congress and Ms. Murella Hebert Powell, BPL)

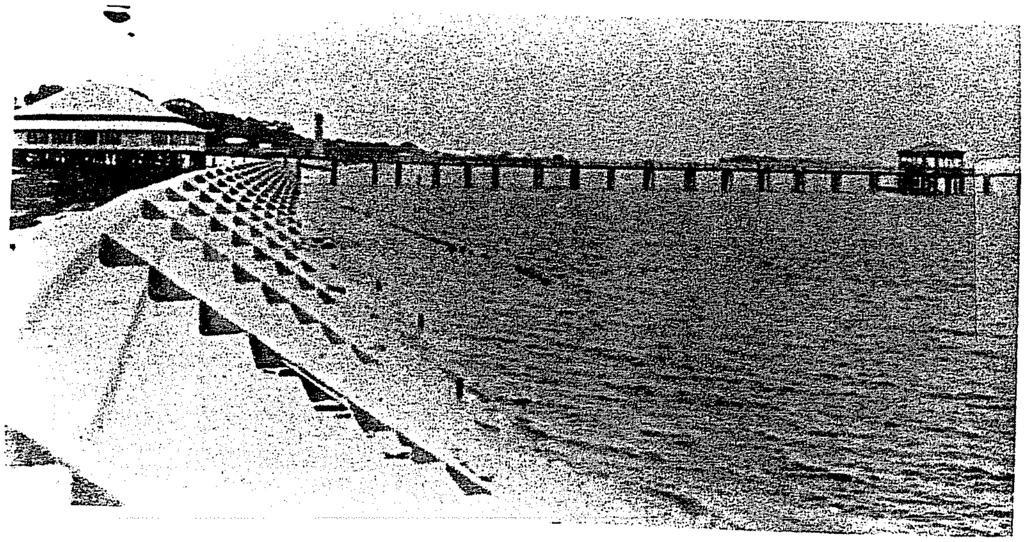


41. Construction of Harrison County seawall, 1920s. (courtesy Library of Congress and Ms. Murella Hebert Powell, BPL)

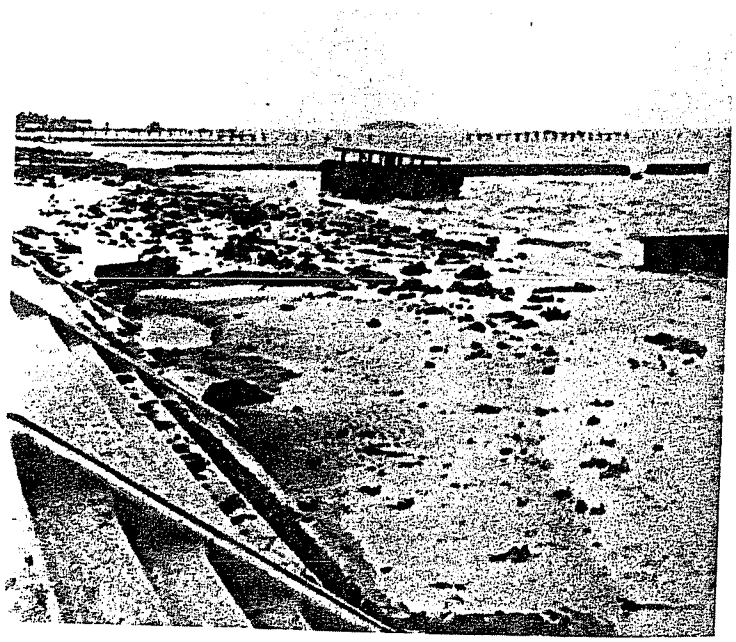


42. Construction of Harrison County seawall, 1920s. (courtesy Library of Congress and Ms. Murella Hebert Powell, BPL)

43. Completed Harrison County seawall, 1920s. (courtesy Library of Congress and Ms. Murella Hebert Powell, BPL)



44. Completed Harrison County seawall, 1940s. (courtesy Ms. Murella Hebert Powell, BPL)



45. Completed Harrison County seawall, 1920s. (courtesy Library of Congress and Ms. Murella Hebert Powell, BPL)

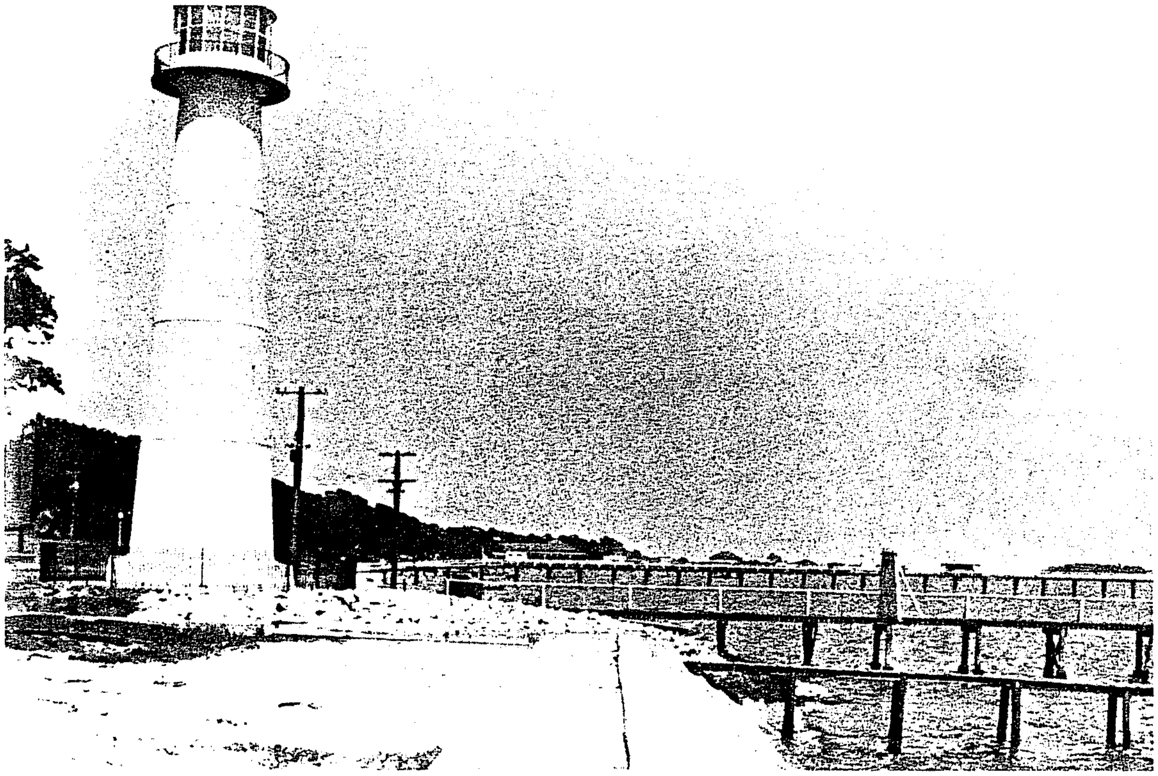
1928 (Sullivan et al., 1985). A series of photographs (Figures 34, 35, and 36) taken between 1909 and the late 1920s from the Biloxi lighthouse clearly show the impacts of the 1915 hurricane as well as the alteration of the coastal landscape as a result of seawall construction and utility pole removal. (The scarp along the Pleistocene barrier also shows up clearly on Figure 34.) Although the seawall does not appear all too impressive in the view from the lighthouse, its 8-ft high (5 ft in some sections) stepped-concrete construction (the design having been borrowed from the Dutch) was a major undertaking (Figures 37, 38, 39, 40, 41, and 42). Construction of the seawall coincided with the great land boom of the Roaring Twenties, and perhaps the security of the seawall contributed to the rampant building of summer homes and hotels (including the Buena Vista, the Tivoli, the Edgewater Gulf, and the White House).

Although the seawall proved to effectively protect the highway and coastal property in the absence of severe storms, the narrow natural beach quickly disappeared, especially to the west of the Biloxi lighthouse (Figures 43, 44, and 45). The lighthouse marked a "nodal point" in the armored Mississippi shoreline for several reasons. Sited on a slight beach promontory, it had been subject to erosion since the 19th century and was perhaps the first structure armored with riprap along the Mississippi coast. This riprap was in place at the time of seawall construction, and the lighthouse effectively separated two reaches of seawall (Figures 46 and 47). Also, eastward from the lighthouse, an indentation of the shoreline led to a subsequent inland-curving and (apparently) lower section of seawall (Figures 48, 49, and 50). In spite of some scouring of beach sands fronting the seawall (especially west of the Biloxi lighthouse), the seawall was viewed quite positively overall.

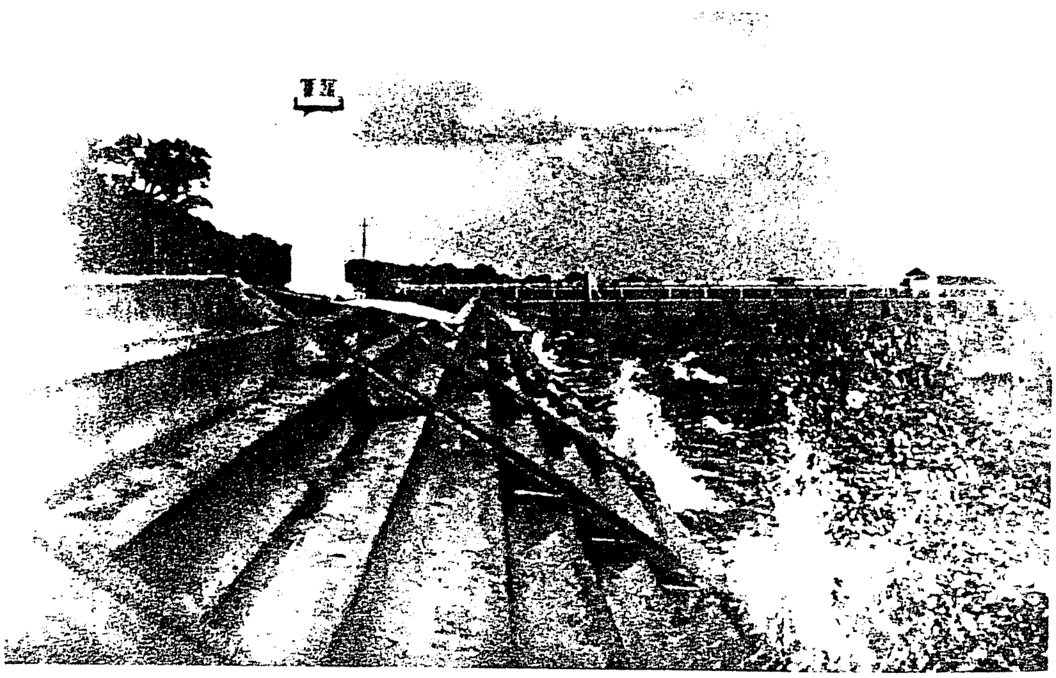
Hancock County, which began to build a seawall on a piecemeal basis in 1915 modeled its 18.5-km-long, stepped seawall after that of Harrison County, and following its completion in 1928--at which time the adjoining Beach Boulevard was constructed--a series of groins was built within which efforts to maintain a sand beach eventually proved ineffective (Sand Beach Planning Team, 1986). The cities of Pascagoula and Ocean Springs also completed seawalls in the late 1920s, although the step design was not adopted (Higginbotham, 1967; Kinser, 1982; and Prior, 1947) (Figure 51). In spite of the Stock Market Crash of 1929, tourism continued to

46. Seawall and riprap, Biloxi lighthouse, circa 1940. (courtesy Ms. Murella Hebert Powell, BPL)

47. Seawall and riprap, Biloxi lighthouse, late 1940s. (courtesy Ms. Murella Hebert Powell, BPL)

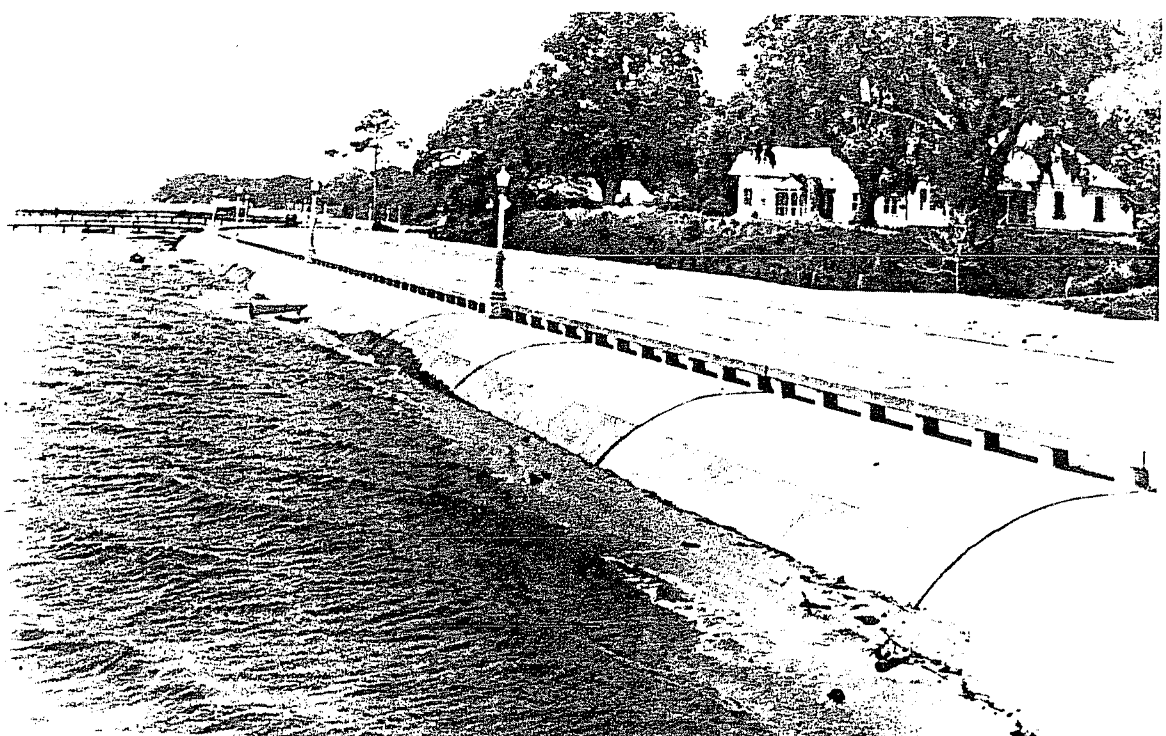


48. Seawall and riprap, Biloxi lighthouse, late 1940s. (courtesy Ms. Murella Hebert Powell, BPL)



49. Seawall and riprap, Biloxi lighthouse, late 1940s. (courtesy Ms. Murella Hebert Powell, BPL)

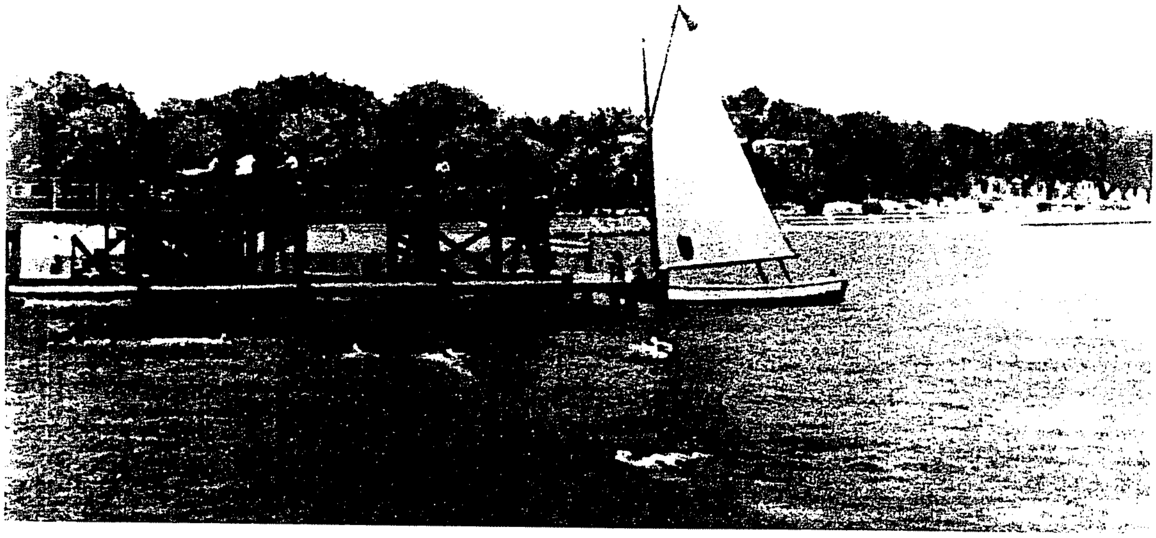
50. West Beach, Biloxi, early 1930s (?). (courtesy Ms. Kat Bergeron, The Sun Herald)



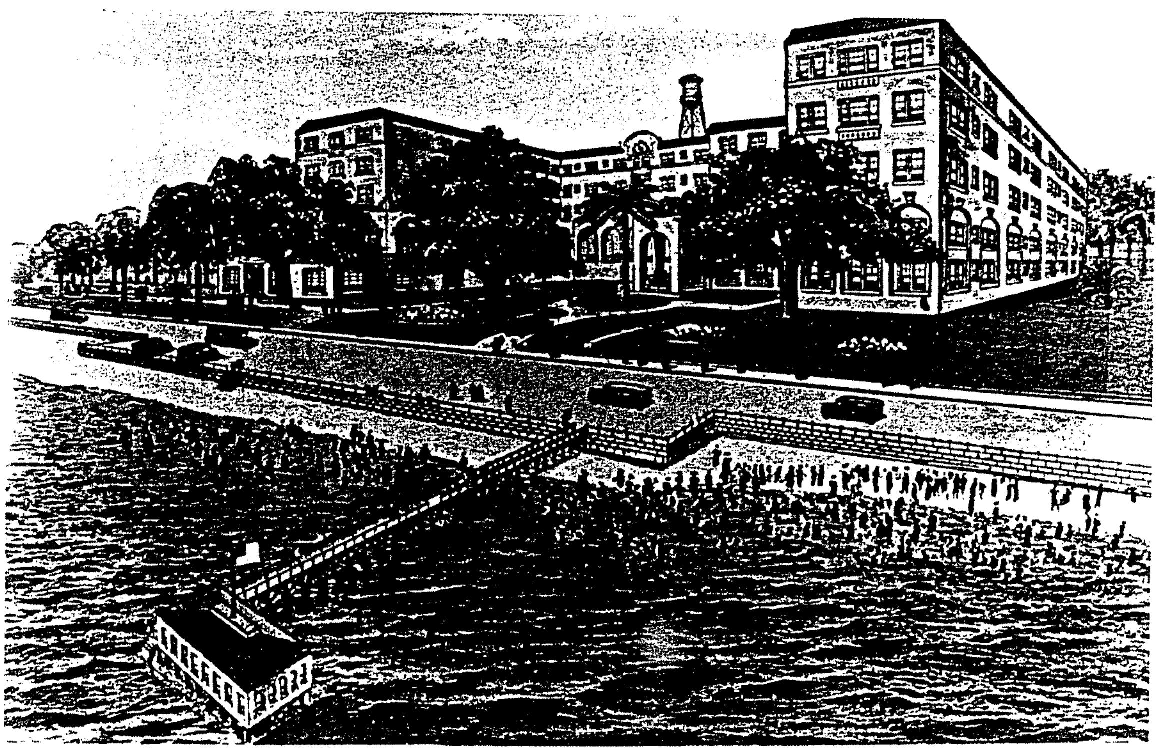
Springs' beachfront, 1942, before the coming of the sand beach. (Courtesy Dixie Press)

51. Front Beach, Ocean Springs, 1942. (courtesy Ms. Murella Hebert Powell, BPL)

B-3—Pier Scene Along the Shoreline of Biloxi, Mississippi

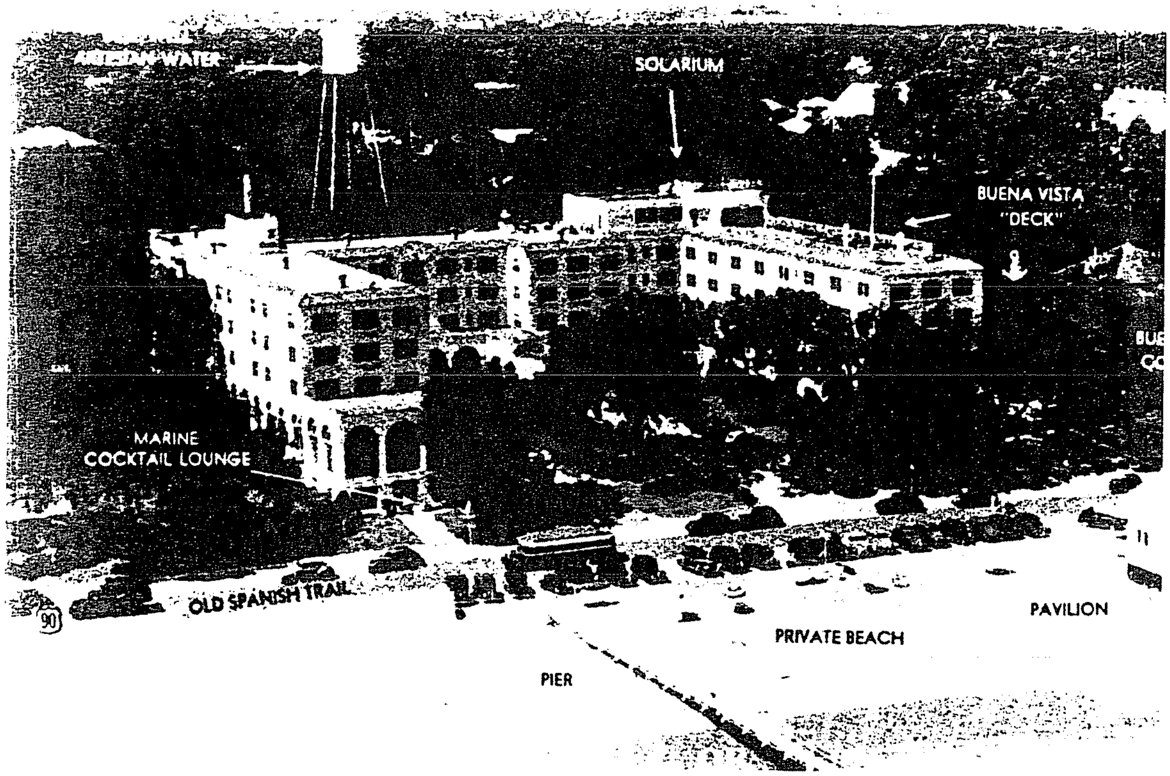


52. Biloxi community pier, early 1930s. (courtesy Ms. Kat Bergeron, The Sun Herald)

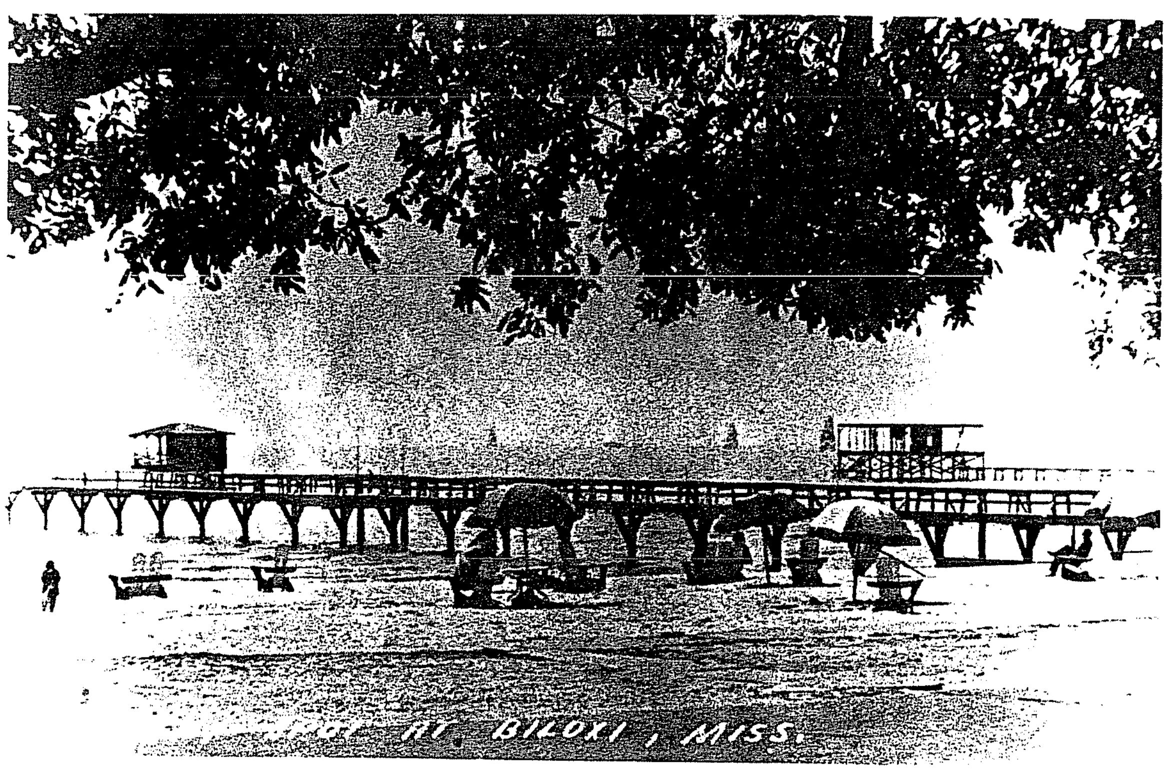


Buena Vista Hotel

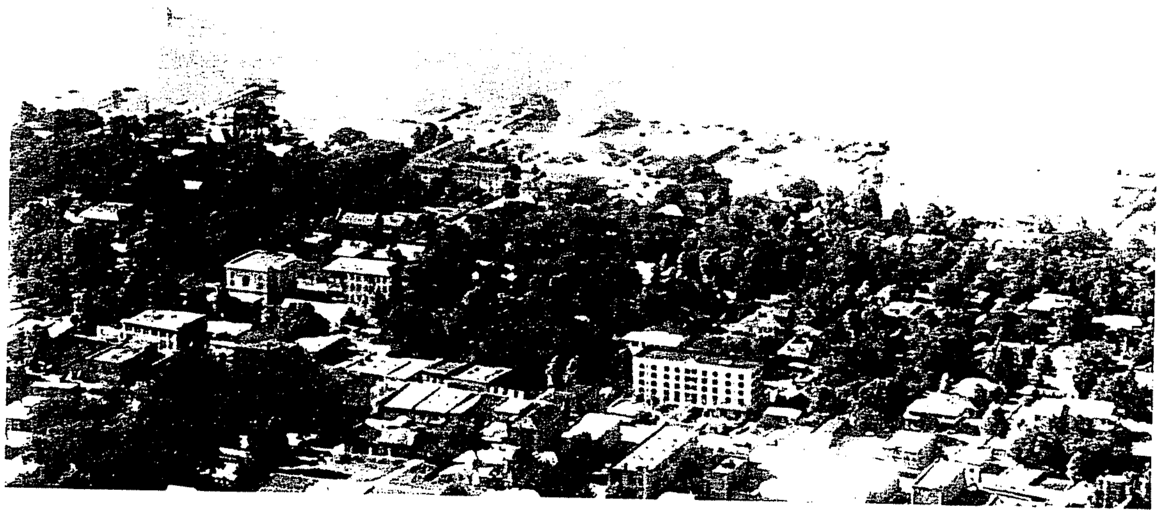
53. Sketch of Buena Vista Hotel, Biloxi, late 1920s. (courtesy Ms. Kat Bergeron, The Sun Herald)



54. Buena Vista Hotel, Biloxi, 1939. (courtesy Ms. Murella Hebert Powell, BPL)



55. Beach fronting Buena Vista Hotel, Biloxi, 1930s. (courtesy Ms. Kat Bergeron, The Sun Herald)



56. Air photo of Biloxi, 1930s. (courtesy Ms. Murella Hebert Powell, BPL)

57. Air photo of Biloxi (Buena Vista Hotel at right), 1930s. (courtesy Ms. Murella Hebert Powell, BPL)

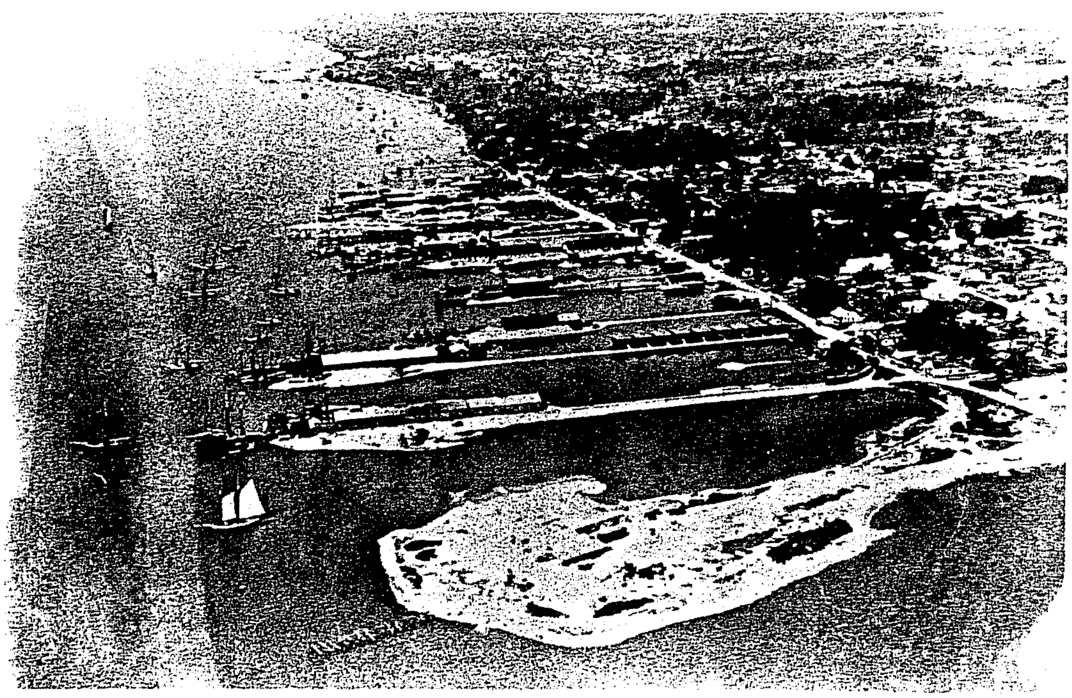
keep much of the Coast's economy afloat, and most of the hotels stayed in business throughout the 1930s (Prior, 1947) (Figure 52).

Biloxi's Buena Vista Hotel was perhaps the grandest of the Mississippi coast hotels during this period (Figures 53 and 54), and it was fortunate in being able to retain a natural sand beach in front of it (Figure 55). This may be partially attributed to its site partially in the lee of Deer Island and offshore shoals which both sheltered the shore from damaging storms (thereby minimizing beach erosion) and also perhaps nourished the beaches (Figures 56 and 57). East of the commercial Biloxi waterfront (site of the Biloxi Yacht Club, the bathing pavilion, and numerous wharves), now extensively modified by reclamation and dock construction (Figure 58), lay both the touristically popular but historically narrow beach known as East Beach as well as most of Biloxi's numerous seafood processing plants (Figure 59). Although Biloxi's centers of tourism activity included the commercial waterfront and East Beach, the favored site for bathing was increasingly Central Beach where the sand beach was much wider (Figures 60 and 61).

At East Beach as well as West Beach west of the Biloxi lighthouse, the natural beaches gradually disappeared in the 1930s and 1940s, and scenes of saltwater lapping up against the seawall were not uncommon (Figures 62, 64, and 65). In spite of the loss of the major natural resource--the sand beach--along most of Mississippi's armored shorelines, the protection afforded by the seawalls allowed the lateral spread of beachfront urbanization (Prior, 1947). One of few hotels built in the economically depressed 1930s was the Broadwater Beach Hotel, which was completed along West Beach in 1940 (Prior, 1947). To restore the tourist resource, the Broadwater created its own sand beach by constructing two groins and pumping sand between them (Figure 66). Bay St. Louis also--again--experimented with beach nourishment in the early 1940s, but--perhaps because of the greater influence of tidal currents--the sands gradually washed away (Sand Beach Planning Team, 1986).

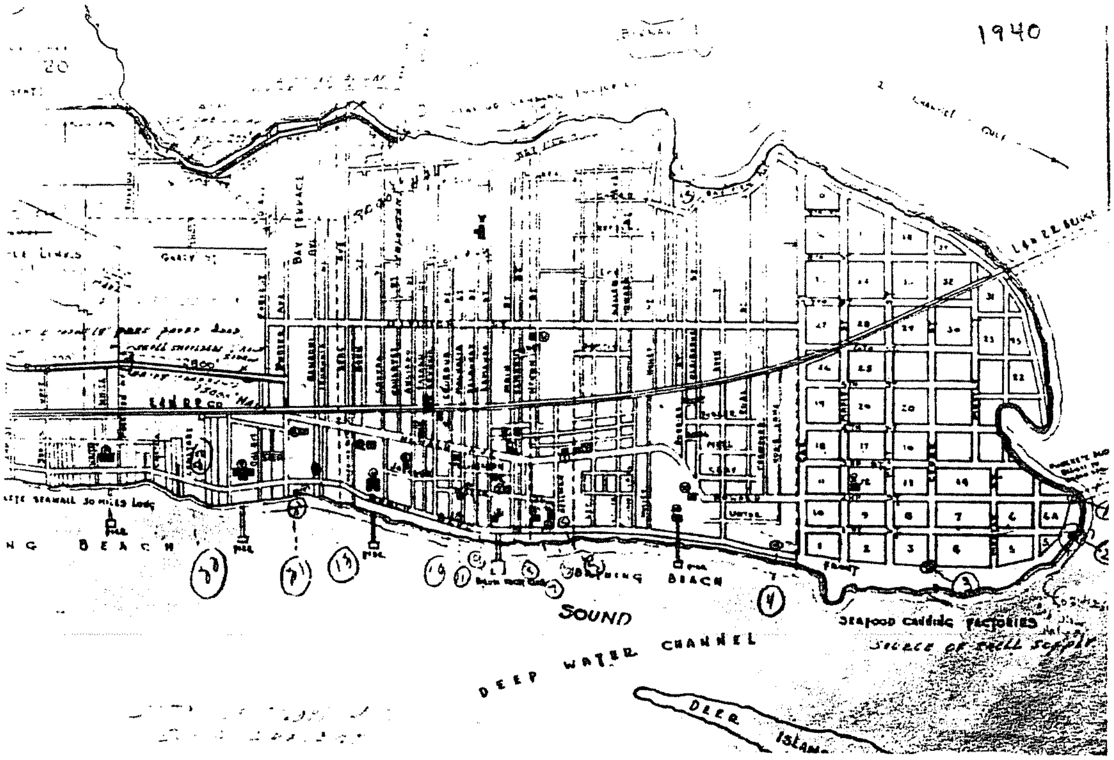
The Mississippi coast was entering a post-World War II rejuvenation in tourism when a severe hurricane made landfall in 1947. This hurricane, the first significant storm since 1915, destroyed much of the Biloxi waterfront, including the Buena Vista pavilion (Sullivan, 1985). The artificial beach fronting the

58. Air photo of Biloxi (Buena Vista Hotel dance pavilion at lower center), circa 1940. (courtesy Ms. Kat Bergeron, The Sun Herald)

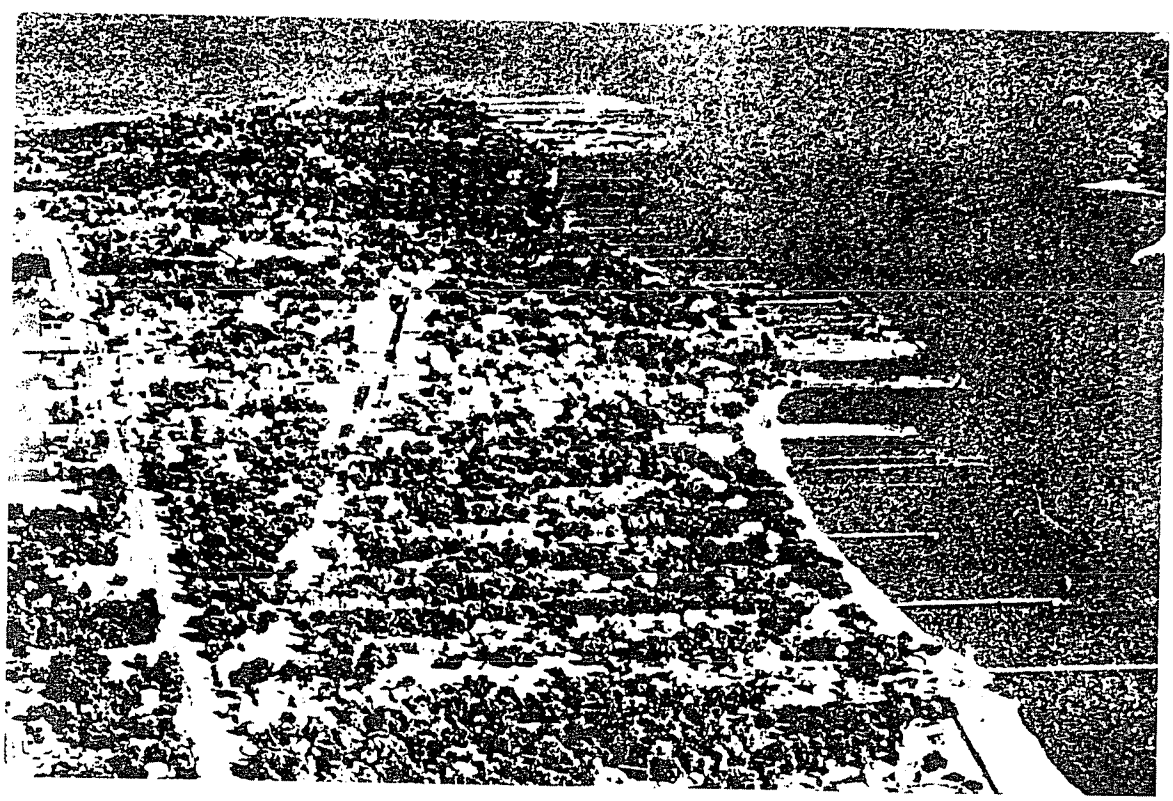


East End section of the Biloxi seafood industry showing vessels and factories, taken from a seaplane in the 1930s (Courtesy Dixie Press)

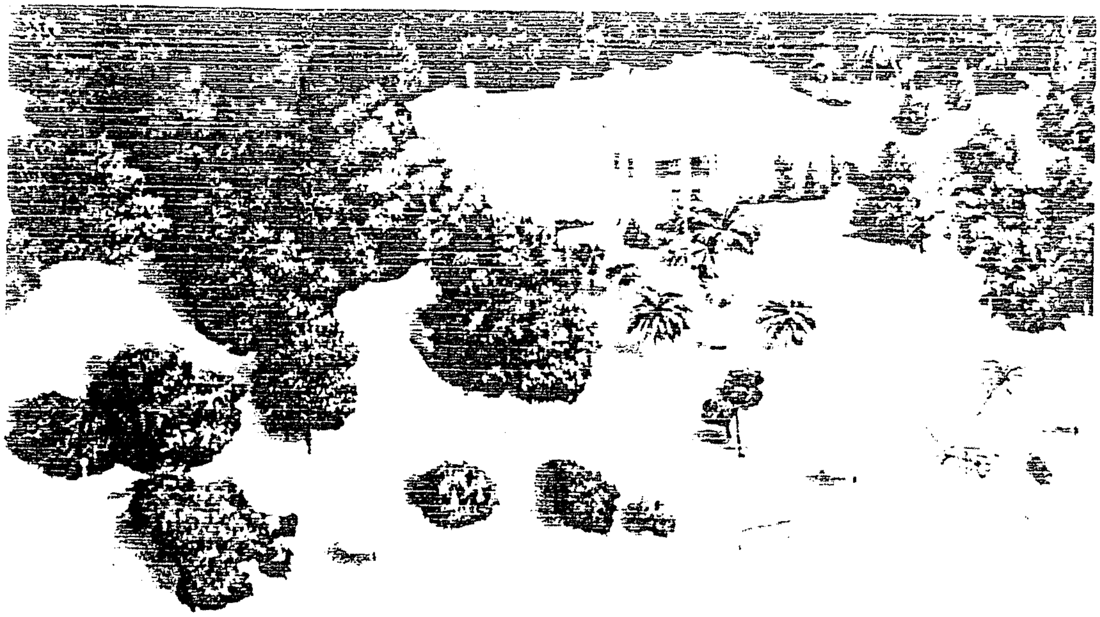
59. East end of Biloxi, late 1930s. (courtesy Ms. Murella Hebert Powell, BPL)



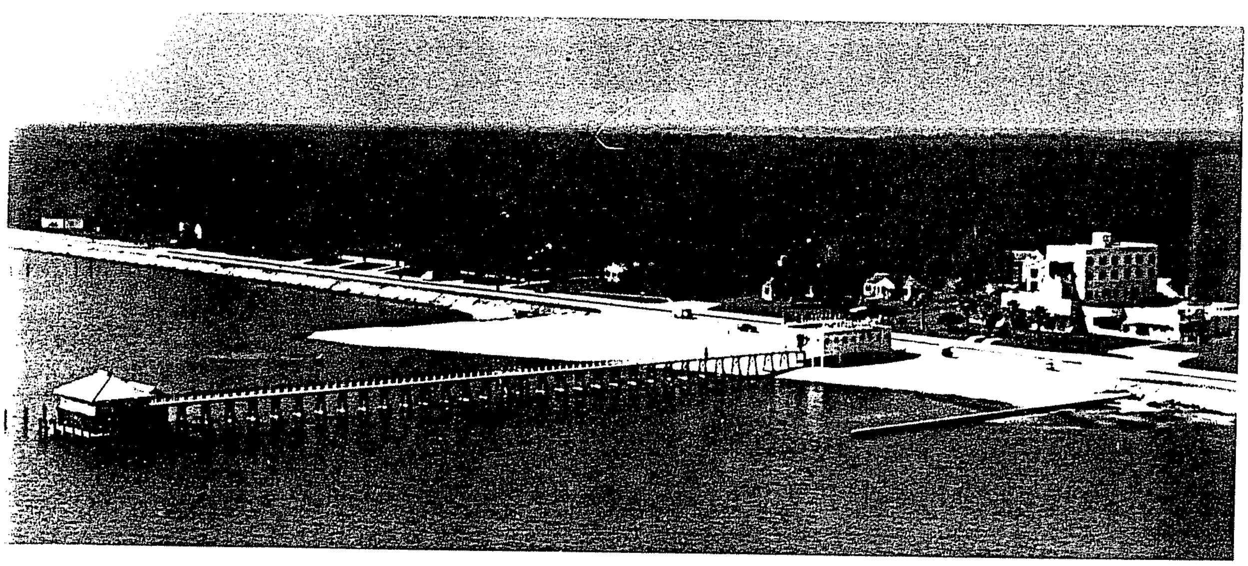
60. Map of Biloxi, 1940. (WPA map courtesy Ms. Murella Hebert Powell, BPL)



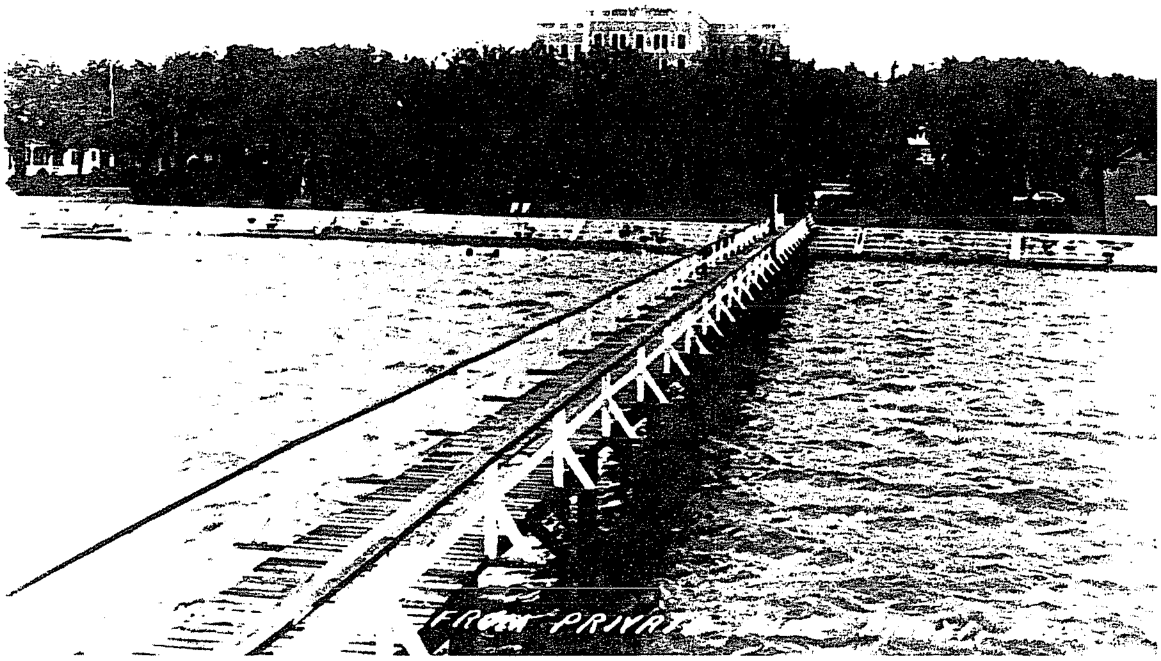
61. Air photo of Biloxi, n.d. (courtesy Ms. Kat Bergeron, The Sun Herald)



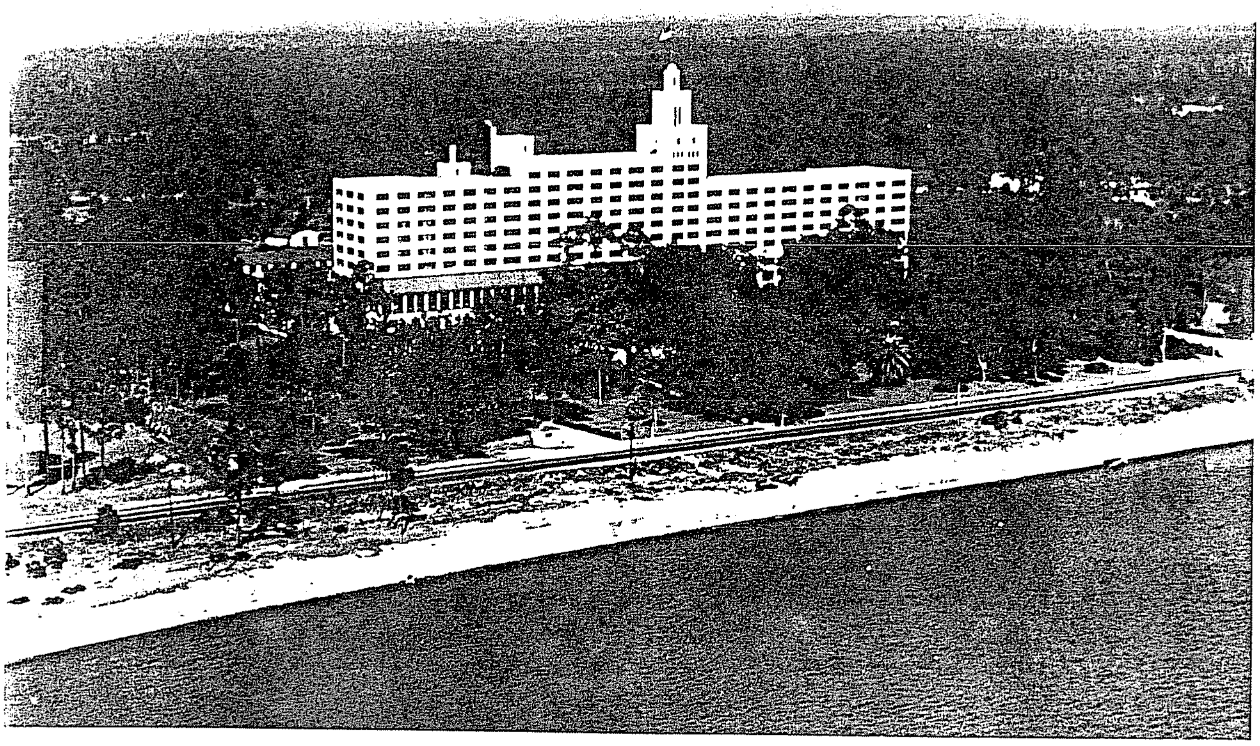
62. Hotel Biloxi, Biloxi, 1940s. (courtesy Ms. Murella Hebert Powell, BPL)



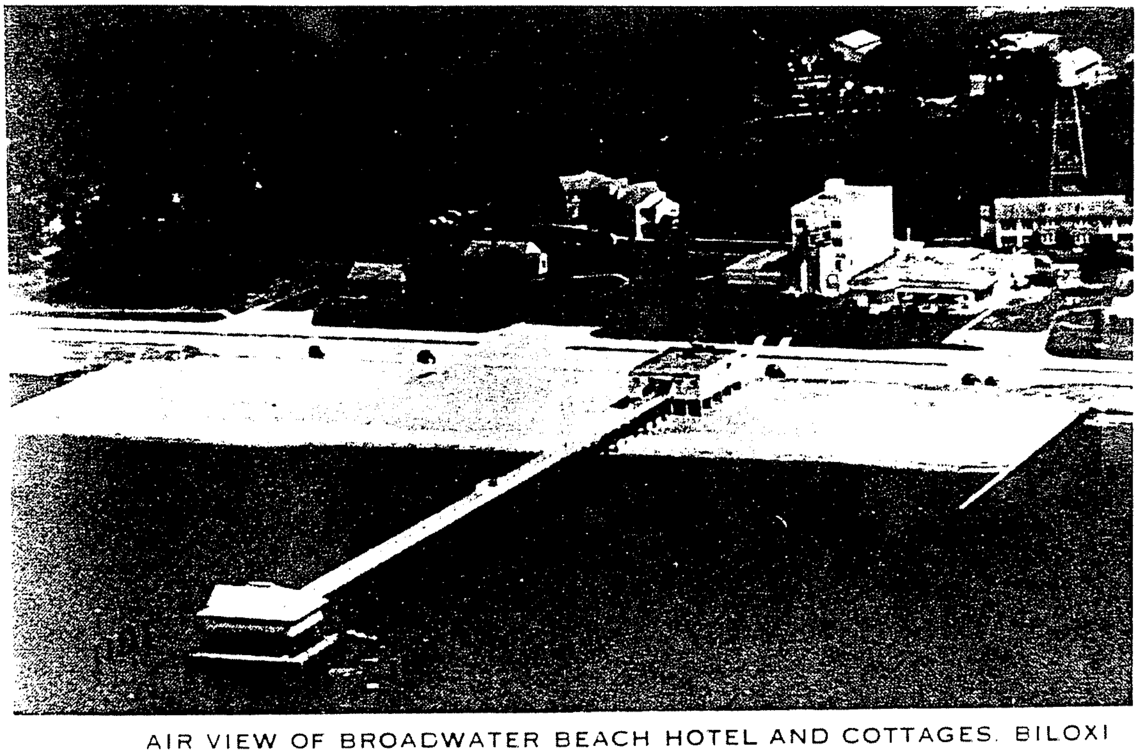
63. Broadwater Beach Hotel, Biloxi, late 1940s. (courtesy U.S. Army Corps of Engineers)



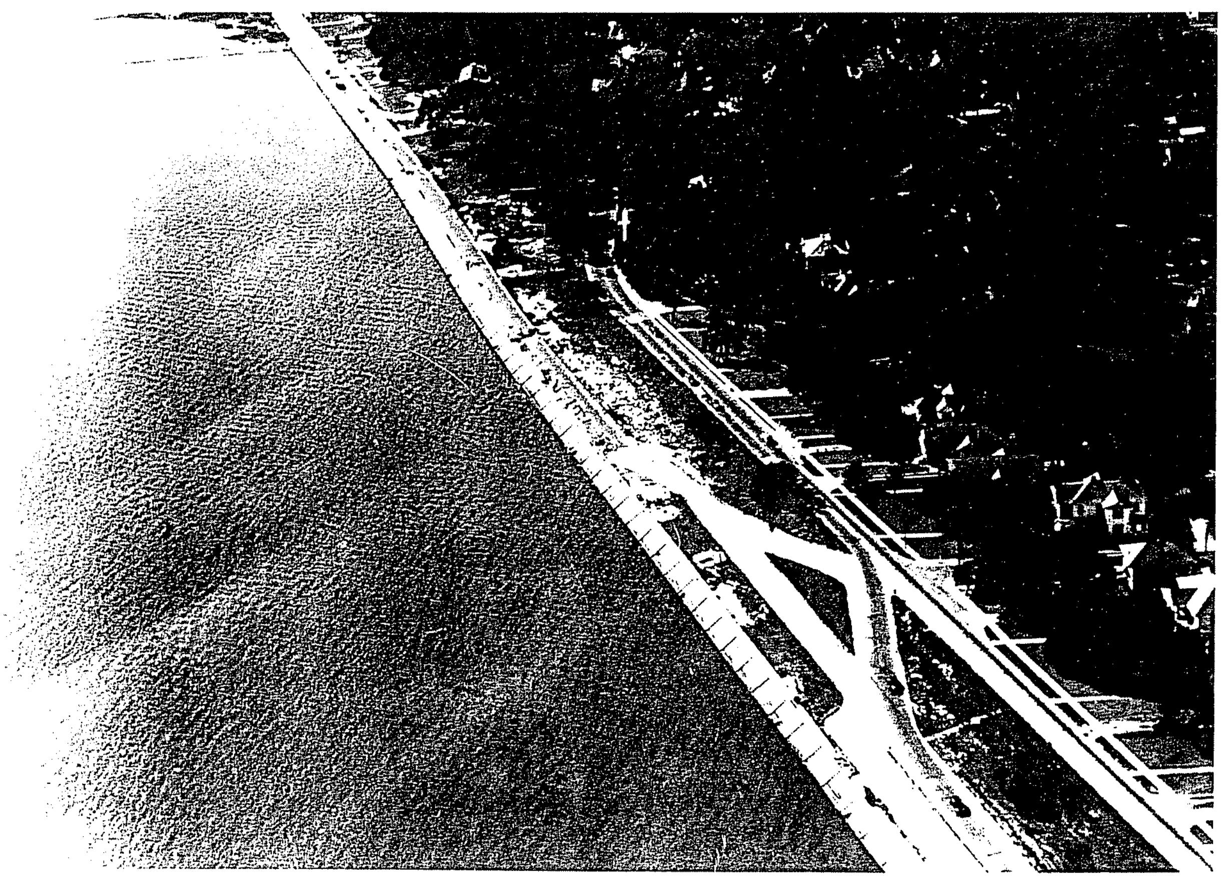
64. Tivoli Hotel, Biloxi, 1940s. (courtesy Ms. Murella Hebert Powell, BPL)



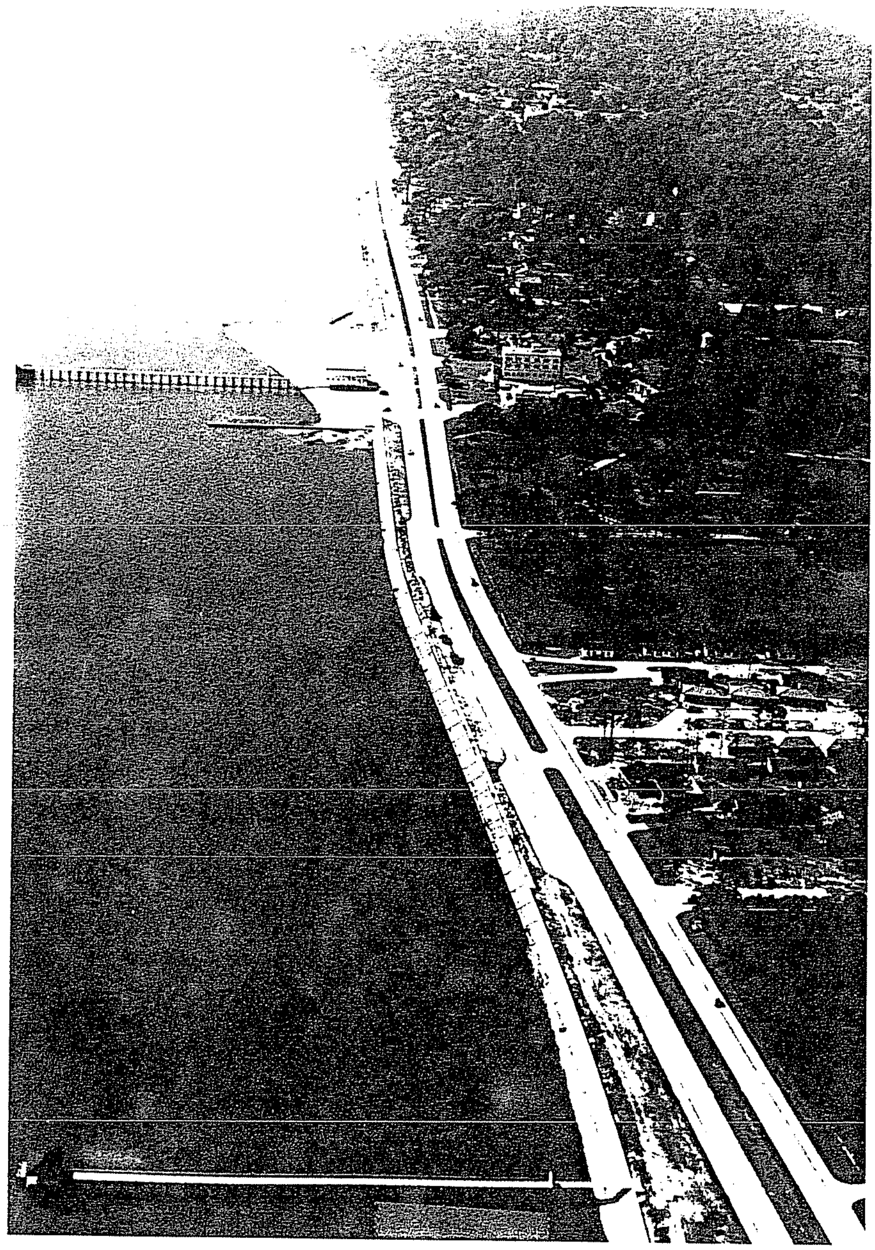
65. Edgewater Gulf Hotel, Biloxi, late 1940s. (courtesy U.S. Army Corps of Engineers)



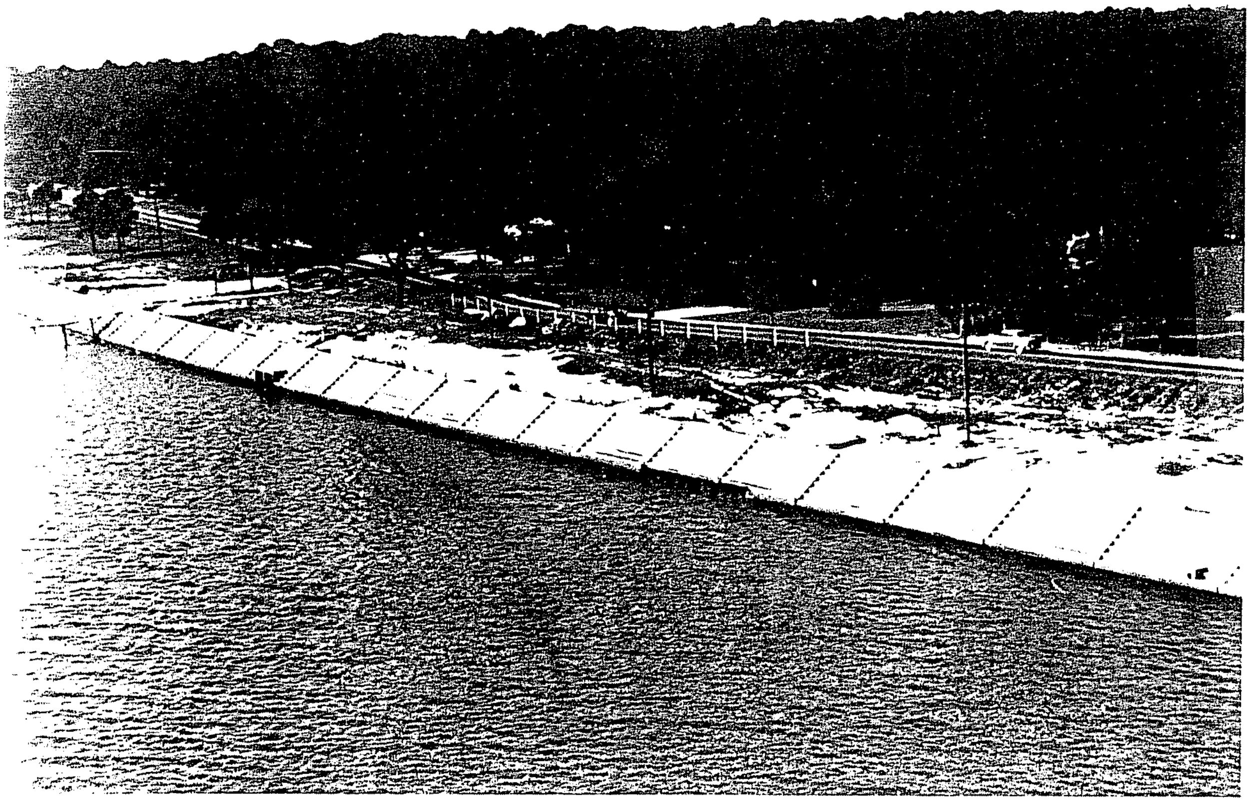
66. Broadwater Beach Hotel, early-to-mid 1940s. (courtesy Ms. Kat Bergeron, The Sun Herald)



68. Gulfport beachfront, late 1940s. (courtesy U.S. Army Corps of Engineers)

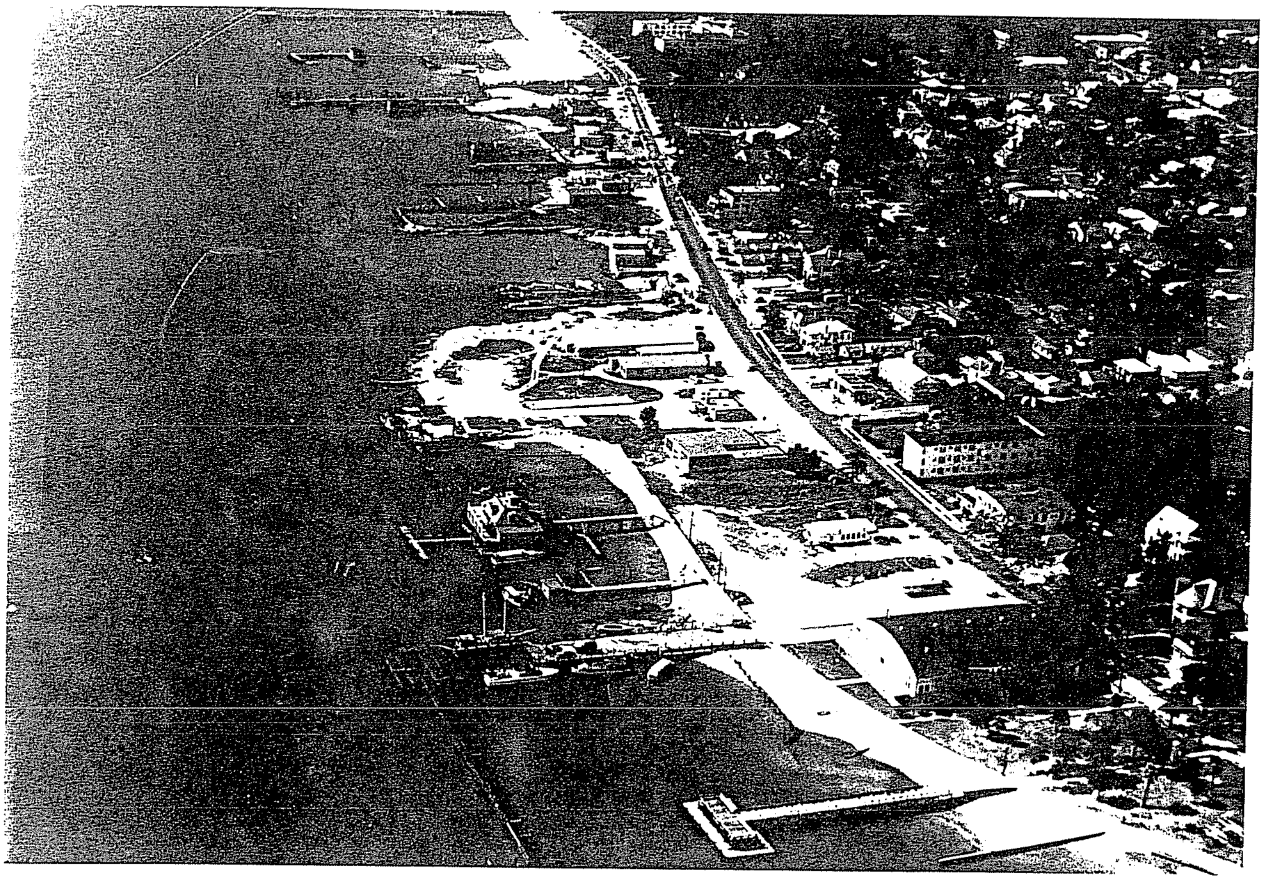


67. Broadwater Beach Hotel, Biloxi, late 1940s. (courtesy U.S. Army Corps of Engineers)

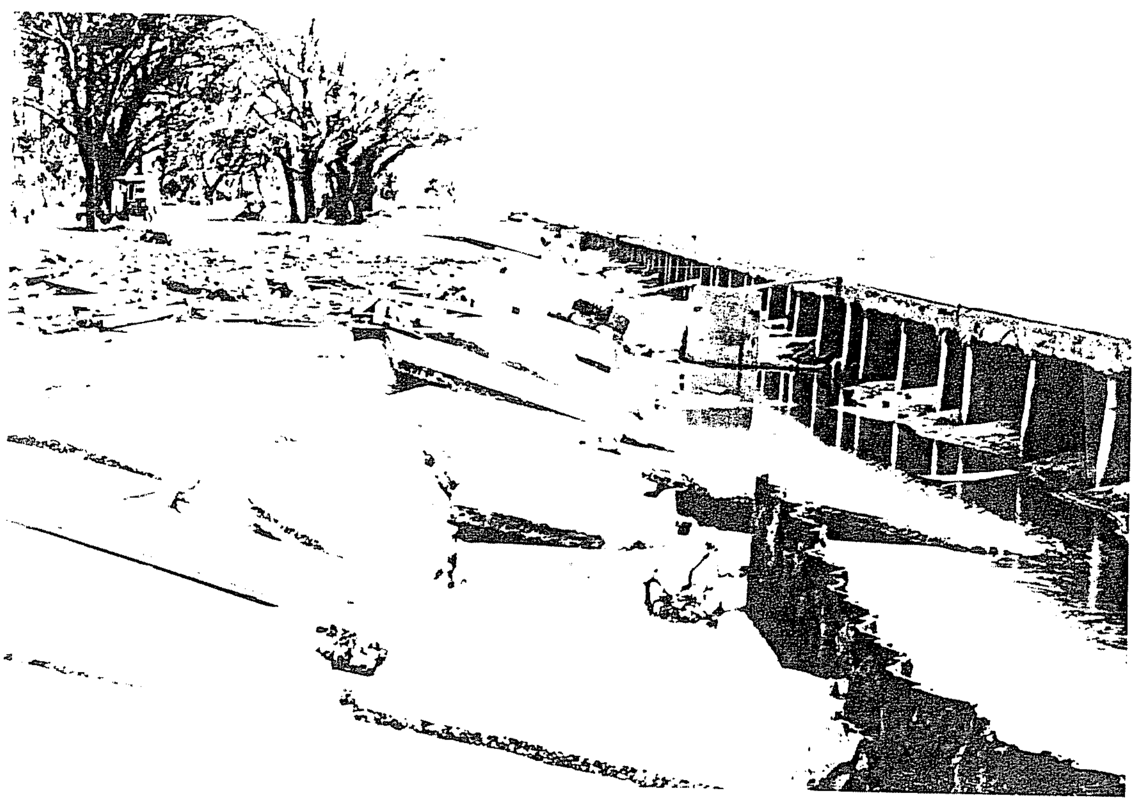


69. Gulfport beachfront, late 1940s. (courtesy U.S. Army Corps of Engineers)

70. Construction of sand beach, Biloxi, circa 1950. (courtesy U.S. Army Corps of Engineers)



71. Construction of sand beach, Biloxi, circa 1950. (courtesy U.S. Army Corps of Engineers)



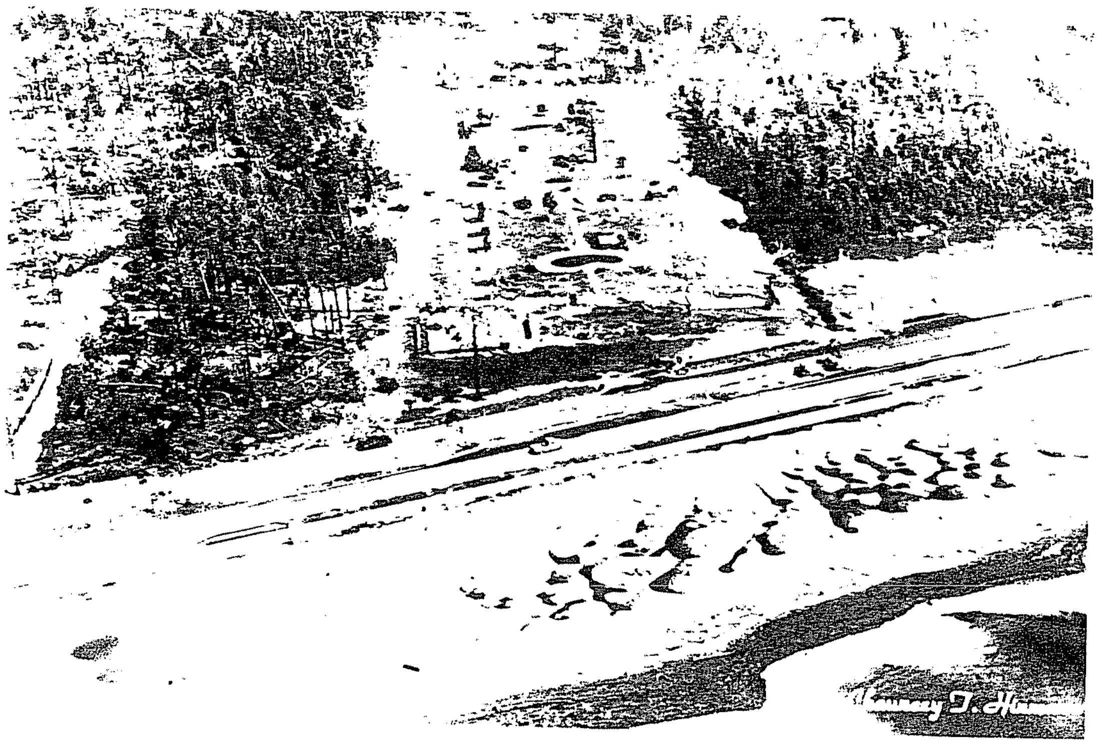
72. Highway damage following hurricane (Camille, 1969?). (courtesy Ms. Murella Hebert Powell, BPL)

Broadwater Beach Hotel sustained only minor erosional damage (Figures 63 and 67), and most of the Harrison County seawall withstood the hurricane relatively well (Figures 68 and 69). Several stretches of seawall in Harrison and Hancock counties were greatly damaged, however, and Harrison County requested that the U.S. Army Corps of Engineers assess the damage. In view of the assessment, it was recommended that artificial nourishment be placed to protect the seawall and highway in the county (Wilson, 1951). By 1951, 285 hectares of beach nourishment, or up to a 90-m wide beach over a 40-km stretch of Harrison County, were created (Escoffier, 1956; Escoffier and Dolive, 1954; MacArthur, 1956; Walton and Purpura, 1977; Watts, 1958) (Figures 70 and 71). Harrison County soon claimed "the longest man-made beach in the world" (anon., 1951), and a new era of beach recreation was ushered in. In Hancock County, 1947 storm damage was also severe (Sullivan, 1985), but no subsequent attempts at beach nourishment were made.

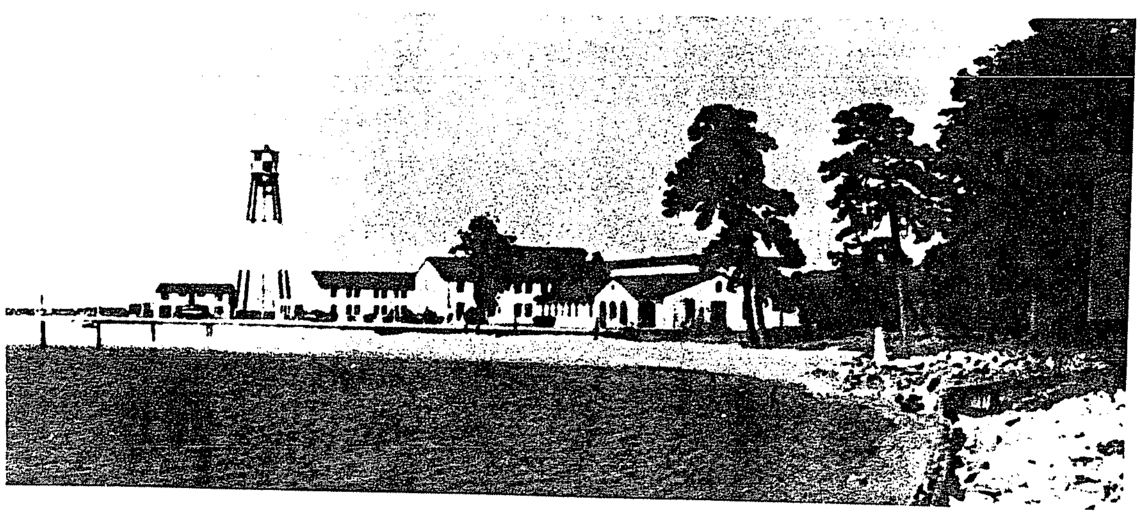
Maintaining the Mississippi Shoreline, 1951-1991

The relative effectiveness of the 1951 beach nourishment project in protecting the seawall became apparent in the 1950s and 1960s as the Mississippi coast was hit by a series of minor and major hurricanes (Sullivan, 1985). Although the minor storms (Hurricane Flossy in 1956 and Hurricane Ethel in 1960) and a major storm (Hurricane Betsy in 1965) removed much of Harrison County's sand beach (and periodic replacement of new fill was necessary), the Corps of Engineers' goal of protecting the seawall seemed to work. By contrast, Hurricane Betsy caused much damage to the still unprotected seawall in Hancock County, and in the aftermath of the storm a 10-km-long artificial beach was completed by 1967 (Dixon and Pilkey, 1991; Sand Beach Planning Team, 1986).

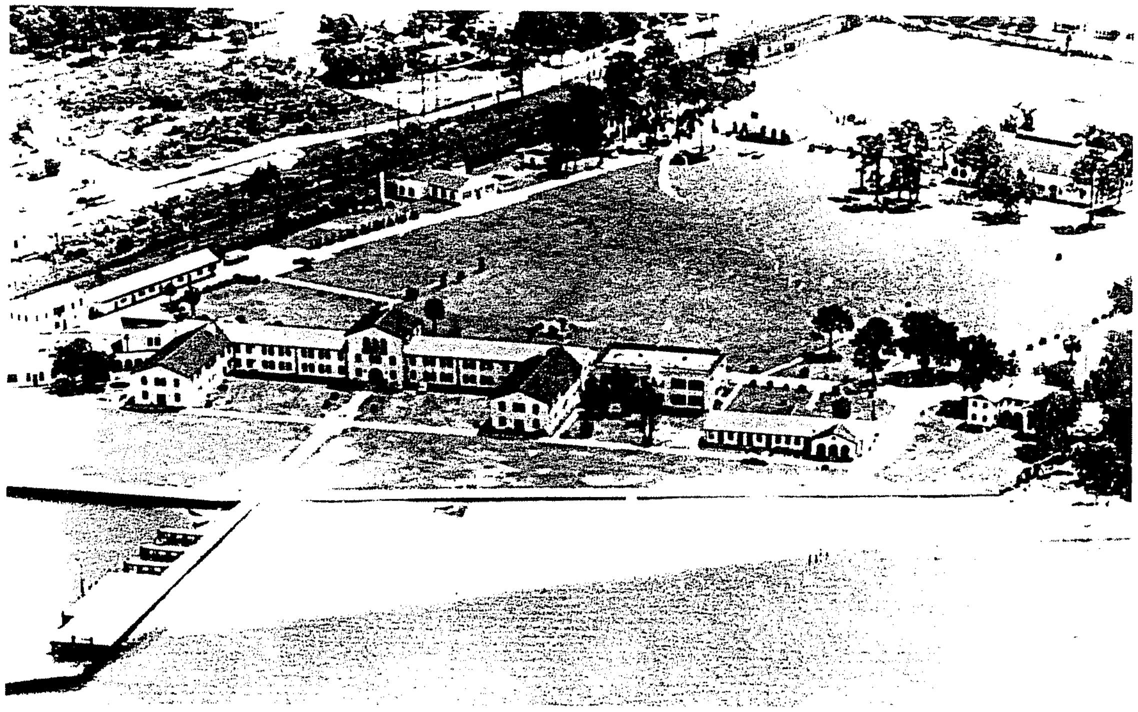
The eye of Hurricane Camille in 1969--Force 5 on the Saffir-Simpson scale and among the worst hurricanes ever to strike the U.S. coast--came ashore at Pass Christian, and most of the Coast experienced extensive destruction and loss of life (Sullivan, 1985; USACE, 1970). The Harrison and Hancock County sand beaches were greatly eroded, but--with minor exceptions--the seawalls withstood the storm relatively well (Sullivan, 1985; USACE, 1970) (Figures 72, 73, 74, 75, and 76). In Harrison County, a major post-storm beach renourishment project was completed in the early 1970s (Brown & Russell, Inc., 1972; Dixon and Pilkey, 1991)



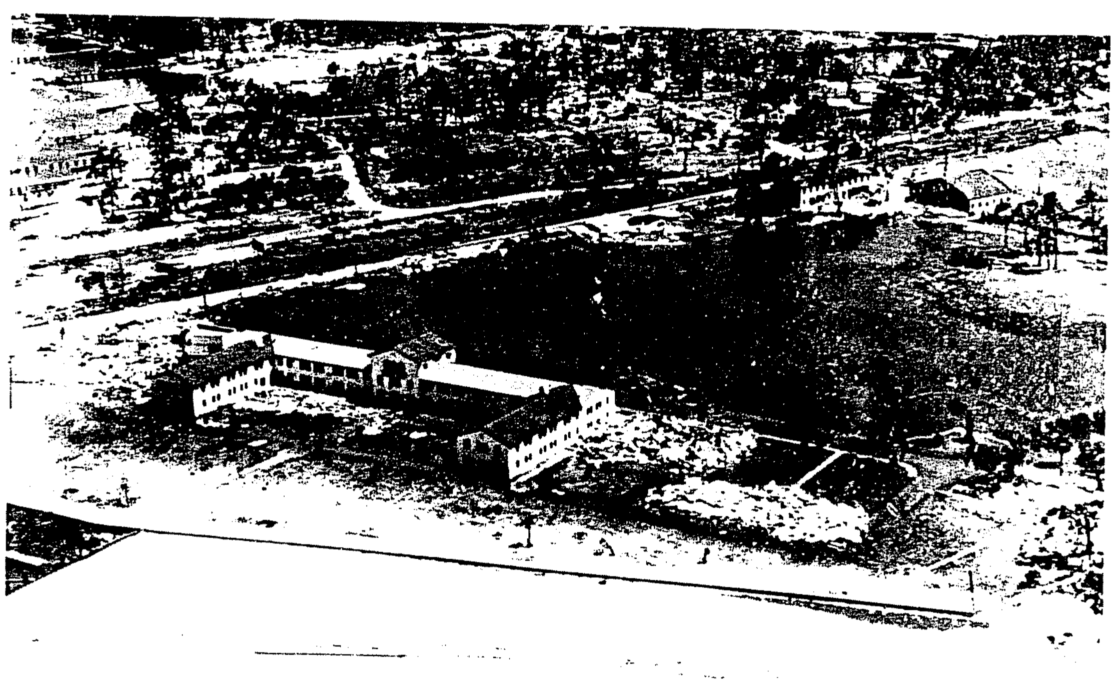
73. Beachfront damage following Hurricane Camille, Pass Christian, 1969. (Chauncey J. Hinman photo courtesy Ms. Murella Hebert Powell, BPL)



74. Old Coast Guard Station, Henderson Point, n.d. (courtesy Ms. Kat Bergeron, The Sun Herald)

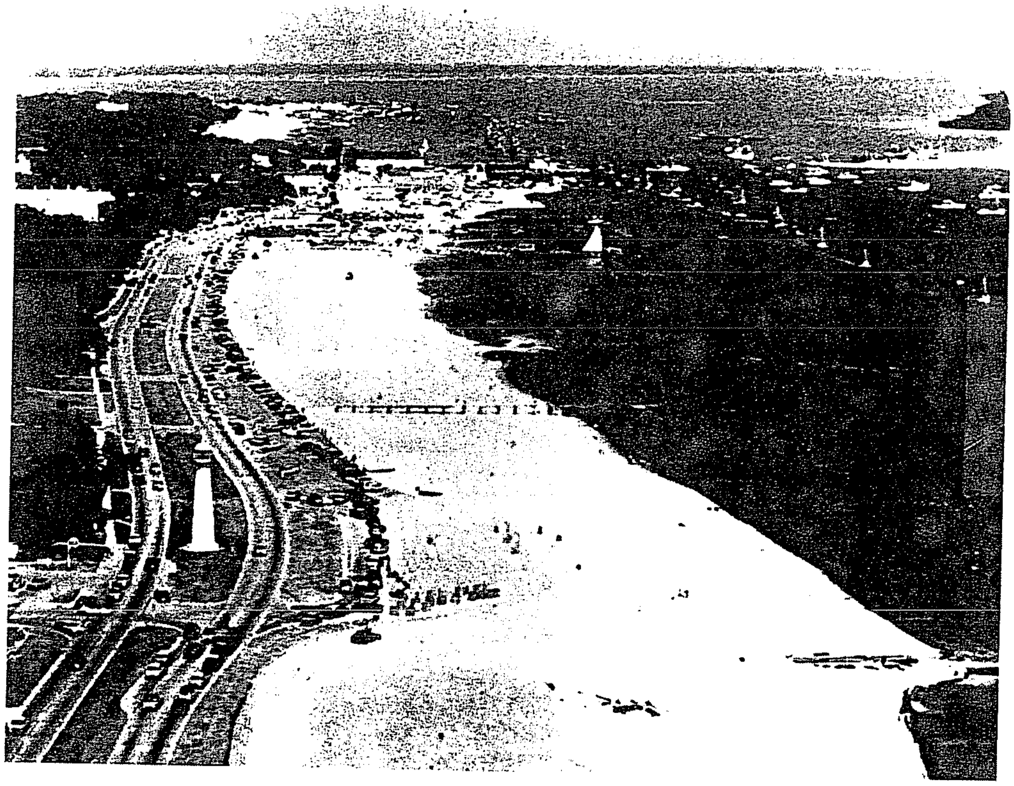


75. Gulfshore Baptist Assembly prior to Hurricane Camille, Henderson Point, 1969. (Chauncey J. Hinman photo courtesy Ms. Murella Hebert Powell, BPL)

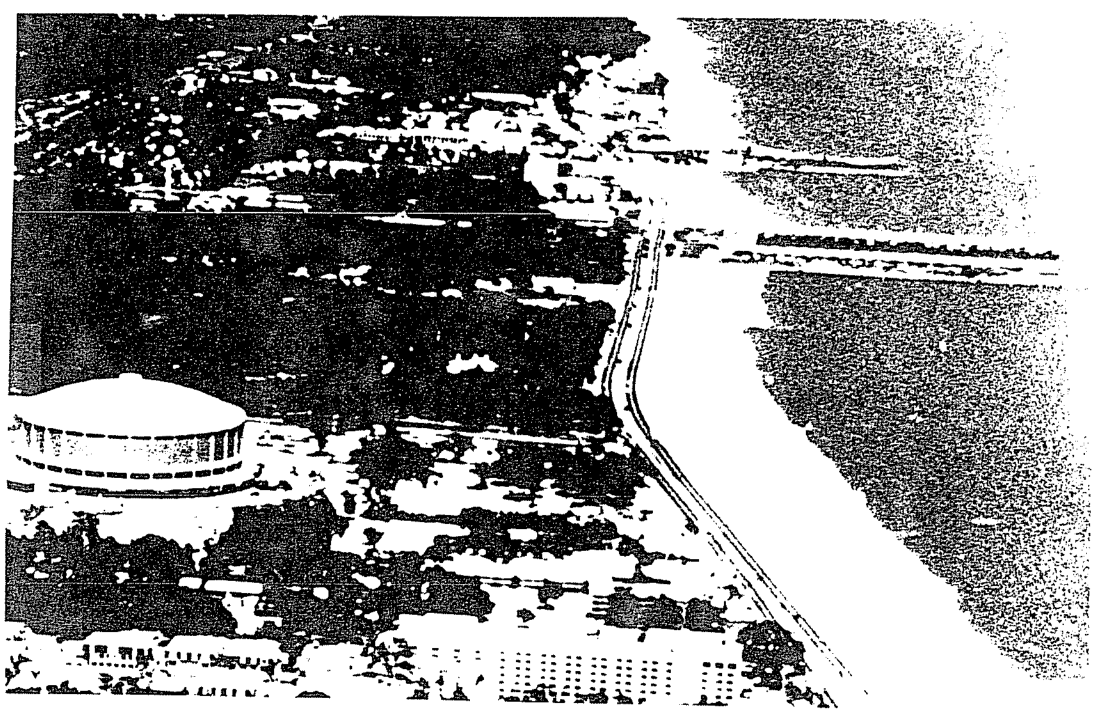


Henderson Point - Gulfshore Baptist Assembly before and after C[illegible]

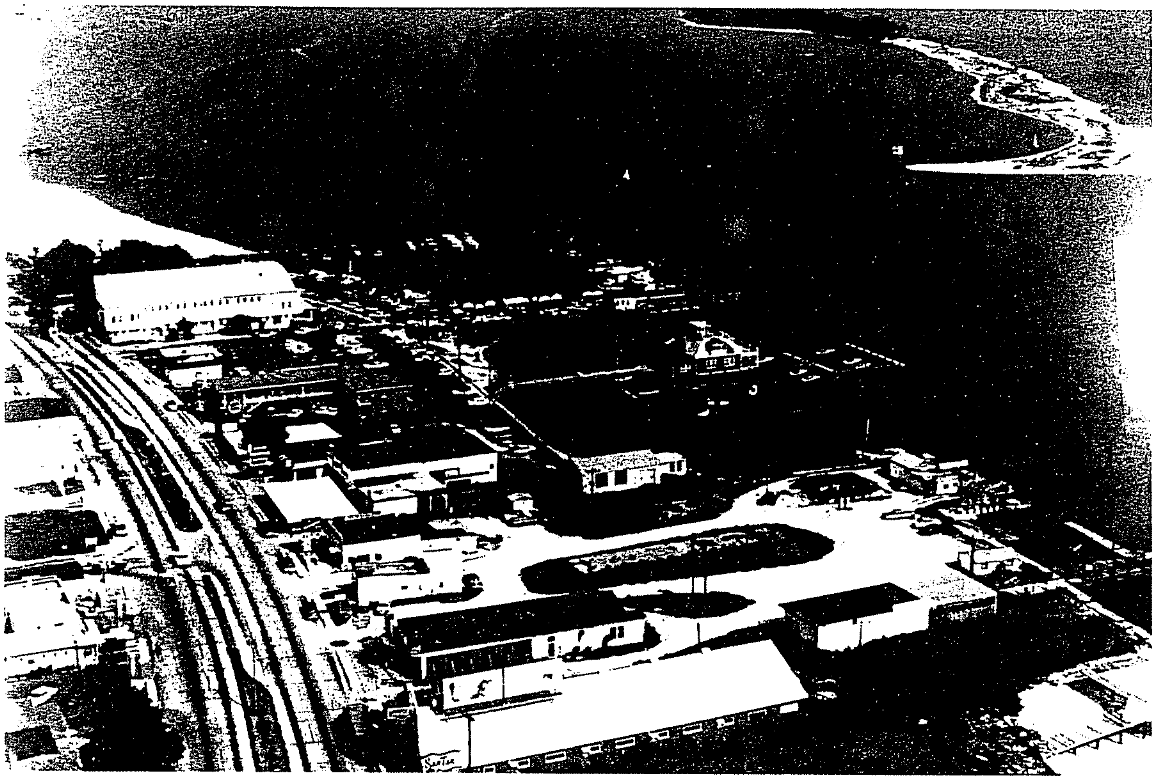
76. Gulfshore Baptist Assembly following Hurricane Camille, Henderson Point, 1969. (Chauncey J. Hinman photo courtesy Ms. Murella Hebert Powell, BPL)



77. West Beach, Biloxi, 1970s? (courtesy Ms. Murella Hebert Powell, BPL)

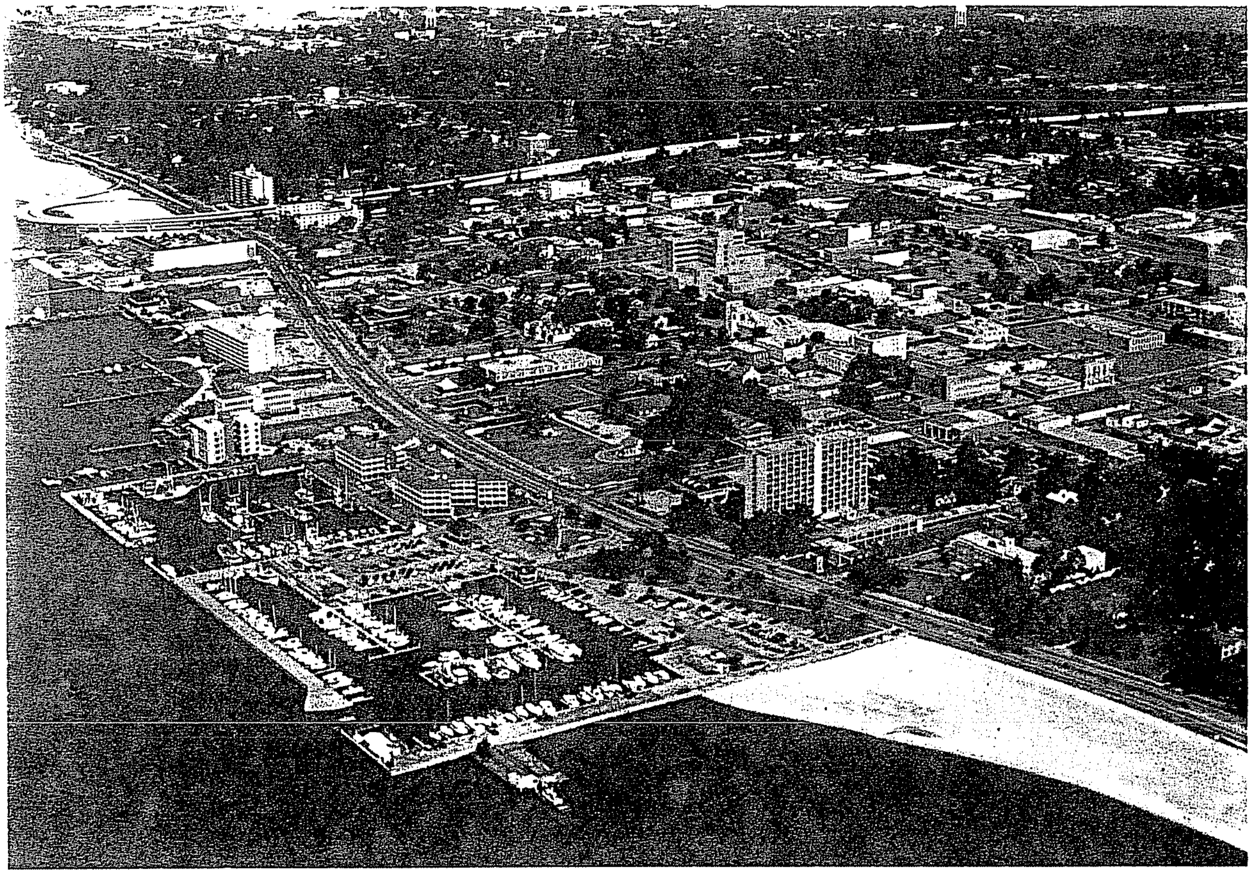


78. West Beach, Biloxi, early 1980s? (courtesy Guice & Guice Advertising and Ms. Murella Hebert Powell, BPL)

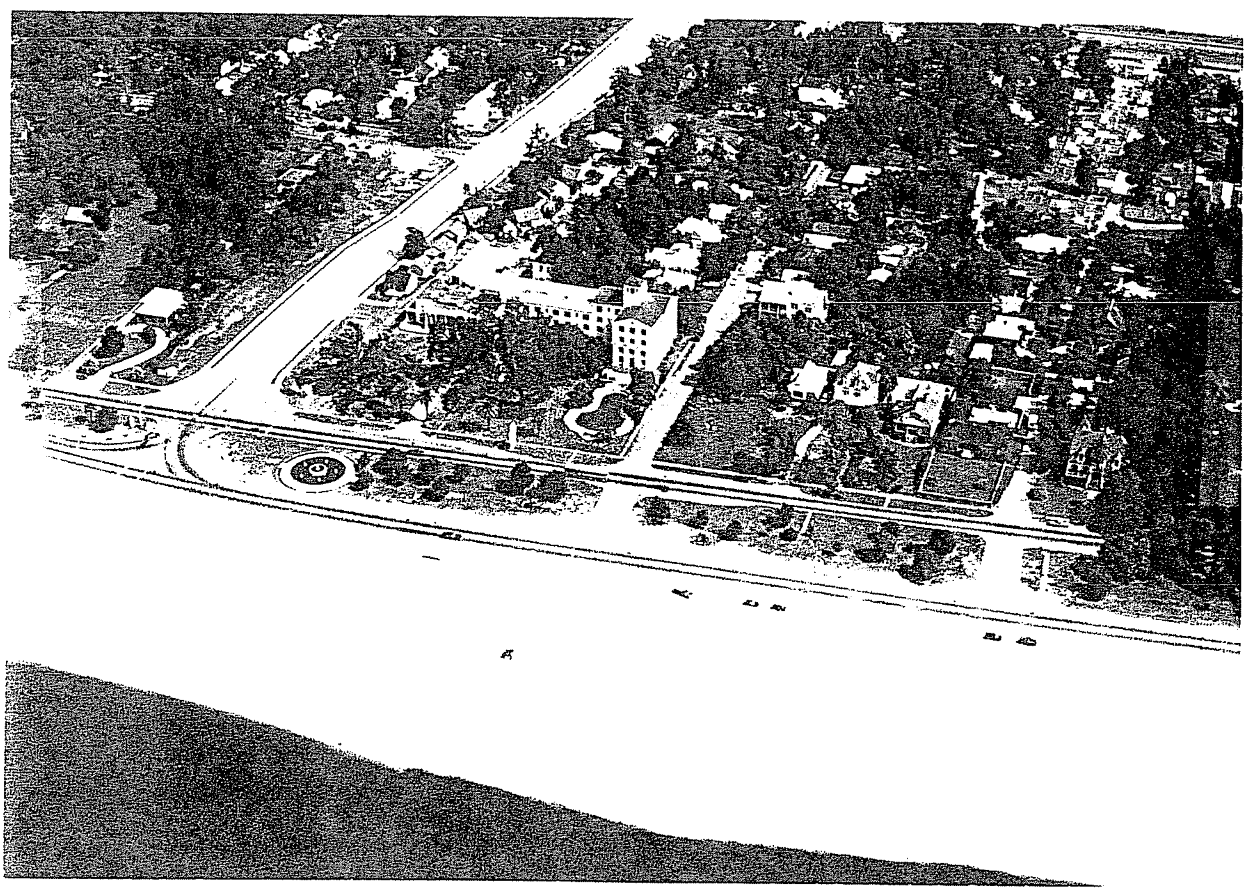


79. Biloxi beachfront, 1963?. (Joe Scholtes photo courtesy Ms. Kat Bergeron, The Sun Herald)

80. Biloxi beachfront, 1963. (Joe Scholtes photo courtesy Ms. Kat Bergeron, The Sun Herald)



81. Biloxi beachfront, 1988. (Photo by Klaus J. Meyer-Arendt)



82. Vacant White Hotel Hotel, Biloxi, 1988. (Photo by Klaus J. Meyer-Arendt)

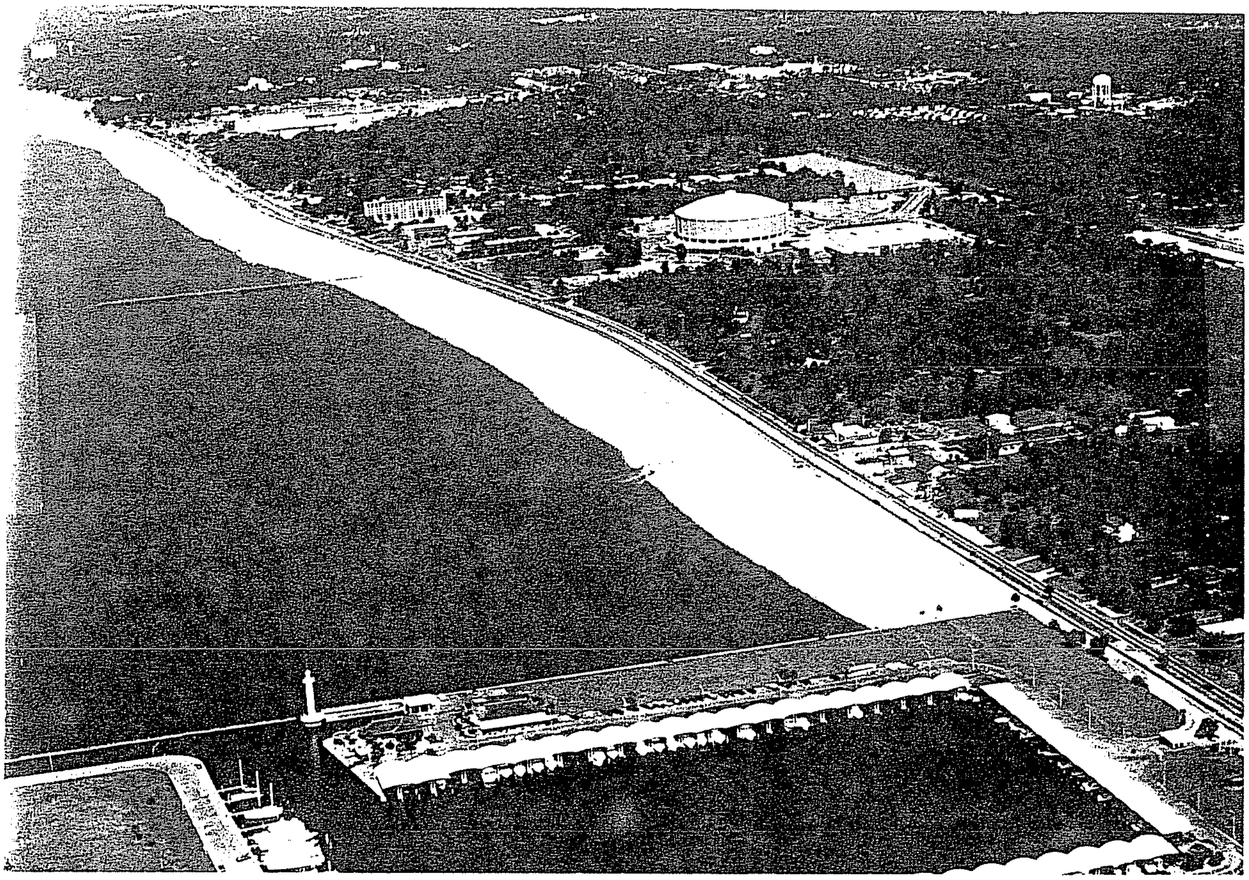
(Figures 77 and 78). Hurricanes in 1985--especially Elena--caused additional removal of beach sand in both counties (Jones and Binkley, 1991), and Hancock County--which had not had its beach renourished following Camille--witnessed the loss of most of its remaining beach.

Summary of Mainland Shoreline Impacts

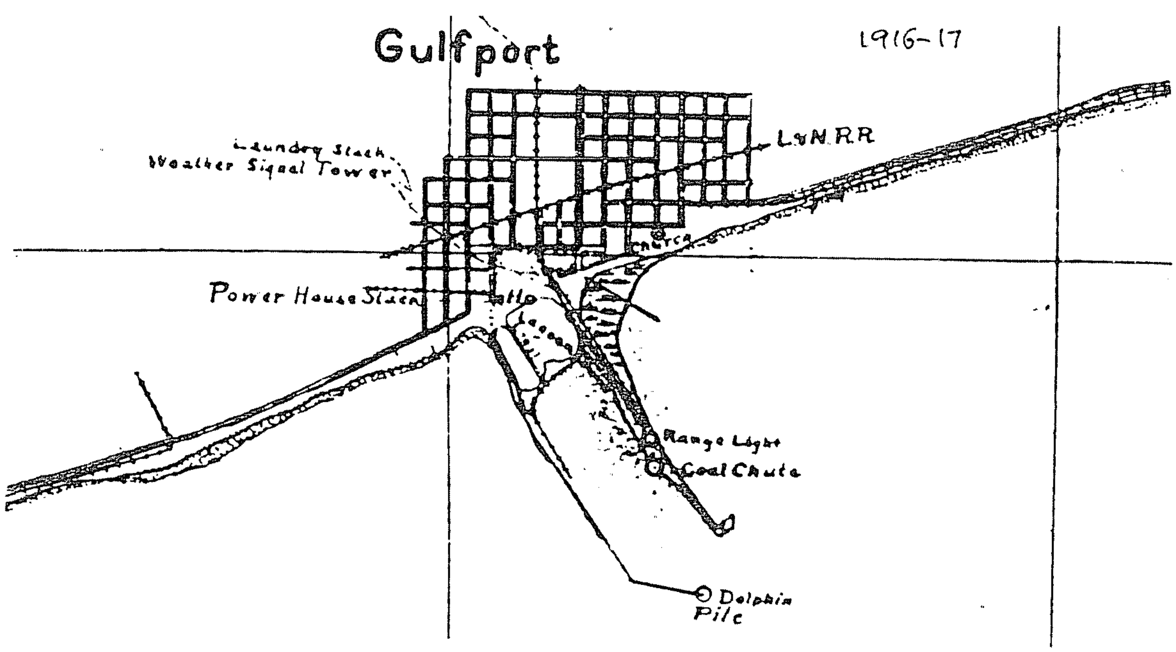
The mainland shoreline of Mississippi has been greatly modified since the first settlers arrived. Urban encroachment into the intertidal/nearshore zone has been greatest at the waterfront of Biloxi, historically the most important commercial center along the Mississippi coast (Figures 79, 80, and 81). Flanking beaches, historically erosive especially since completion of the seawall in 1928, are today relatively healthy as a result of the 1951 beach nourishment project and subsequent renourishment and grading (Figures 82 and 83). The seawall/artificial beach complex, which has held up relatively well under normal wave conditions, has--in Harrison County--extended the shoreline farther seaward than it was even 100 years ago. At Gulfport, this seawall/artificial beach complex flanks the artificial harbor which was first constructed at the turn of the century and has been expanded and modified several times since then (Figures 84 and 85).

The northern shore of St. Louis Bay (Harrison County) still appears much as it did historically (Figure 86), although the western shore of the bay--within the greater urban area of Bay St. Louis (Hancock County)--is characterized by a beachless, seawall-armored shoreline (Figure 87). The northern shore was subject to hotel construction in the 1920s land boom, but because of the construction of the Highway 90 bridge across the bay (Bay St. Louis to Henderson Point), the Pine Hills Hotel soon went out of business and was finally torn down in the early 1980s by the Dupont Corporation which had acquired the property (Figure 88).

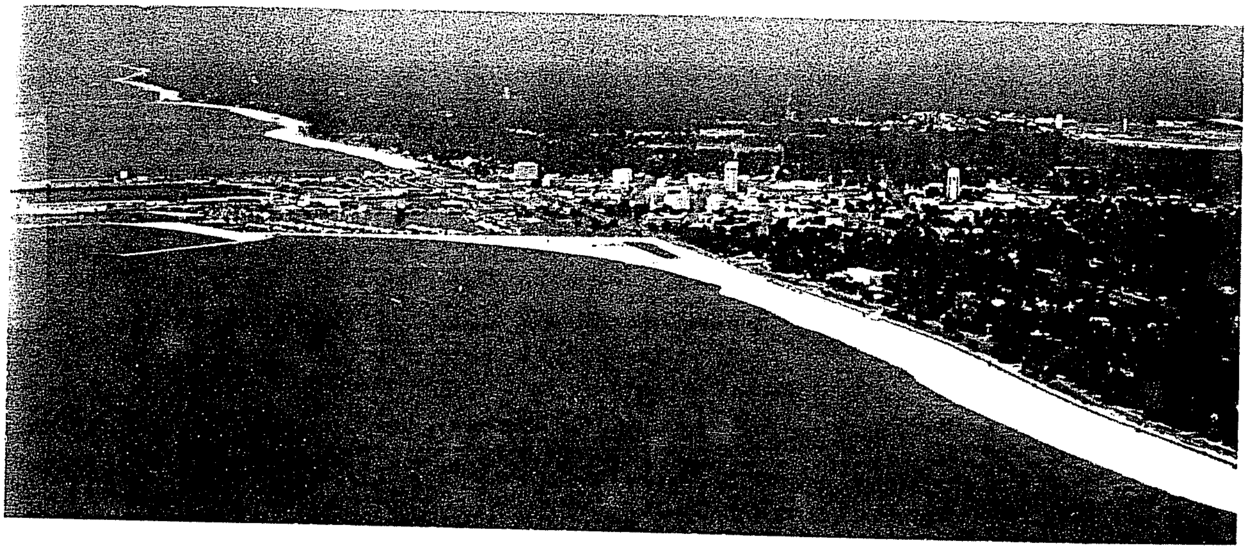
Henderson Point marks the western terminus of the Harrison County sand beach, and a terminal groin separates the artificial beach from a private seawall (Figure 89). A new building stands on the site of the old Baptist Assembly (see Figures 75 and 76), where a groin protects a short reach of sand beach. In Hancock County, sand beach eroded away in the aftermath of Hurricane Elena (1985) has not been restored (Figure 90), but in 1991 the county applied for a permit for a beach renourishment project using sands to be



83. Broadwater Beach marina, Biloxi, 1988. (Photo by Klaus J. Meyer-Arendt)



84. Map of Gulfport and harbor, 1916-17.



85. Gulfport and harbor, 1988. (Photo by Klaus J. Meyer-Arendt)

86. Beach at north shore of St. Louis Bay, near site of old Pine Hills Hotel, 1988. (Photo by Klaus J. Meyer-Arendt)

dredged from just offshore of Henderson Point. Only in the Belle Fontaine/Gautier Pleistocene headland complex have homes been built along an erosive (and non-armored) shoreline (Figure 91). Although several groins have been built to conserve the limited amount of sand, erosion continues, and several landowners have requested state assistance in shore protection.

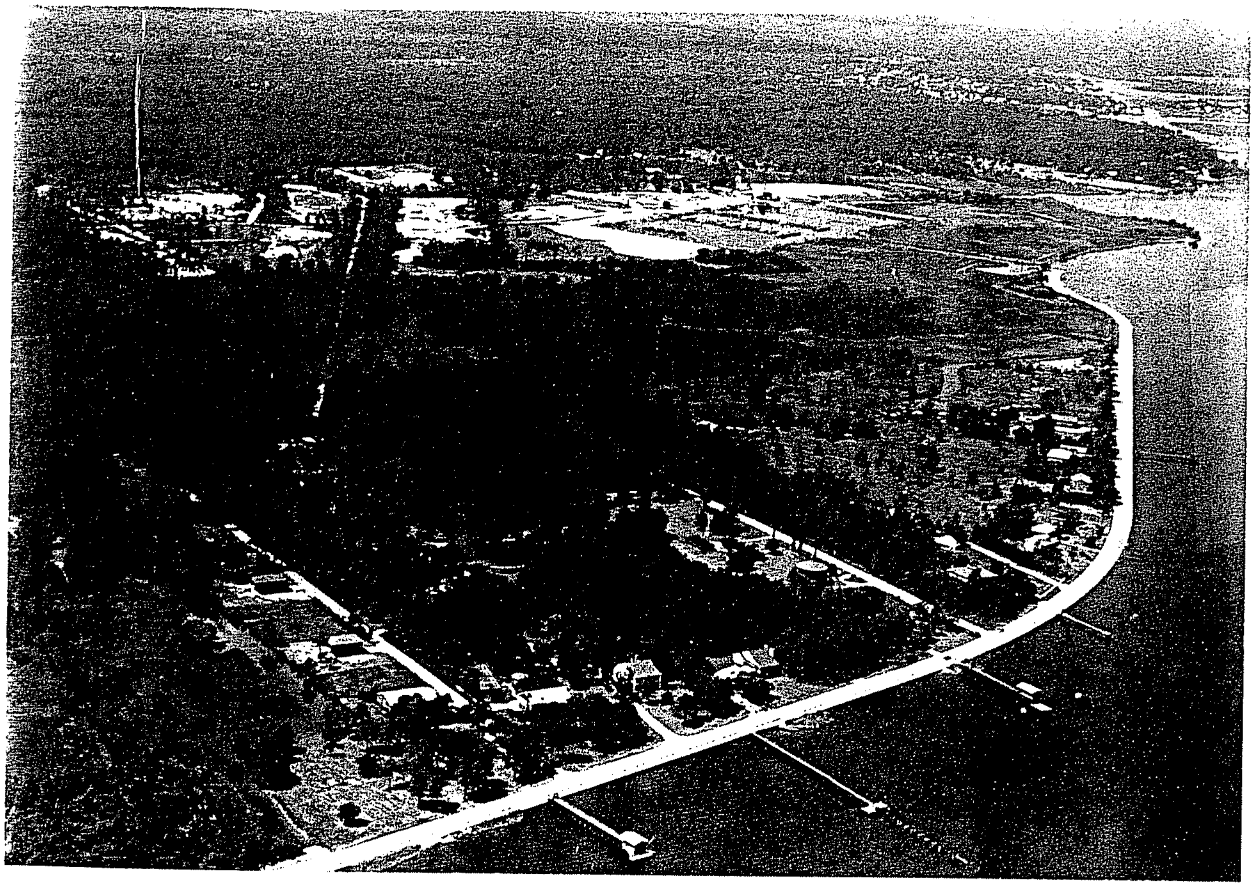
The shorefront of Pascagoula is characterized mostly by a seawall, although a 3000-ft artificial beach (Pascagoula Beach) is contained within a coastal park. The two sections of protected shorelines at Ocean Springs--Front Beach and East Beach--where seawalls were constructed in the late 1920s, have had fronting beaches in place since the 1950s. As at Bay St. Louis, however, tidal currents seem to accelerate beach erosion, and at Front Beach periodic renourishment has been necessary.

Human Modification of Wetlands in Mississippi

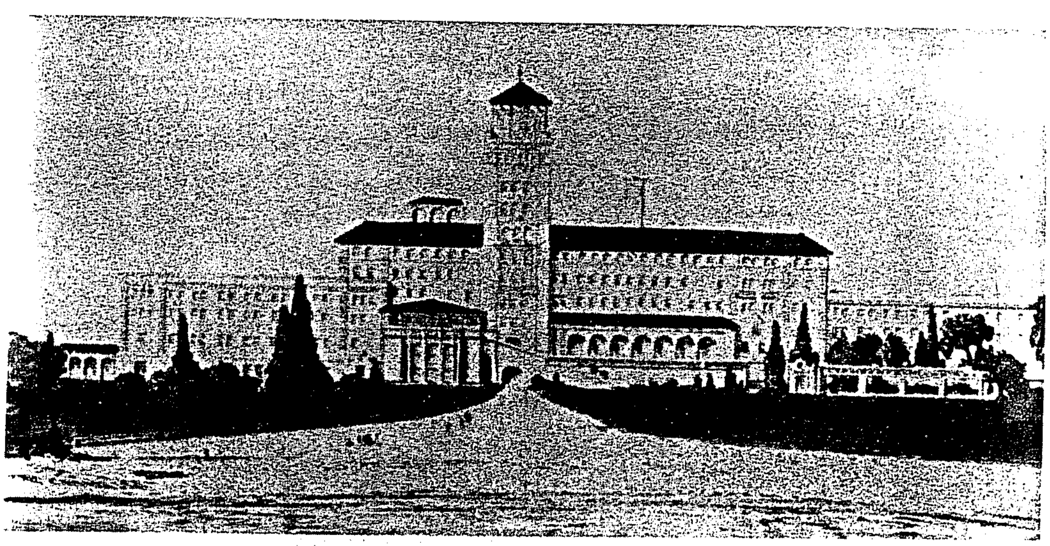
Until the 1940s, Mississippi's coastal wetlands remained relatively unaffected by human activity. This began to change in the 1950s and 1960s as a national craze for residential canal waterfront lots made inroads into Mississippi. Developers would select what was previously considered undesirable lands (low-elevation pine flats and marshlands) and convert them into residential subdivisions. Between 1956 and 1973, the wetland area of Mississippi was reduced by over 2,000 ha--from over 28,000 ha to less than 26,000 ha (Meyer-Arendt, 1989; Meyer-Arendt and Gazzier, 1990). Half of this loss was within marshes fringing the estuarine embayments of St. Louis Bay and Back Bay of Biloxi (Meyer-Arendt, 1989). In addition to loss to residential subdivisions, wetlands succumbed to industrial development, dredging for roadbed fill, and deposition of spoil material. Passage of the Mississippi Wetlands Protection Law in 1973 appears to have fairly effectively halted the previously high rates of wetland conversion, at least in terms of urban/industrial impacts (Meyer-Arendt, 1989).

Human Modification of Mississippi's Barrier Islands

Human alteration of Mississippi's barrier islands has been minor in comparison with the mainland shoreline or the mainland wetlands. Historically, the islands were seen as refuges from hostile Indians, and Cat Island and Deer Island contained small settlements. Commercially, Ship Island became most important,

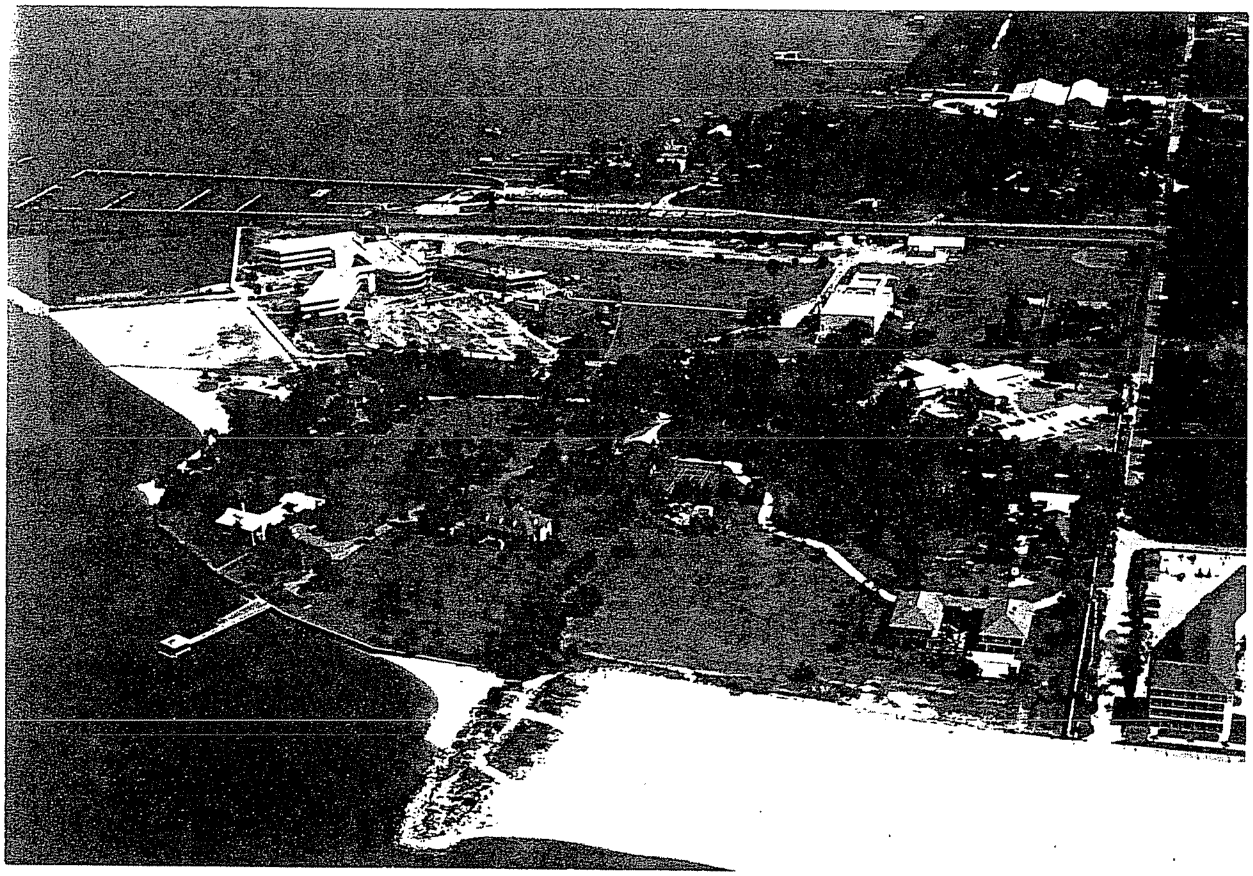


87. Seawall along western shore of St. Louis Bay, just north of Bay St. Louis bridge, 1988. (Photo by Klaus J. Meyer-Arendt)

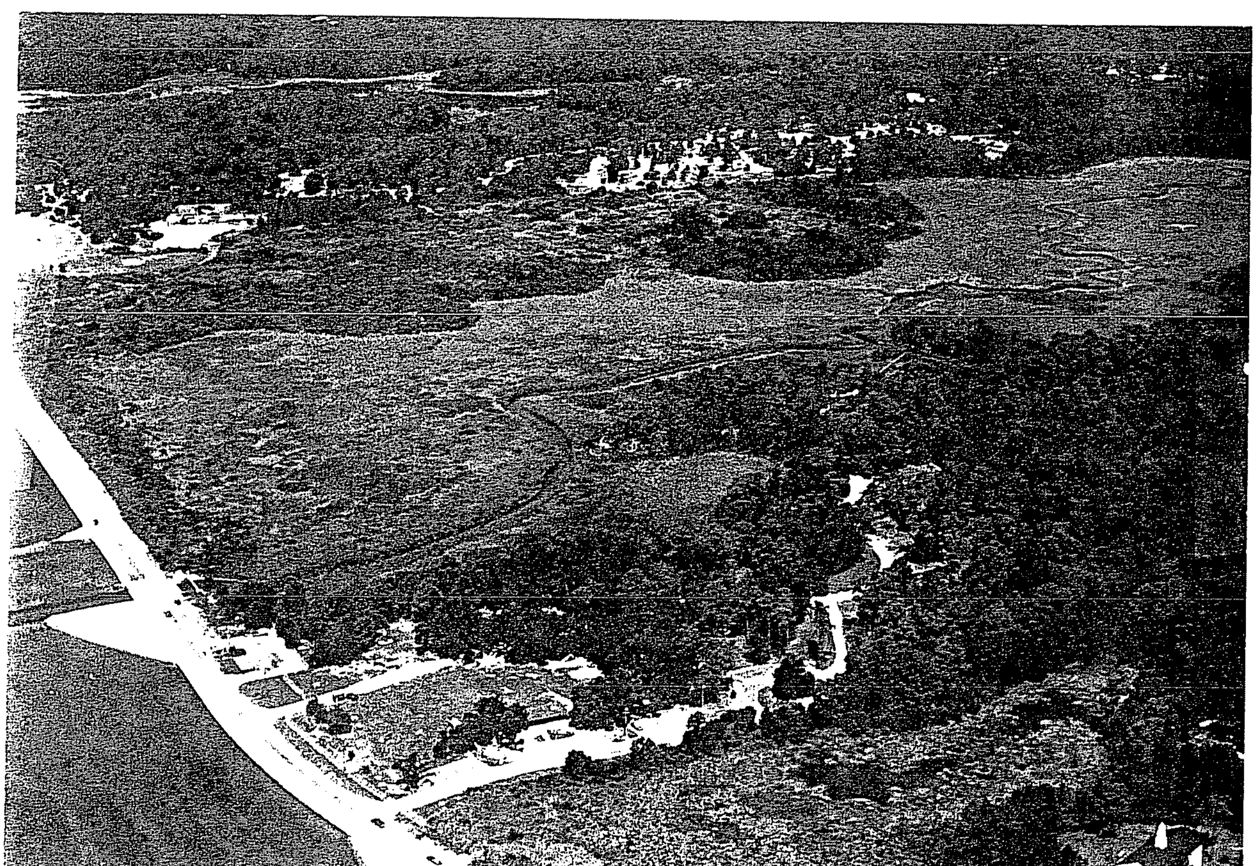


The old Pine Hills Hotel was closed because the Highway 90 bridge diverted most of the traffic away from it, and it has had a variety of owners through the years.

88. The old Pine Hills Hotel, north shore of St. Louis Bay, n.d. (courtesy Ms. Murella Hebert Powell, BPL)



89. Henderson Point, 1988. (Photo by Klaus J. Meyer-Arendt)

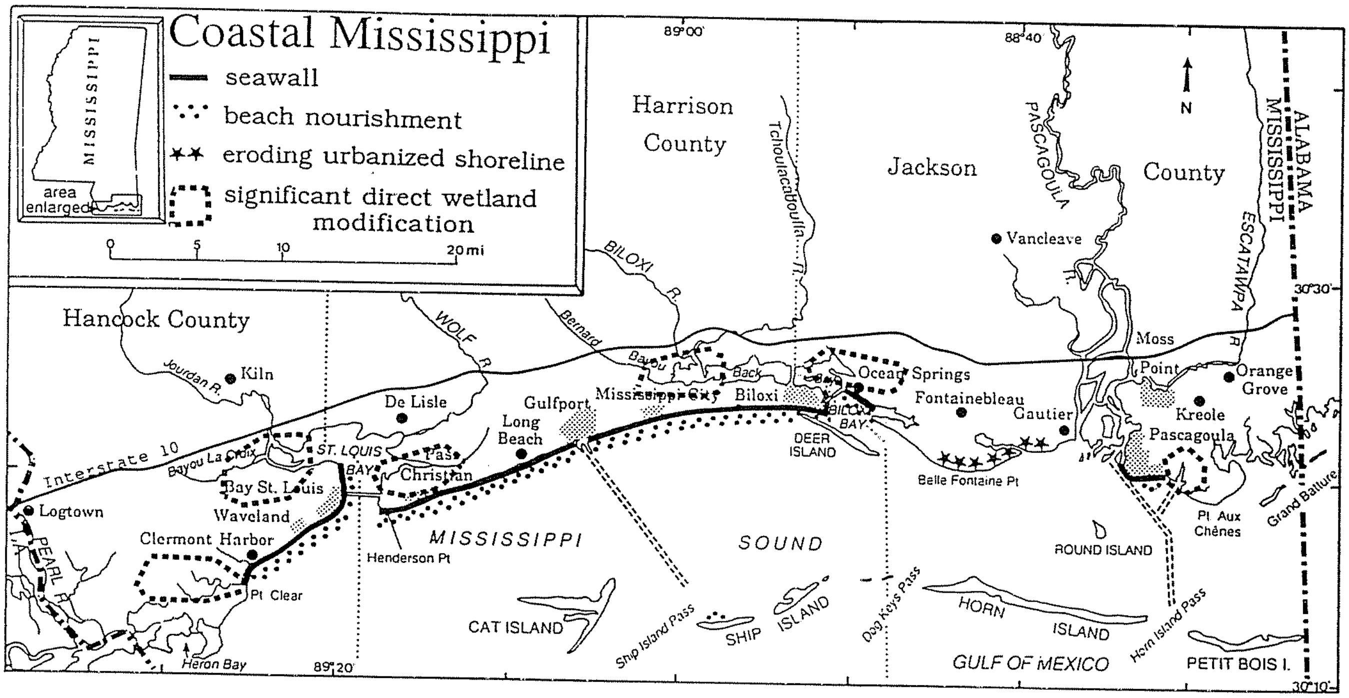


90. Beach remnants along seawall/groin complex near Buccaneer State Park, Waveland, 1988. (Photo by Klaus J. Meyer-Arendt)

especially during the 19th century, because of its natural ship anchorage. Fort Massachusetts was built in the 1850s and a quarantine station was constructed nearby after the 1893 hurricane destroyed the one on Chandeleur Island in Louisiana (Sullivan et al., 1985). Lighthouses were built on the islands, including Horn Island, Cat Island, and Round Island, but early 20th century hurricanes (1901, 1909, 1915, 1916) eventually removed most of these structures. Cattle-grazing was common on the barrier islands well into the 1950s, and during World War II, the U.S. military conducted mustard gas experiments on Horn Island. The most significant geomorphic modifications of the islands included a mid-1970s beach nourishment project to protect a severely eroding Fort Massachusetts and loss of westward-drifting longshore sediments to navigation channels at the west ends of Petit Bois and Ship islands.

Tourism development has also affected Mississippi's islands, but lasting human impacts have been minor. Deer Island, a transgressive Holocene-emergent barrier island flanking the entrance to Biloxi Bay, was briefly developed as the "Coney Island of the South" prior to landfall of the 1915 hurricane (Meyer-Arendt and Gazzier, 1990). During the 1950s boom, elaborate plans for enlarging the island three-fold by dredge-and-fill activity were proposed (Rader and Associates, 1958), but these plans never materialized. Subsequent similar development schemes were bitterly opposed by local environmental groups (Rhode and Hall, 1982; Rhode, 1983). Although retreat rates have not been as high as other barrier island or even mainland shores, Deer Island is subject to frequent storm erosion (Hurricane Elena breached the island in 1985).

In one of the first efforts to develop islands directly fronting the Gulf of Mexico, local entrepreneurs selected the shifting Dog Island for resort construction in the 1920s (Powell, 1988; Rucker and Snowden, 1988). Renamed the Isle of Caprice, the island casino and hotel did a booming business during the Roaring 20s, but shifting shoals led to the gradual crumbling of the resort by 1932 (Rucker and Snowden, 1988). With the exception of the Goose Point Club on Cat Island (anon., 1930), the erosion and destruction of the casino resort of Isle of Caprice (presently the Dog Keys shoals) effectively halted offshore resort development plans for several decades. In the late 1960s and early 1970s, plans for the development of Horn Island surfaced at about the time



91. General types of human modification in the Mississippi coastal zone. (map by Michele D. Meyer-Arendt)

the National Seashore program was acquiring coastal propterties. Except for Cat Island which has the longest history of private ownership, Mississippi's barrier islands are included in the Gulf Islands National Seashore. Development plans for Cat Island surface from time to time, and even in the late 1980s a causeway to the island was proposed!

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HISTORICAL SHORELINE CHANGE IN MISSISSIPPI

by
Stephen M. Oivanki and Barbara Yassin

INTRODUCTION

Primary to any study of shoreline erosion in Mississippi is a documentation of past shoreline changes from the most accurate data available. The Office of Geology, in Year One of the Cooperative Coastal Geology and Regional Marine Study, contracted with the Louisiana Geological Survey (LGS) to accomplish this task by digitizing historical shorelines of Mississippi from USGS and NGS T-sheets dating back to the first surveys in the 1850s. LGS had previously completed a similar historical shoreline study of the Louisiana coastline.

The USGS and NGS maps are the only reliable official maps of the U.S. coastline. There are many historical maps of the Mississippi coast dating back to the 1700s, however none of them were surveyed accurately. While the accuracy of the digitized USGS and NGS maps is only on the order of +/- 10 meters, the trends shown by analysis of the data show a reasonable and consistent amount of shoreline retreat between surveys. The historical shoreline change trends can be checked using short-term change rates surveyed with GPS.

RESEARCH METHOD

Digitized shoreline positions from mylar T-sheet copies from the 1850s, circa 1917, and circa 1956 were delivered to the Office of Geology, and a 1986 1:24,000 scale vertical photo set was obtained and interpreted by LGS, and the shoreline digitized. All of the data were standardized to a common scale and projection and entered into the ARC/Info GIS at the Office of Geology. In 1993 the shoreline was surveyed using Trimble Pathfinder GPS equipment. Accuracy of the historical digitized data is on the order of +/- 10 meters, while the accuracy of the GPS data is +/- 2 meters.

Measurement of shoreline change is made in ARC/Info by overlaying the shorelines for different years and calculating the changes seen from water to land and vice-versa. Tidal and dredge channel openings along the shoreline are closed off at the same location for each data set to eliminate the influence of interior channel changes on the shoreline changes calculated by this method. A complete treatment of shoreline changes in Mississippi is given in Oivanki, et al. (1993), which is included in Appendix E of this Report.

BARRIER ISLAND SHORELINE CHANGE

The Mississippi barrier islands show a constant trend of movement and migration from east to west throughout recorded history. The subject of Mississippi barrier island shoreline changes has been treated in the past by Waller and Malbrough (1976), Byrnes, et al. (1991), and others. The reader is referred to these authors for detailed information on island migration. The erosion of the barrier islands since the 1850s, however, will be addressed in this report. Shoreline positions for each of the islands for each of the time periods studied are shown in the maps at the end of this section. Figure 1 shows the relative location of each of the barrier islands.

	1850-1917	1917-1950	1950-1986	1850-1986
Petit Bois	-248.7	-320.4	-220.0	-789.1
Horn	+55.3	-293.7	-262.6	-501.0
Ship	-127.1	-352.6	-152.7	-632.4
Cat	-175.4	-339.7	-267.9	-783.0
Sand	-	-	+50.1	+50.1
TOTAL	-495.9	-1306.4	-853.1	-2655.4

Table 1. Total area changes for the barrier islands in acres.

Figure 2 is a graphic representation of erosion on the Mississippi barrier islands for the three time periods studied. Figures 3, 4, 5, and 6 are graphs of the individual island changes. Table 1 gives the erosion figures for the time periods studied. The islands, as they migrate, erode on their eastern ends and deposit sand on the western ends of each island. In the graph in Figure 2, erosion is almost equal to accretion for all of the islands for the time period 1850-1917. Between 1917 and 1950 the rate of erosion remains almost the same, but the rate of accretion

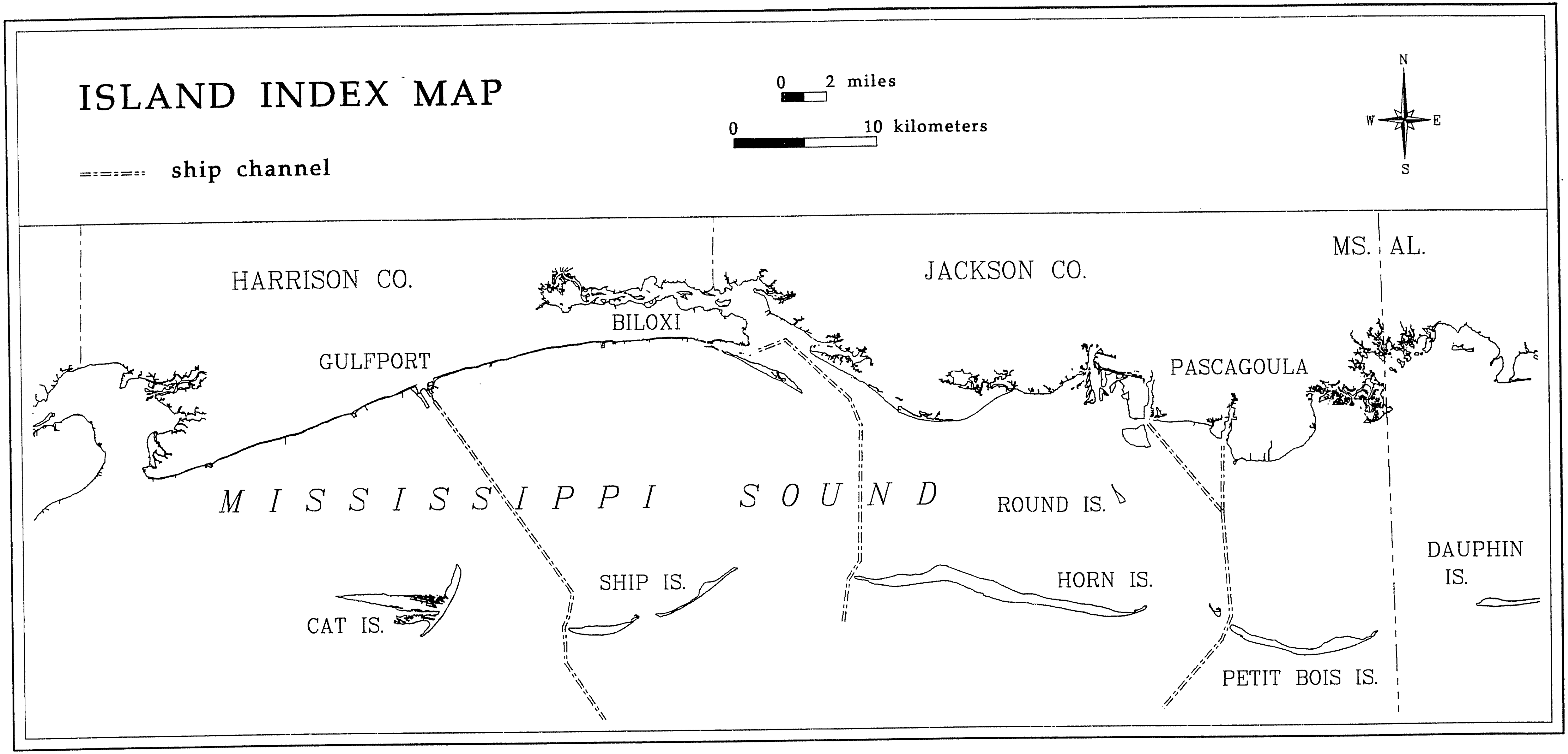

ISLAND INDEX MAP
ship channel
0 2 miles
0 10 kilometers
N
W
E
S
HARRISON CO.
JACKSON CO.
MS.
AL.
BILOXI
GULFPORT
PASCAGOULA
M I S S I S S I P P I S O U N D
ROUND IS.
DAUPHIN IS.
SHIP IS.
HORN IS.
CAT IS.
PETIT BOIS IS.

Figure 1

is drastically reduced. This corresponds with the approximate time that shipping channels were first dredged for the ports of Gulfport and Pascagoula. These channels were dredged at the western ends of Ship and Petit Bois islands. The sand migrating westward along the south shores of these islands started moving into the ship channels instead of building a sand platform westward into the passes. The trend has continued to this day. The barrier islands are now falling into the ship channels instead of migrating westward.

In an attempt to solve this dilemma, the Corps of Engineers tried to bypass sand past the Pascagoula channel west of Petit Bois Island. They created a dredge spoil island (Sand Island) on the west side of the ship channel in the hope that this island would continue to migrate westward like the others. This has not occurred, however, and Sand Island has instead simply eroded in place. The best solution to the problem would be to move the ship channels farther west away from the west ends of the islands. This idea has thus far been rejected as too expensive. The alternative, however, of losing the barrier islands would be many orders of magnitude more costly. Without the protection of the barrier islands, the mainland coast beaches and infrastructure would be irreparably damaged by wave energy from the open Gulf of Mexico. The Gulfport channel was moved one kilometer to the west last year, however the sand from the dredging was broadcast westward instead of being used to fill the old channel and provide a platform for the island to build upon.

Island Name	Accretion (acres)	Erosion (acres)	TotalChange (acres)
East Ship	11.42	19.04	-7.62
West Ship	7.34	19.39	-12.05
Horn	70.95	58.84	+12.11
Sand	2.28	7.97	-5.69
Petit Bois	28.45	32.25	-3.80

Table 2. Shoreline change on the barrier islands (1993-1994).

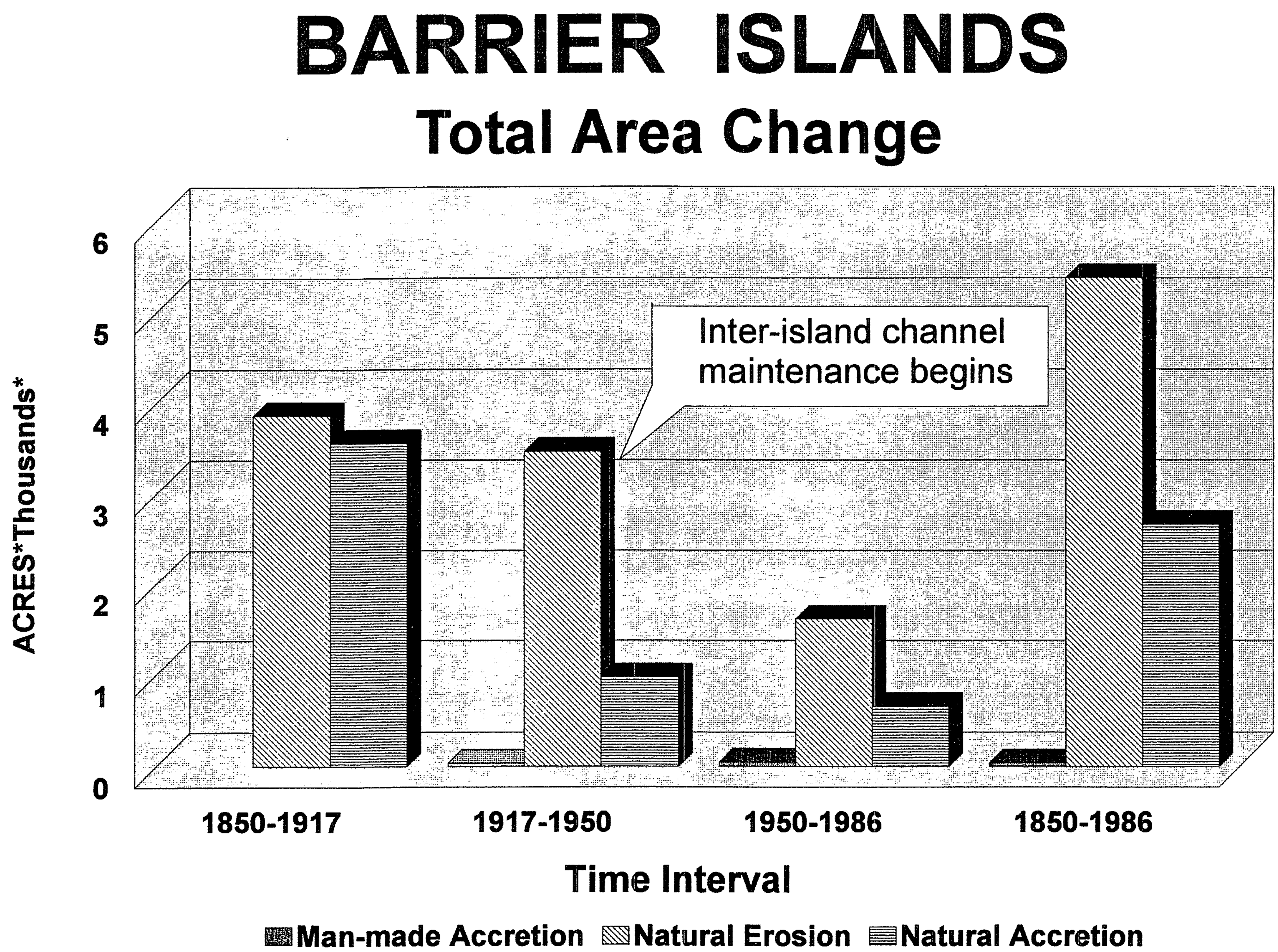

BARRIER ISLANDS
Total Area Change
Inter-island channel maintenance begins
ACRES*Thousands*
0
1
2
3
4
5
6
1850-1917
1917-1950
1950-1986
1850-1986
Time Interval
Man-made Accretion
Natural Erosion
Natural Accretion

Figure 2

SHIP ISLAND

Total Area Change

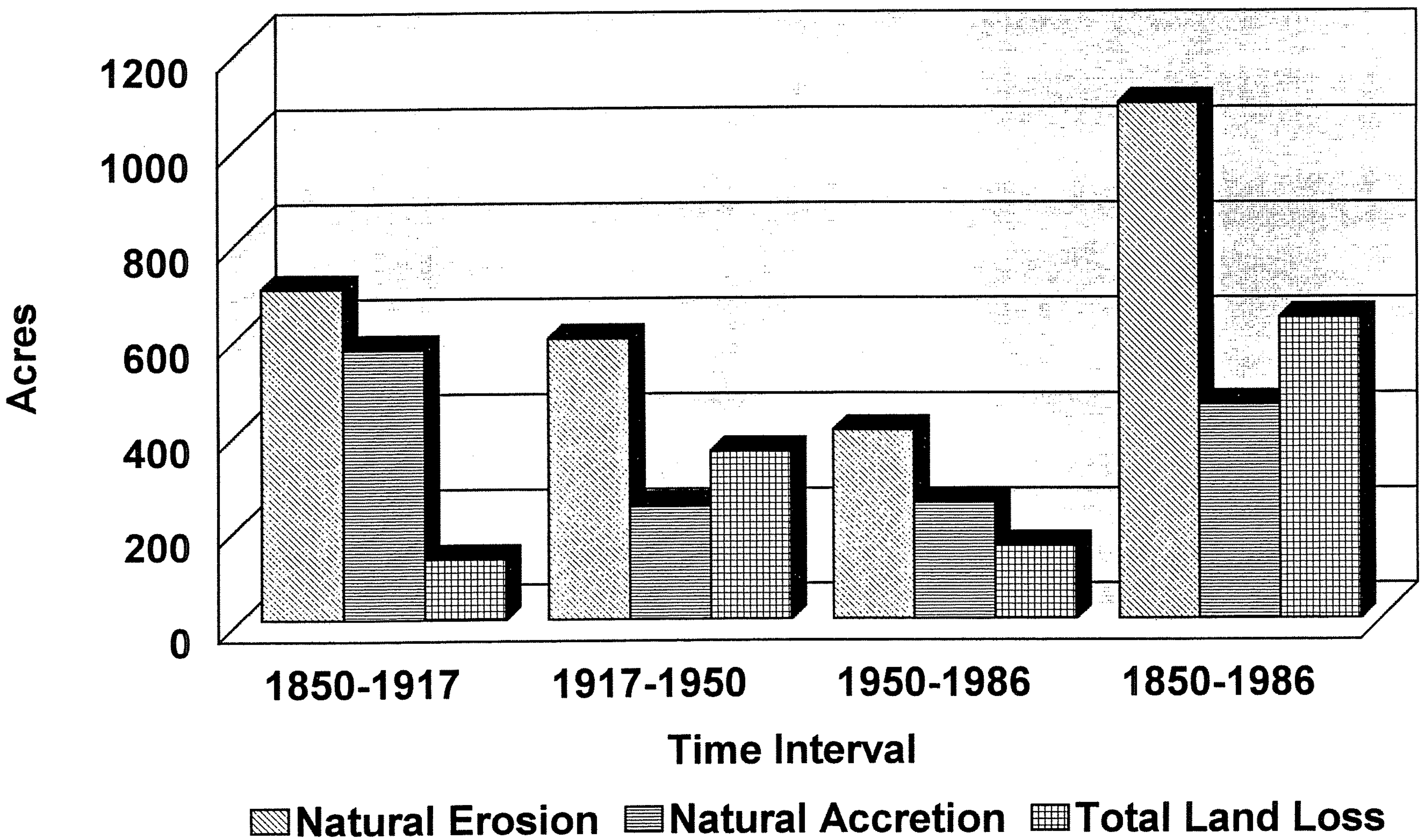


Figure 3

HORN ISLAND

Total Area Change

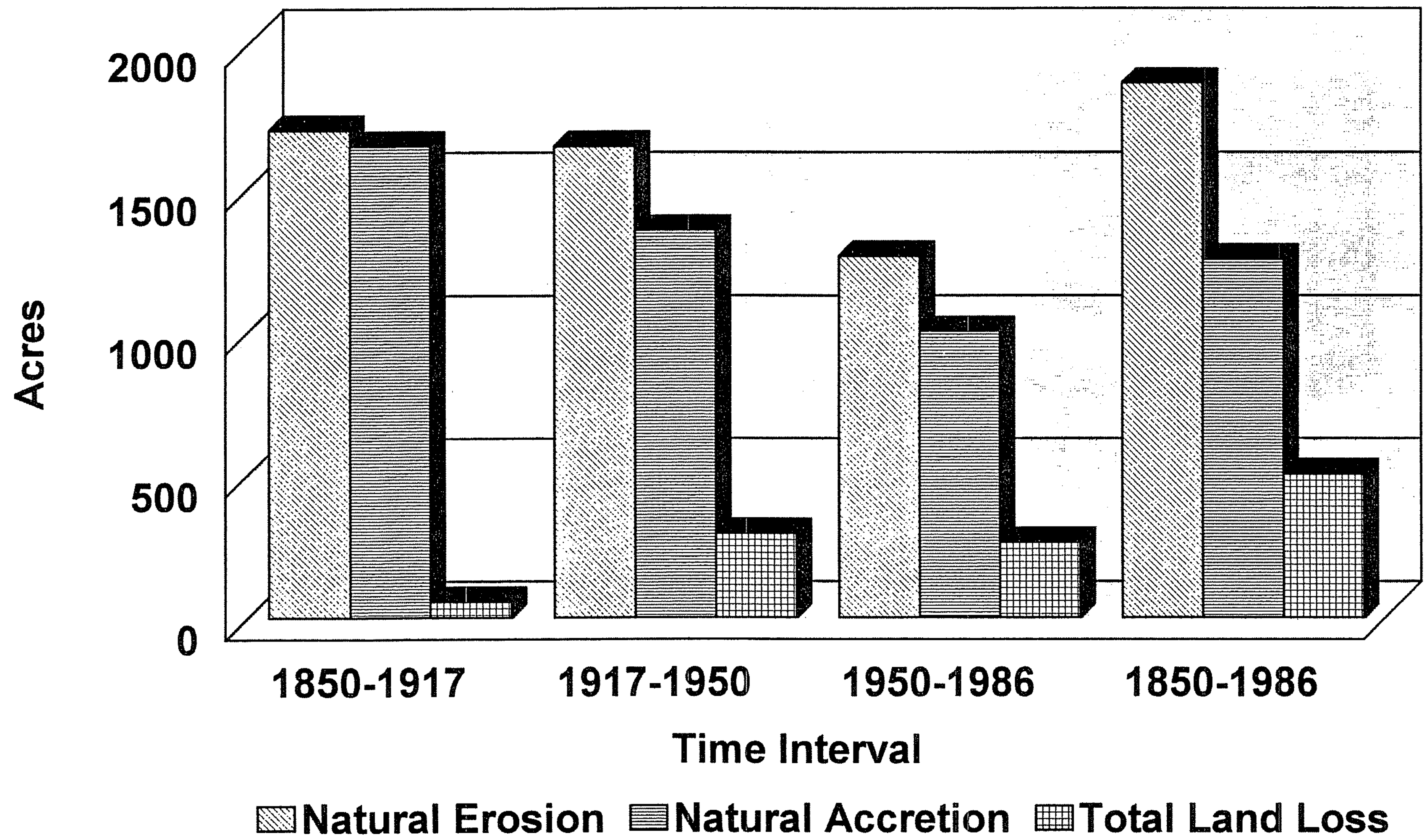


Figure 4

PETIT BOIS ISLAND

Total Area Change

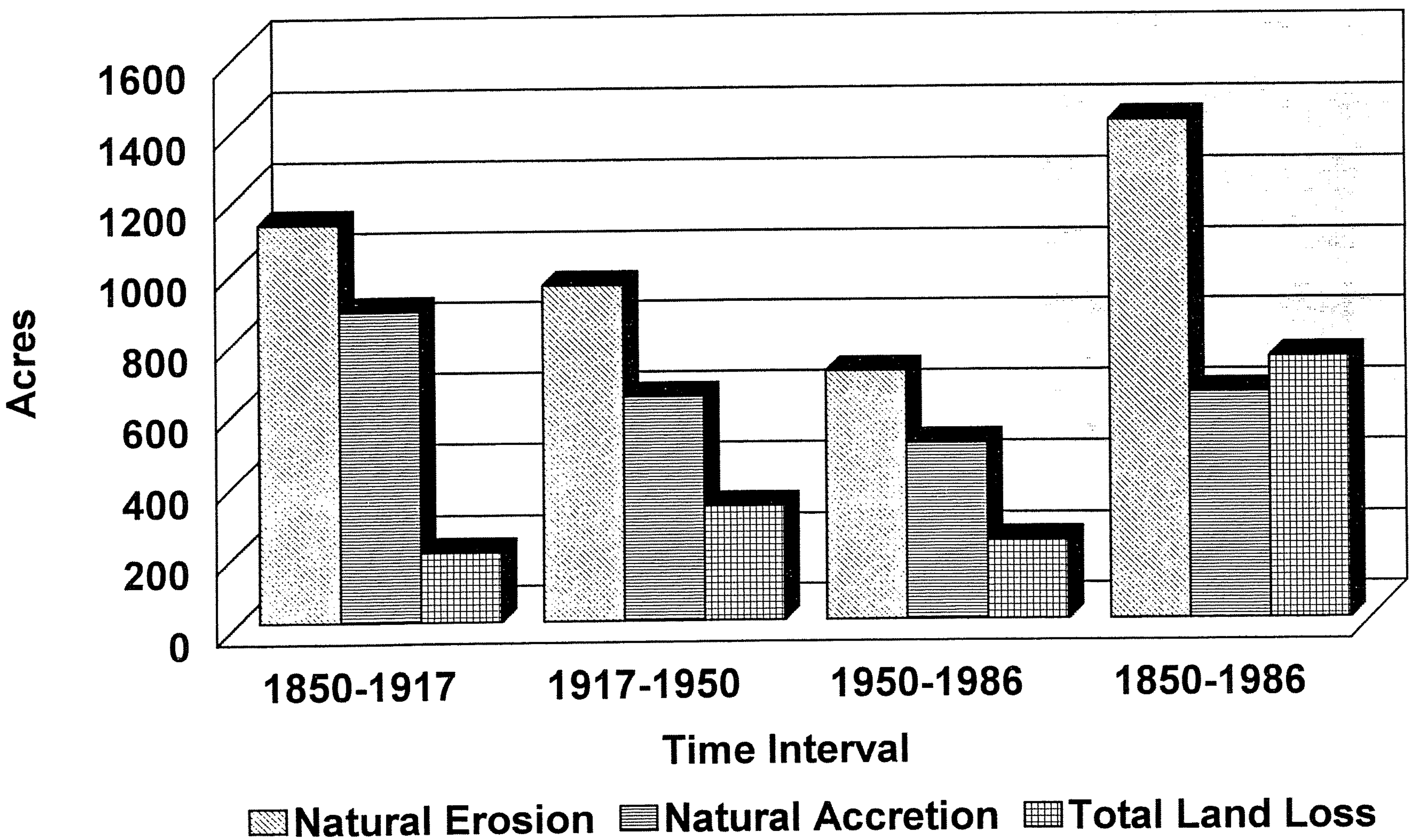


Figure 5

CAT ISLAND

Total Area Change

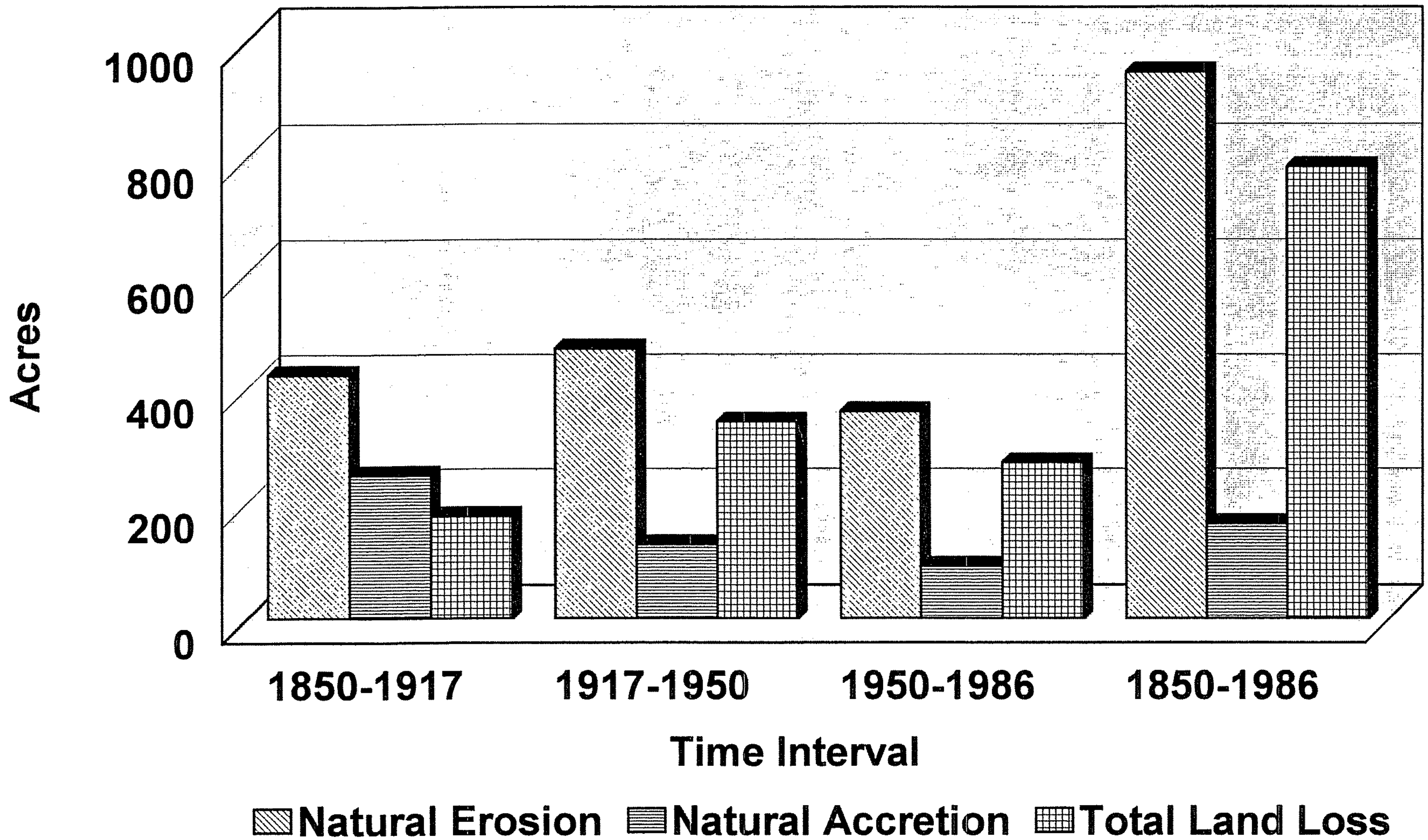


Figure 6

Ship, Horn, Sand, and Petit Bois islands were surveyed using GPS methods in 1993 and 1994. These accurate (compared with the T-sheet interpretations done previously) shoreline change figures for the one year period are shown in Table 2.

Cat Island, unlike the other barrier islands, is not migrating westward. Its development history is different from the other islands in that it was formed by beach accretion ridges, possibly attached to the mainland, prior to the building of the St. Bernard delta of the Mississippi River over 2600 years ago. Its original east-west orientation was changed by placement of the delta and the resulting alteration of the tidal currents and wave patterns. The eastern end of the island was eroded back to form the northeast-southwest sand spit that characterizes the island today. Erosion on Cat Island shows a similar trend with the other islands. Erosion is fairly constant all around the island, and the old beach ridges, now colonized by mature pine forest, are subsiding into the soft mud substructure. A complete treatment of the development history of Cat Island is given by Rucker and Snowden, (1989). Maps showing individual island changes for each of the time periods studied are included in Appendix A of this section.

MAINLAND SHORELINE CHANGES

The mainland coast of Mississippi is quite diverse in habitat, land use, and development history. For this report, the mainland shoreline is divided into segments based on shoreline type and development history. The location of these individually studied segments is shown in Figure 7. Man-made structures are included as part of the shoreline where they extend out into the water. Overall, the mainland shoreline has lost approximately 3148 acres to erosion between the 1850s and 1986. During that same time period man-made accretion, primarily due to dredge spoil disposal and beach nourishment, has reclaimed about 1725 acres. Figure 8 gives a graphical representation of the mainland shoreline changes during the study period.

Hancock County

The Hancock County shoreline can be divided into two distinct types. The shoreline from the Mississippi/Louisiana border at the

Mainland Shoreline

Total Area Change

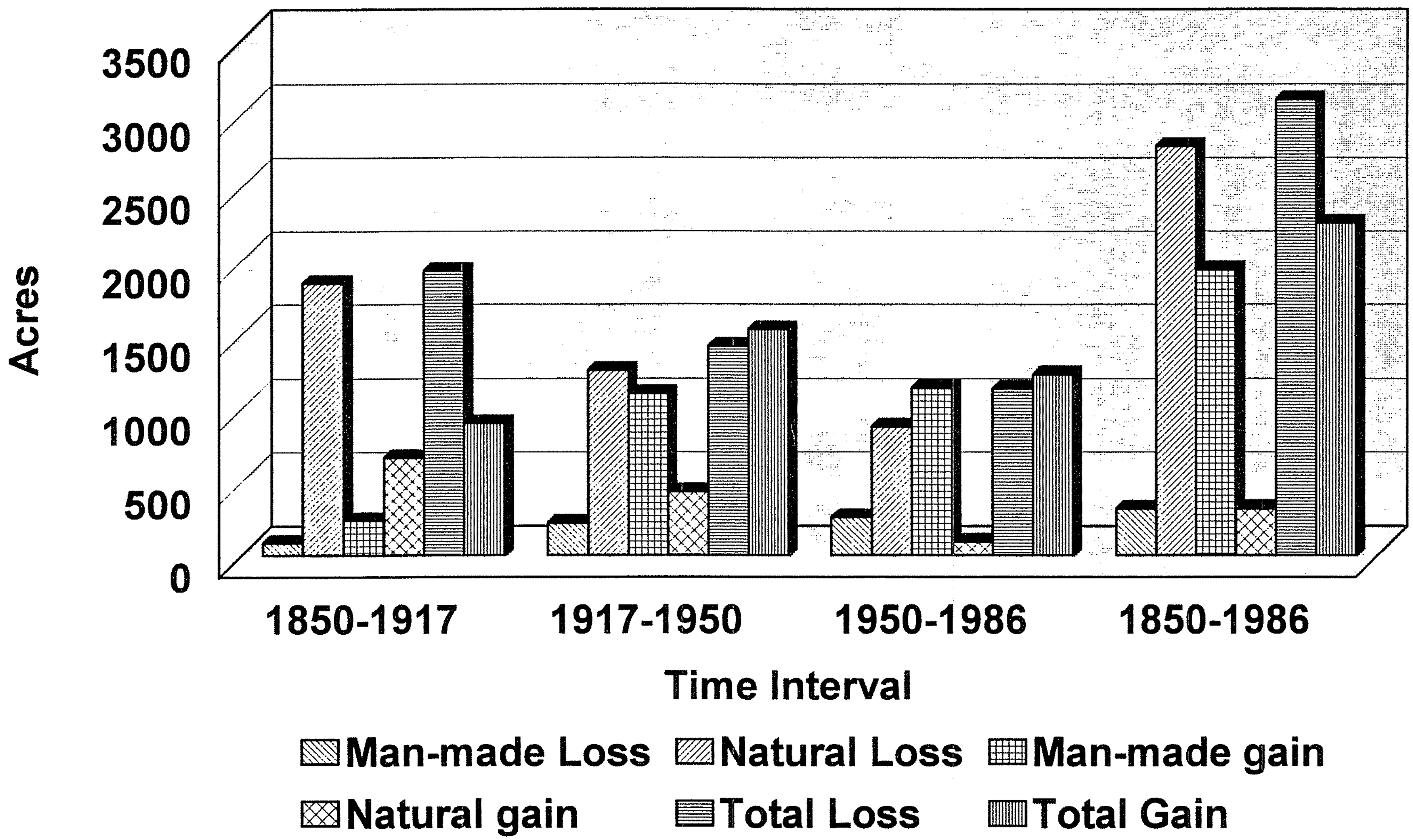
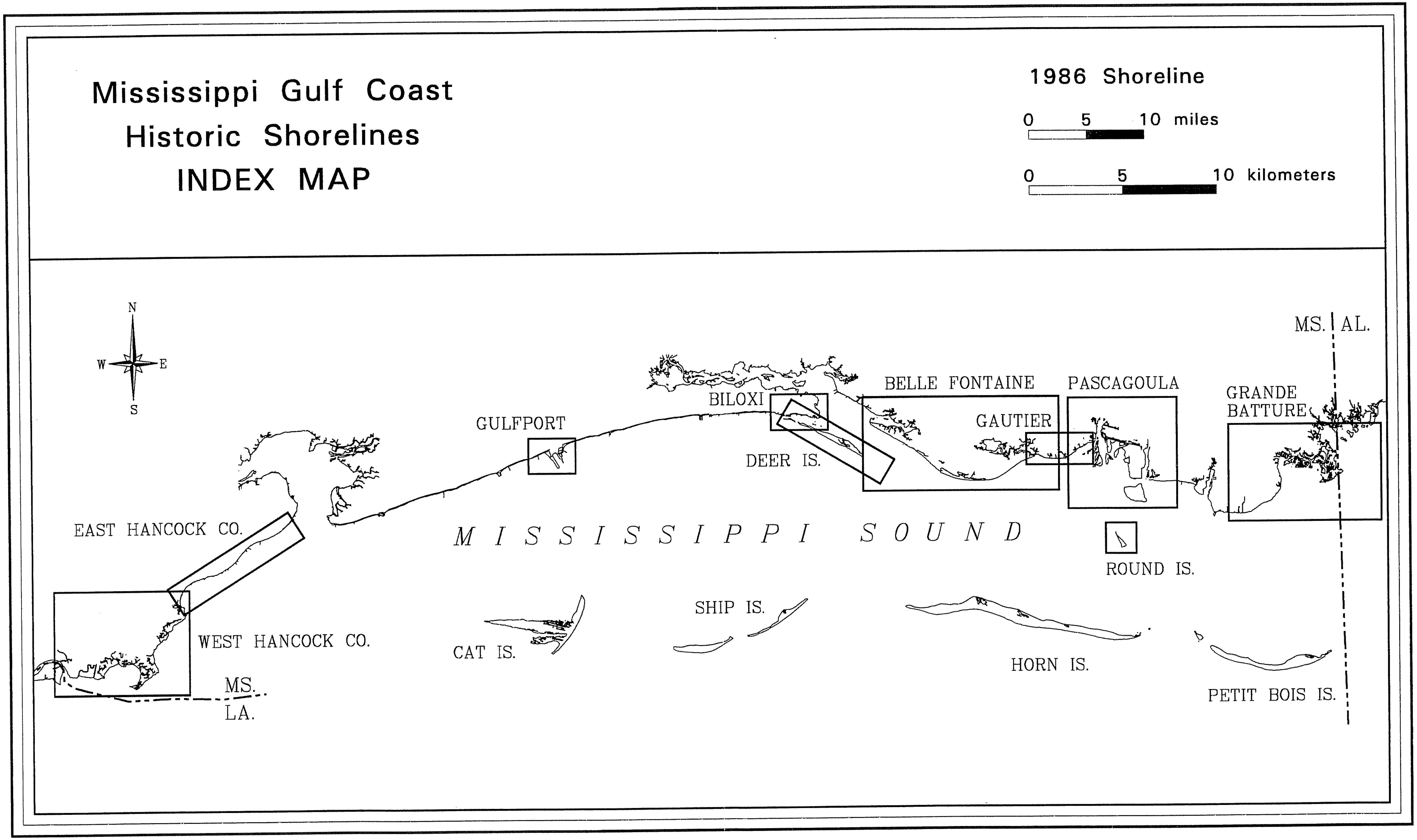


Figure 8



Mississippi Gulf Coast
Historic Shorelines
INDEX MAP
1986 Shoreline
0 5 10 miles
0 5 10 kilometers
N
W
E
S
MS.
AL.
GRANDE BATTURE
PASCAGOULA
BELLE FONTAINE
GAUTIER
BILOXI
DEER IS.
GULFPORT
EAST HANCOCK CO.
M I S S I S S I P P I S O U N D
ROUND IS.
WEST HANCOCK CO.
CAT IS.
SHIP IS.
HORN IS.
PETIT BOIS IS.
MS.
LA.

Figure 7

WEST HANCOCK CO.

0 1 2 Miles

0 1 2 Kilometers

1850 to 1986

ACCRETION

EROSION

SHORELINE CHANGE IN ACRES

	MAN-MADE EROSION	MAN-MADE ACCRETION	NATURAL EROSION	NATURAL ACCRETION
1850-1917	0.0	0.0	379.2	30.8
1917-1950	0.0	0.0	372.8	15.1
1950-1986	0.0	0.0	285.7	15.8
1850-1986	0.0	0.0	1007.4	0.3

Figure 9

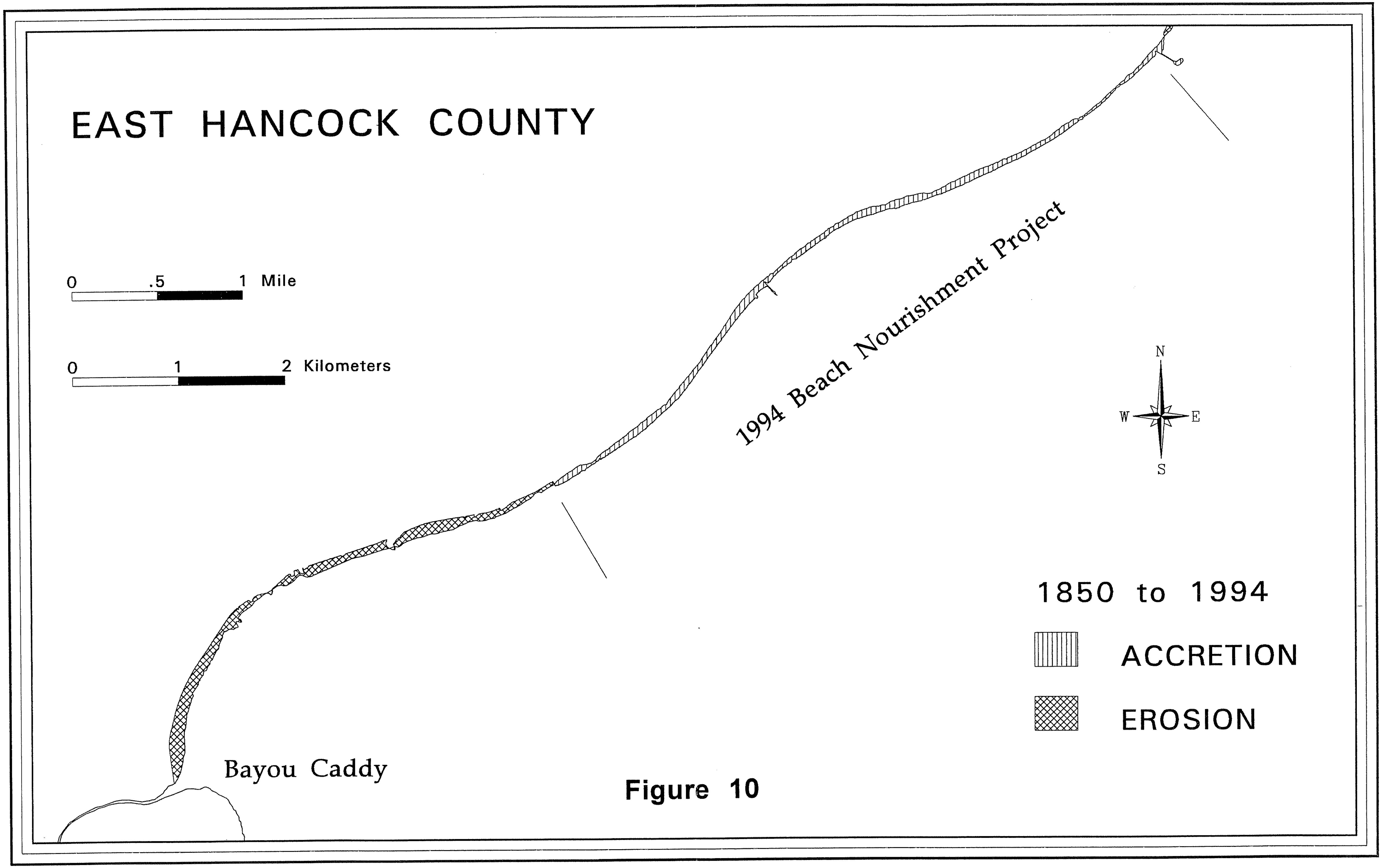

EAST HANCOCK COUNTY
0 .5 1 Mile
0 1 2 Kilometers
1994 Beach Nourishment Project
N
W
E
S
1850 to 1994
ACCRETION
EROSION
Bayou Caddy

Figure 10

Pearl River to Bayou Caddy is comprised of natural marsh. The shore from Bayou Caddy to St. Louis Bay is fronted by a seawall with an artificial beach in front of the seawall. Overall erosion figures for the county are given in Table 3.

	1850-1917	1917-1950	1950-1986	1850-1986
Man-made Loss	0.0	6.1	6.5	105.1
Man-made Gain	0.0	0.0	29.1	12.1
Natural Loss	393.5	491.3	285.6	934.3
Natural Gain	88.2	15.8	16.1	0.4
Total Loss	393.5	497.5	292.0	1039.4
Total Gain	88.2	15.8	45.2	12.5

Table 3. Hancock County shoreline changes in acres.

The marsh shoreline in the western portion of Hancock County has one of the highest erosion rates in Mississippi. The shore there has lost 1007 acres between the 1850s and 1986. Shore retreat rates averaged 5 feet (1.5 meters) per year during this time period. The long fetch for southeast wind-generated waves attacking this shoreline segment results in rapid erosion during most of the year. Low-tide waves undercut the exposed marsh substrate, causing the overburden to topple into the surf. High-tide waves then break directly on the undercut marsh platform and contribute to the collapse of the shoreline. There is no sand in this area to form a berm or barrier to the wave attack. Figure 9 shows the shoreline changes between the 1850s and 1986 for this segment.

The portion of the shore fronted by the seawall is relatively fixed in location. The seawall was constructed in 1927-28, and the first beach was pumped in front of it in 1967. Construction of the seawall and beach actually expanded the shoreline, but the beach was all but destroyed by hurricanes in 1969 and 1985. The new beach, pumped into place in 1994, was surveyed with GPS and is shown in Figure 10 compared with the shoreline position in 1850. For the time period 1850-1994 the East Hancock County shoreline has lost 101 acres to erosion, and man has rebuilt 90 acres with seawall construction and the new beach nourishment in 1994.

Harrison County

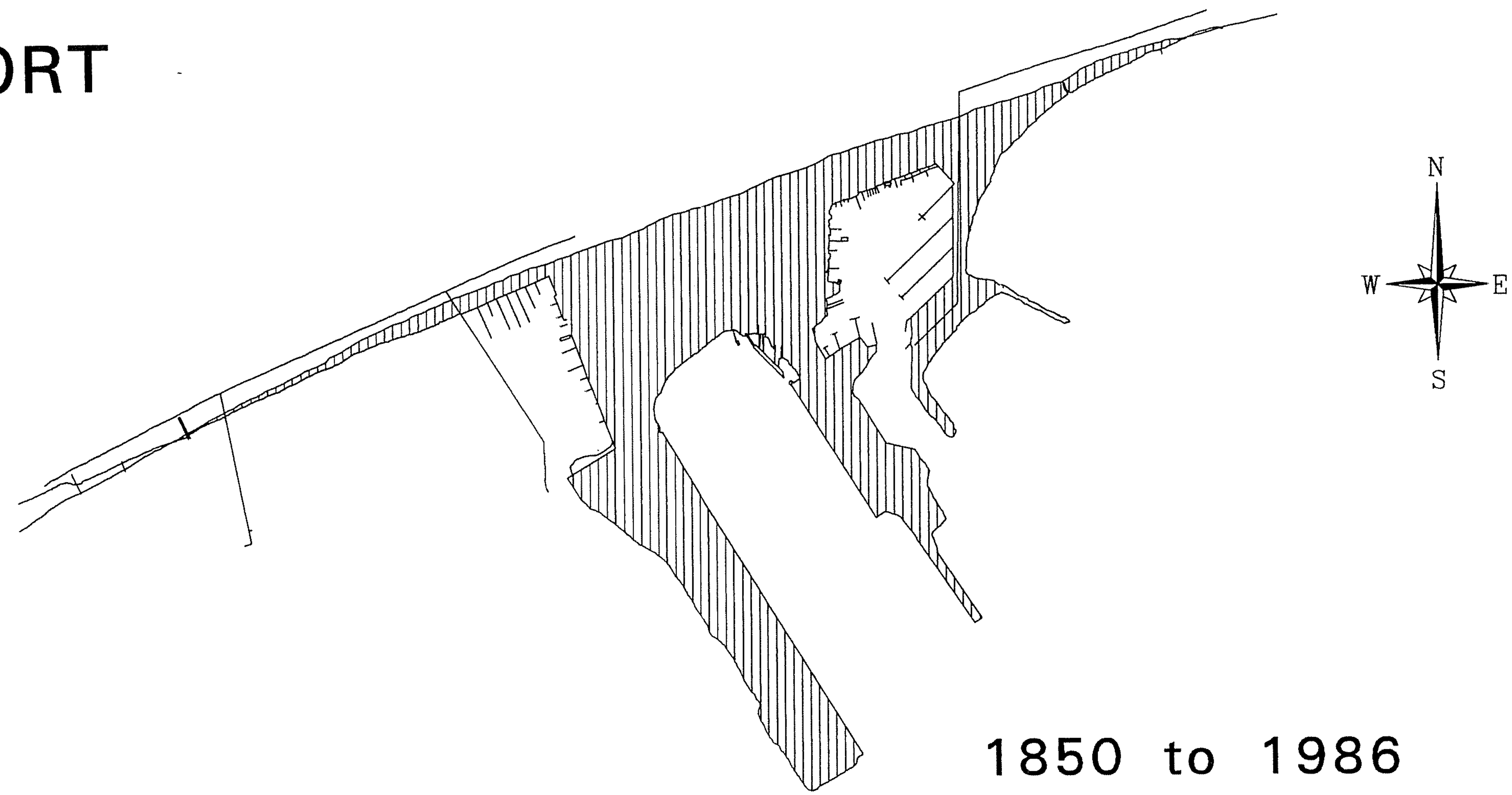
Harrison County is fronted along its entire shoreline by a seawall and artificial beach. When compared with the natural shoreline in the 1850s, the man-made shoreline in 1986 had added 612 acres (Table 4). 235 acres of this addition are due to the building and expansion of the Port of Gulfport (Figure 11) and the surrounding harbor area. Biloxi (the area near Point Cadet) shows an addition of 110 acres between 1950 and 1986 (Figure 12). Continued additions to the Harrison County shoreline are occurring today as a result of casino construction. For more detailed analysis of additions to the Harrison County shoreline please refer to "Beach and Nearshore Sediment Budget of Harrison County, Mississippi: A Historical Analysis" by Klaus Meyer-Arendt in another section of this report.

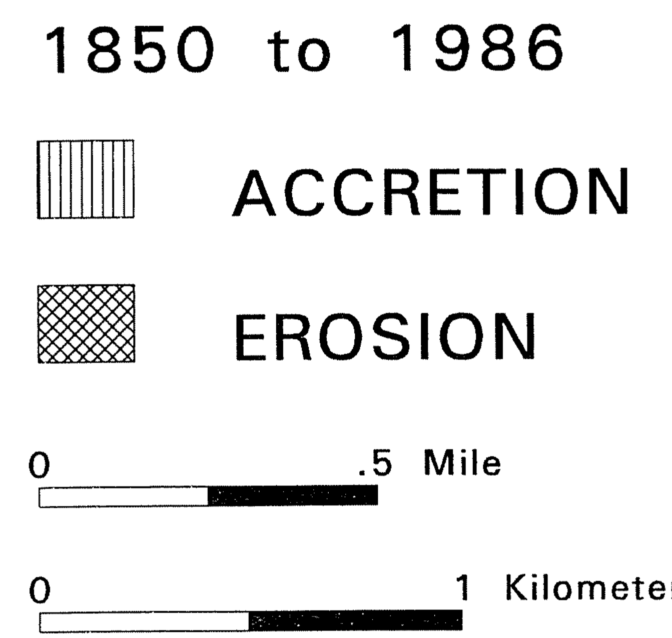
Deer Island, located in Harrison County just offshore of Point Cadet in Biloxi, is a remnant Pleistocene beach ridge once attached to the mainland. The island is privately owned, although no development is allowed due to wetlands restrictions and the Coastal Barrier Protection Act. The island has lost 288 acres since the 1850s, and 16 acres have been added to the west end of the island through dredge spoil disposal and the construction of a breakwater for the Biloxi harbor. Most of the erosion has occurred on the east end of the island where several remnant islands have disappeared. Deer Island changes are shown in Figure 13.

	1850-1917	1917-1950	1950-1986	1850-1986
Man-made Loss	8.6	15.0	144.6	44.7
Man-made Gain	123.8	667.8	105.1	612.4
Natural Loss	206.6	0.0	0.0	0.0
Natural Gain	37.3	0.0	0.0	0.0
Total Loss	215.1	15.0	144.6	44.7
Total Gain	161.7	667.8	105.1	612.4

Table 4. Harrison County shoreline change in acres.

GULFPORT



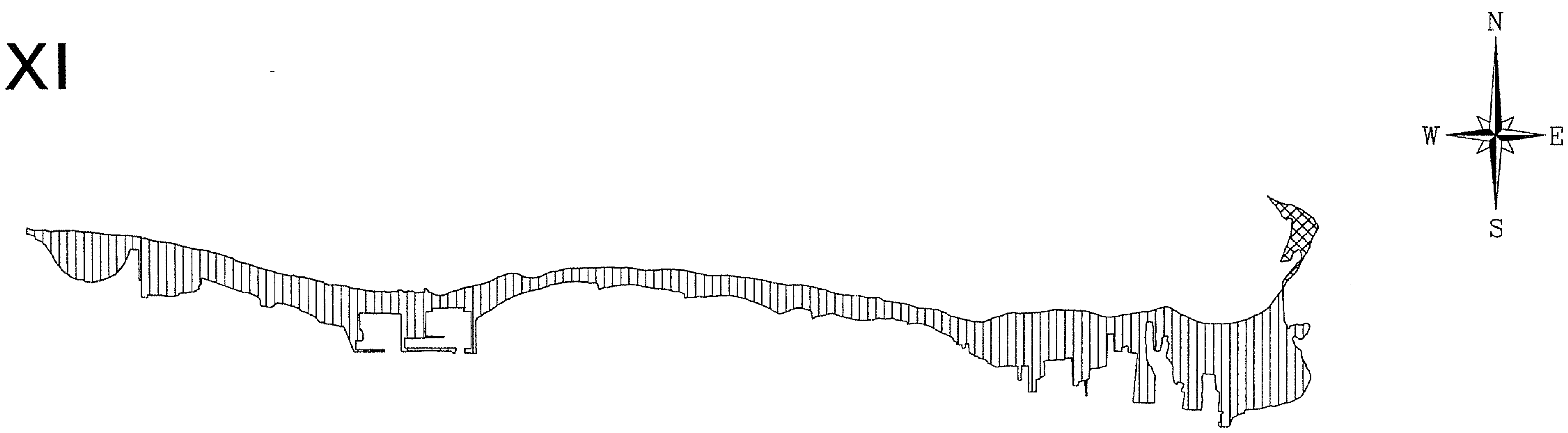


SHORELINE CHANGE IN ACRES

	MAN-MADE EROSION	MAN-MADE ACCRETION	NATURAL EROSION	NATURAL ACCRETION
1850-1917	0.4	98.4	14.1	5.2
1917-1950	4.6	115.2	0.0	0.0
1950-1986	12.2	47.1	0.0	0.0
1850-1986	0.0	234.7	0.0	0.0

Figure 11

BILOXI



1850 to 1986

ACCRETION

EROSION

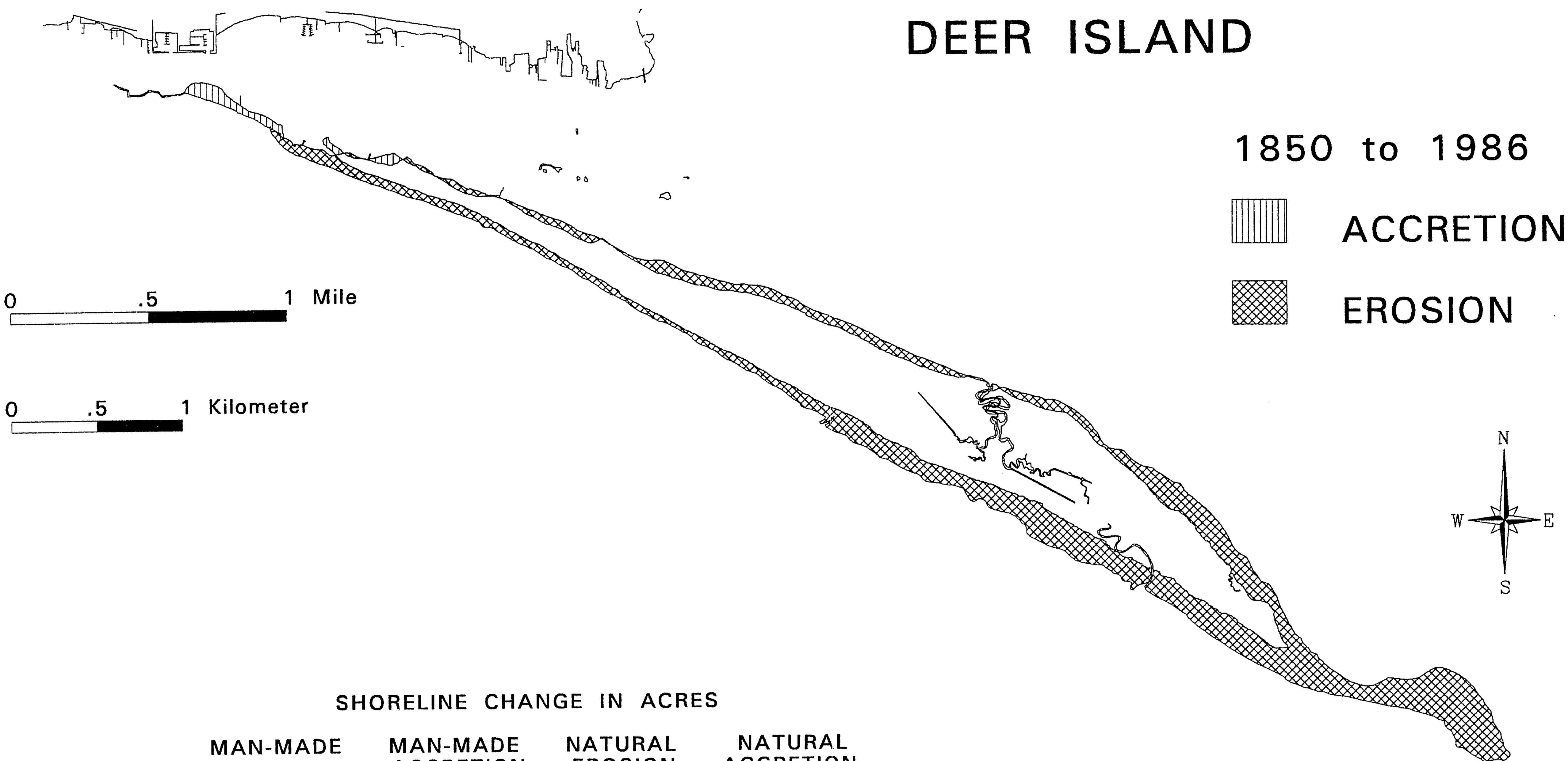
0 .5 Mile

0 1 Kilometer

SHORELINE CHANGE IN ACRES

	MAN-MADE EROSION	MAN-MADE ACCRETION	NATURAL EROSION	NATURAL ACCRETION
1850-1917	8.1	25.6	1.3	0.5
1917-1950	7.4	77.1	0.0	0.0
1950-1986	3.7	25.0	0.0	0.0
1850-1986	3.2	110.5	0.0	0.0

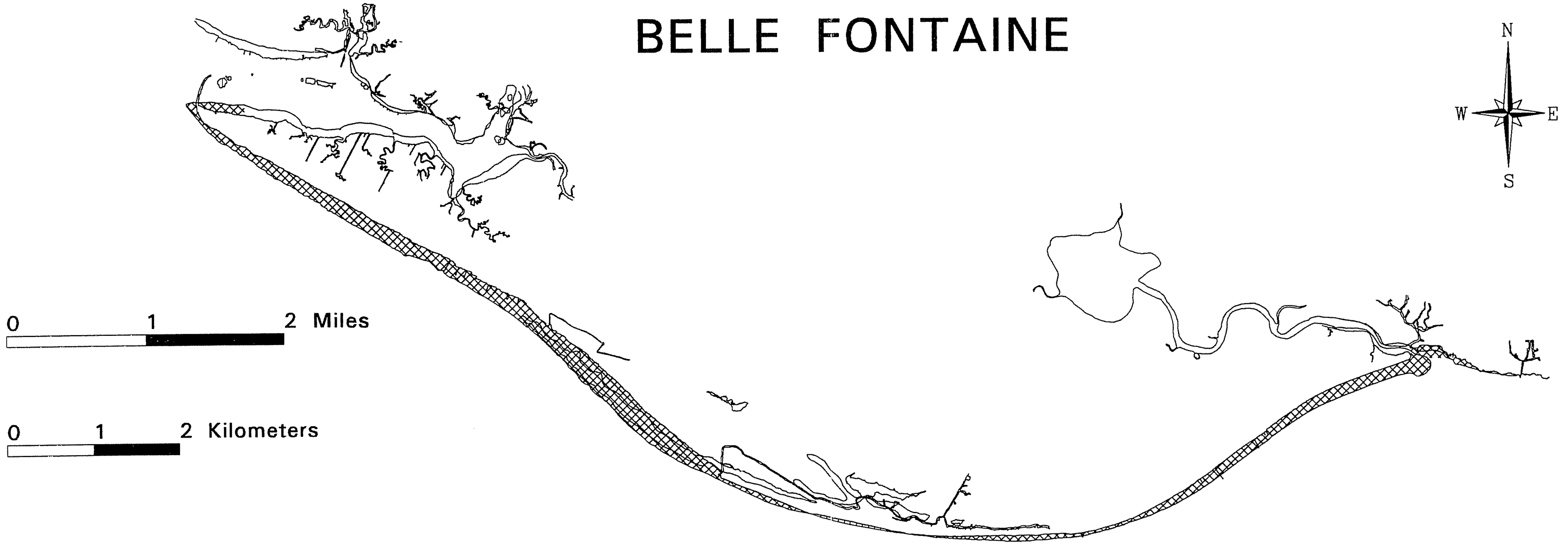
Figure 12



SHORELINE CHANGE IN ACRES

	MAN-MADE EROSION	MAN-MADE ACCRETION	NATURAL EROSION	NATURAL ACCRETION
1850-1917	0.0	0.0	136.2	31.9
1917-1950	0.0	2.3	110.6	11.8
1950-1986	2.3	0.0	81.2	12.2
1850-1986	0.0	0.0	288.0	15.9

Figure 13



SHORELINE CHANGE IN ACRES

	MAN-MADE EROSION	MAN-MADE ACCRETION	NATURAL EROSION	NATURAL ACCRETION
1850-1917	0.0	0.0	326.9	7.2
1917-1950	0.0	0.0	80.4	42.4
1950-1986	13.0	0.4	105.4	3.7
1850-1986	13.0	0.0	470.9	11.2

1850 to 1986

ACCRETION

EROSION

Figure 14

The Harrison County shoreline, by virtue of its heavy use as a tourist beach, and the great cost for the county to keep it clean and in place, has been the subject of considerable research effort in the past. The Office of Geology began surveying the Harrison County beach using GPS methods in 1993. The beach was re-surveyed in 1994, however, the total shoreline change for the one year period was not large enough to exceed the margin of error for GPS measurement.

Jackson County

Jackson County can be roughly divided into five segments based on shoreline type and erosion rates: Ocean Springs, Belle Fontaine, Gautier, Pascagoula, and the Grande Batture area.

Ocean Springs is located just across Biloxi Bay from Biloxi and Harrison County. The shoreline is fronted by a seawall with an artificial beach in front of the seawall. Although this shoreline extends into Davis Bayou for some distance, the measured shoreline was cut off at the entrance to Davis Bayou due to a lack of accurate shoreline positions for several historic time periods. The Ocean Springs shoreline has gained 27 acres between the 1850s and 1986 due to construction of the seawall and beach. The protected nature of this shore behind Deer Island prevents any extensive erosion of the beach.

The Belle Fontaine shoreline segment extends from the mouth of Davis Bayou (Marsh Point) to the mouth of Graveline Bayou. This area is the subject of an extensive study in "Belle Fontaine, Jackson County, Mississippi: Human history, Geology, and Shoreline erosion", Mississippi Office of Geology Bulletin 130, which is included as an attachment to this Report. The natural shoreline at Belle Fontaine has lost 473 acres since the 1850s. For more detailed analysis of this shoreline segment the reader is referred to the above-mentioned Bulletin. Figure 14 shows the shoreline changes here between the 1850s and 1986.

Gautier is located between Belle Fontaine and the Pascagoula River. The area is entirely residential, and many portions of the shoreline are protected by private bulkheads. This shoreline is relatively protected from the predominant southeast wave climate by the Pascagoula River delta, Singing River Island, and Round Island. The shore is composed of Pleistocene material which is resistant to wave erosion. Total shoreline change between 1850 and 1986 is small, only 39 acres (Figure 15).

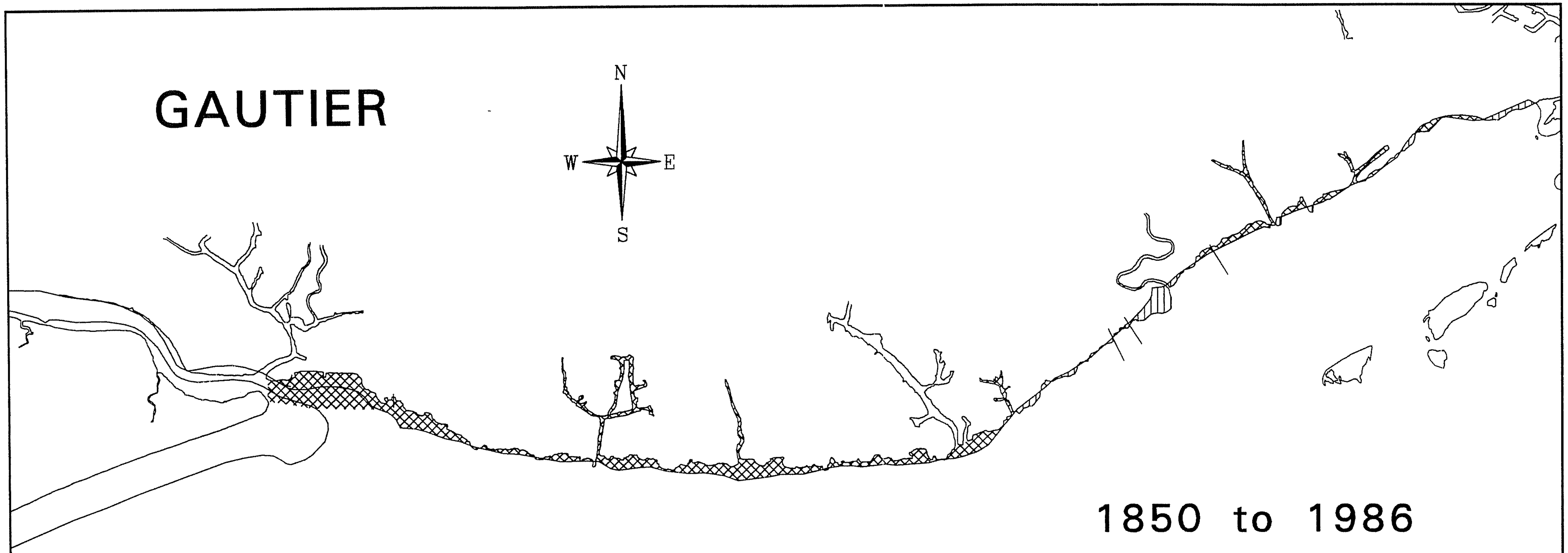
Round Island, located in Jackson County offshore of Pascagoula, is another remnant Pleistocene portion of the mainland. This small, and not even close to "round", island has lost about 84 acres to erosion between the 1850s and 1993. Several attempts to protect the historic lighthouse at the east end of the island have added small parcels to the shoreline in recent years, however the rate of erosion on the southeast-facing shore is greater than these efforts. Some sand eroded from the southeast shore is deposited in a spit at the northwest end of the island, and this spit moves about regularly in response to changing wind directions much like the wagging of a dogs tail. Round Island shoreline changes are shown in Figure 16.

The Pascagoula area includes the Pascagoula River delta, and the extensive Ingalls Shipyard complex and the Port of Pascagoula. A very large volume of dredge and fill has occurred in this area since the 1850s. Overall, about 249 acres have been added to the shoreline, including Singing River Island, the site of the U. S. Navy Homeport Pascagoula, which is an island built entirely from dredge spoil taken out of the harbor. Figure 17 shows the shoreline changes which have occurred in this area.

The Grande Batture area extends from Bayou Cassotte eastward into Alabama. This area has the highest rate of erosion in Mississippi. The shoreline is entirely marsh subject to direct wave attack from waves in Mississippi Sound. In 1850 the Grande Batture Islands protected much of this shoreline and Point Aux Chênes Bay from wave erosion. These former delta-front islands have been eroded away, however, and the wetlands behind them are rapidly disappearing. Shoreline retreat rates here have averaged 2 meters per year since the 1850s, and over 1400 acres have been lost to erosion. Figure 18 shows the shoreline changes between the 1850s and 1986 in this area.

CONCLUSIONS

The mainland shoreline of Mississippi has a complex history of natural development and man-made intervention. Erosion has taken about 3150 acres since the 1850s, and man has reclaimed about 1725 acres. The recent concern for preservation of wetlands and natural



1850 to 1986

ACCRETION

EROSION

0 .5 Mile

0 1 Kilometer

SHORELINE CHANGE IN ACRES

	MAN-MADE EROSION	MAN-MADE ACCRETION	NATURAL EROSION	NATURAL ACCRETION
1850-1917	0.0	0.0	112.5	0.0
1917-1950	0.0	0.0	5.4	65.1
1950-1986	0.0	0.0	10.8	24.9
1850-1986	0.0	0.0	44.7	5.5

Figure 15

ROUND ISLAND

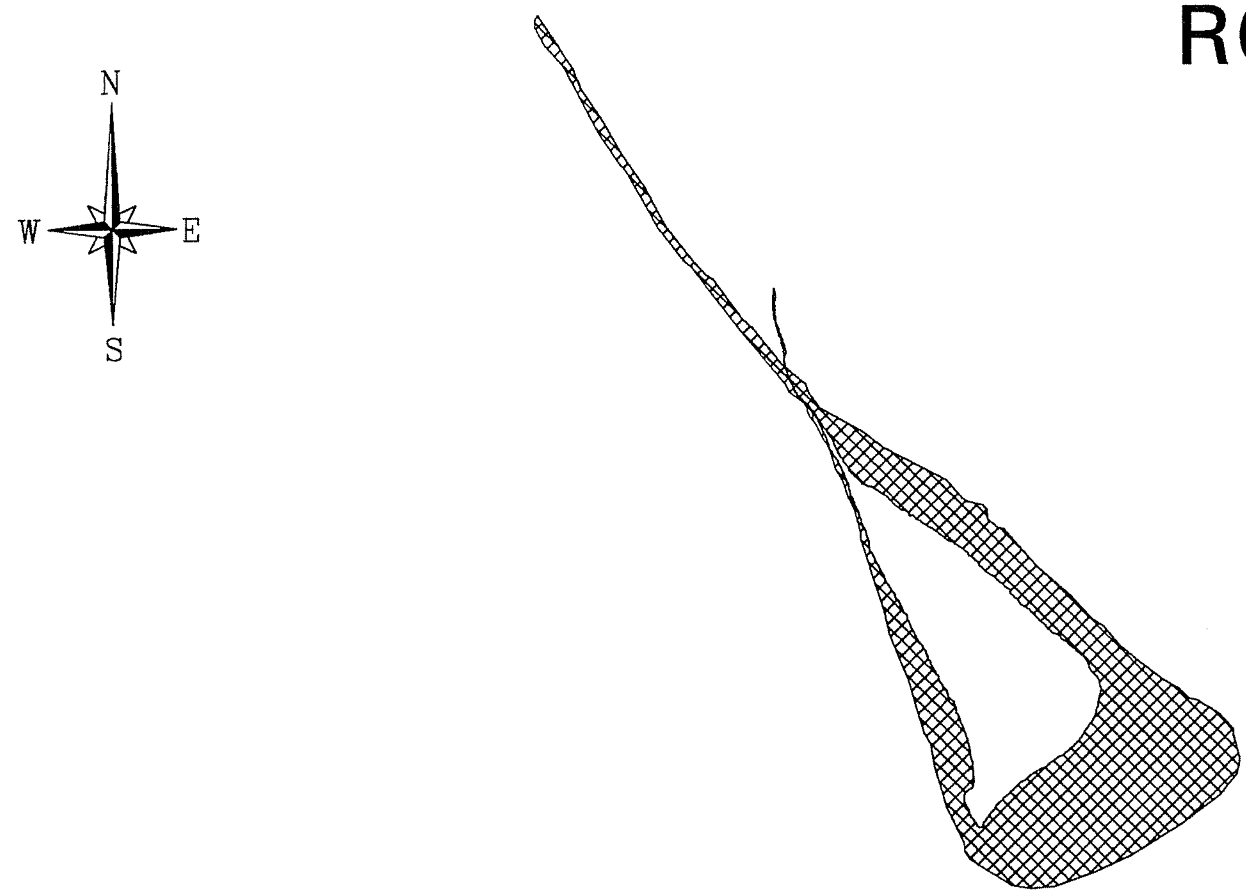
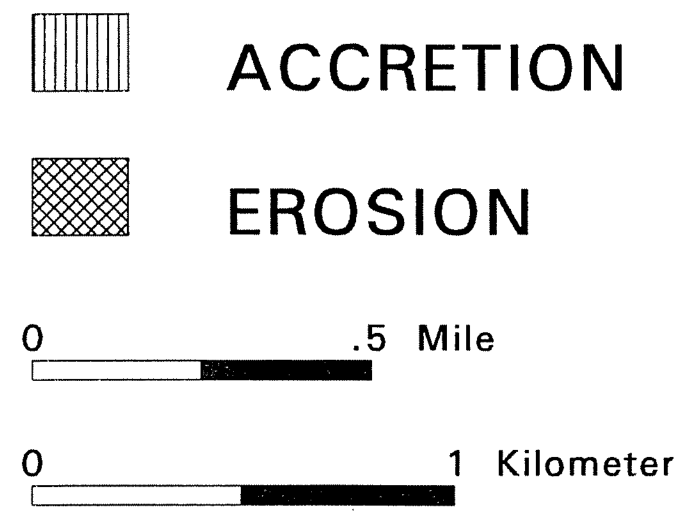


Figure 16

1850 to 1993



SHORELINE CHANGE IN ACRES

	MAN-MADE EROSION	MAN-MADE ACCRETION	NATURAL EROSION	NATURAL ACCRETION
1850-1917	0.0	0.0	27.2	6.5
1917-1950	0.0	0.0	32.6	0.4
1950-1993	0.0	2.0	31.5	0.3
1850-1993	0.0	0.0	84.4	0.4

PASCAGOULA

0 1 2 Miles

0 1 2 Kilometers

1850 to 1986

ACCRETION

EROSION

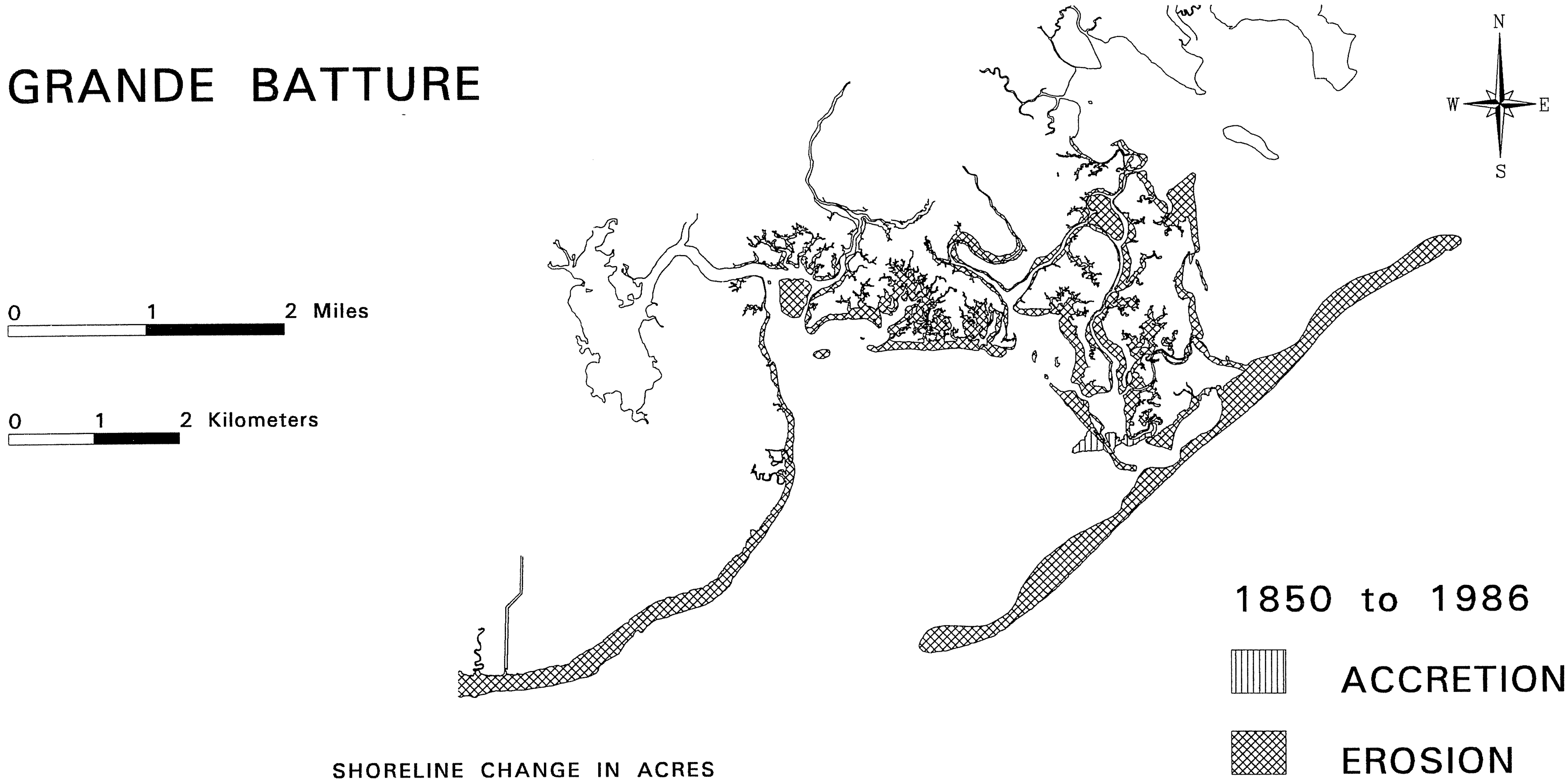
SHORELINE CHANGE IN ACRES

	MAN-MADE EROSION	MAN-MADE ACCRETION	NATURAL EROSION	NATURAL ACCRETION
1850-1917	56.3	111.4	70.7	306.1
1917-1950	158.2	349.2	115.4	115.7
1950-1986	60.2	824.9	68.5	5.7
1850-1986	106.2	1136.7	76.8	248.5

N
W E
S

Figure 17

GRANDE BATTURE



SHORELINE CHANGE IN ACRES

	MAN-MADE EROSION	MAN-MADE ACCRETION	NATURAL EROSION	NATURAL ACCRETION
1850-1917	0.0	0.0	777.6	190.5
1917-1950	0.0	0.0	571.7	203.4
1950-1986	0.0	0.0	421.0	42.9
1850-1986	0.0	0.0	1418.4	55.0

Figure 18

habitats has slowed the man-made reclamation of the mainland shoreline, but areas of accretion still exist near highly developed sections of the shore, such as Biloxi and Pascagoula. The highest rates of erosion are located in the undeveloped marsh areas of the state, where there has been little public concern for shoreline protection. The artificial beach in Harrison County receives the most attention due to its highly visible nature and value as a tourist attraction.

The barrier islands, by virtue of their status as a National Park, have been relatively ignored by other state and federal agencies. The National Park Service has declined to develop erosion mitigation methods to reverse the current erosion trend, except to protect Fort Massachusetts on Ship Island with dredged sand. To save these islands from their eventual fate at the hands of the channel dredges will require more pressure on the part of organizations and individuals to change the current inter-island channel maintenance practices. The loss of these islands would be catastrophic to the economy of Mississippi.

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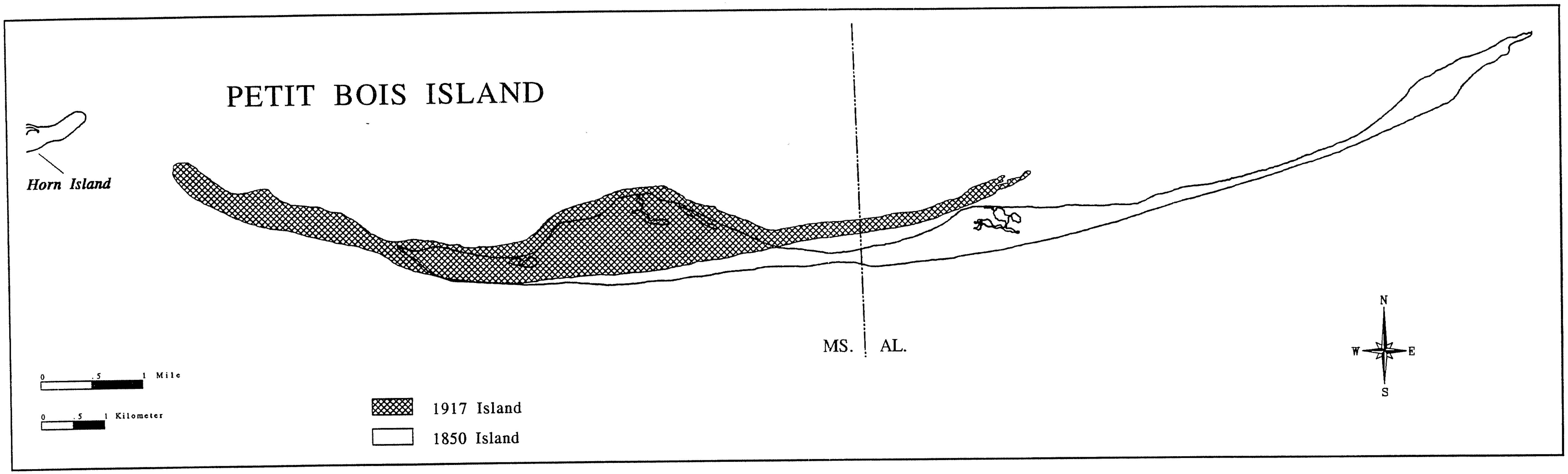
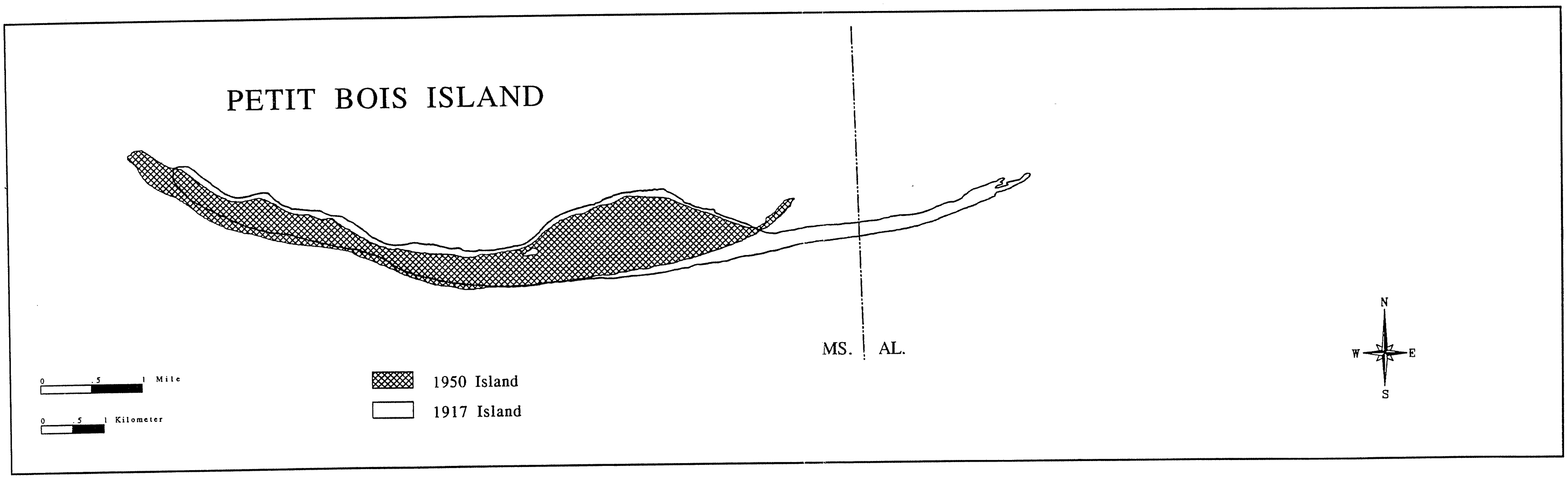
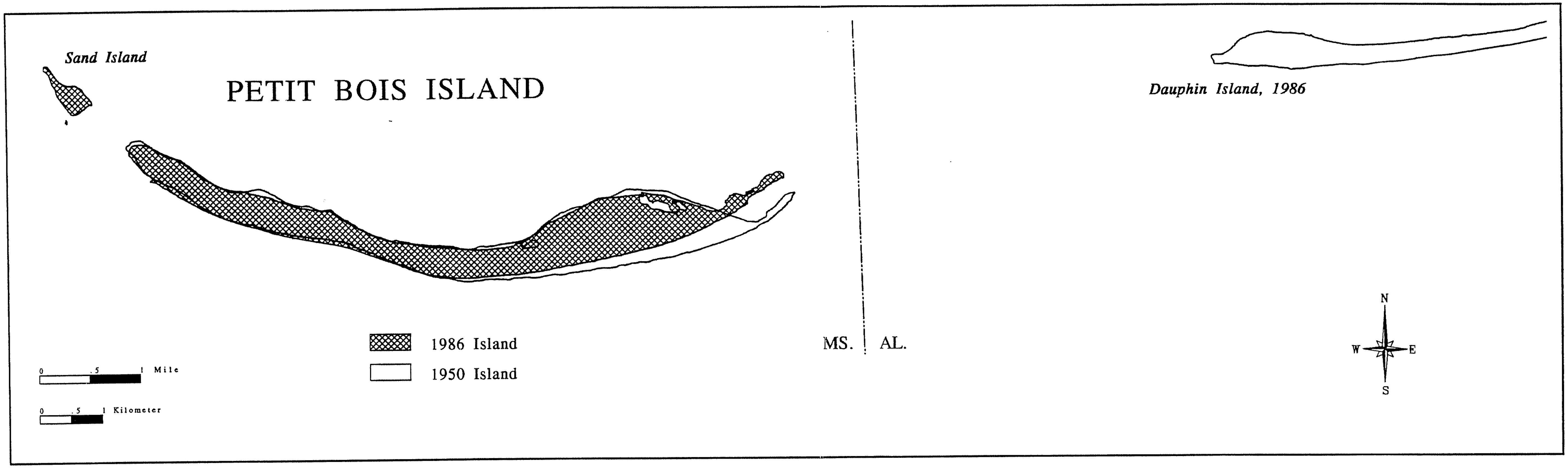
APPENDIX A

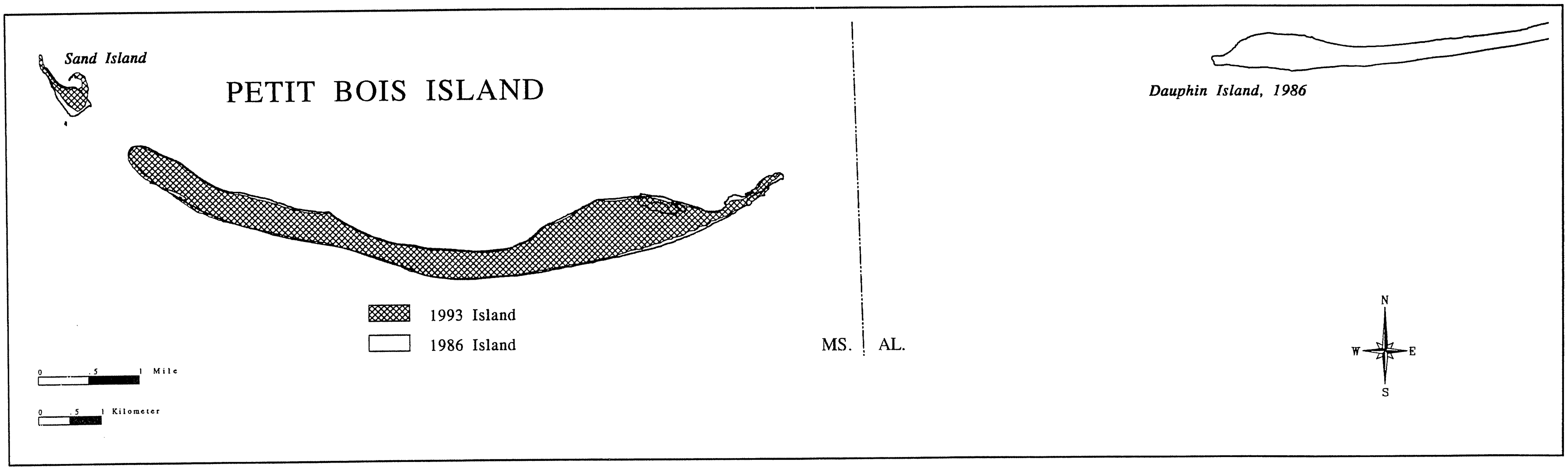
Mississippi Barrier Islands Shoreline Change Maps



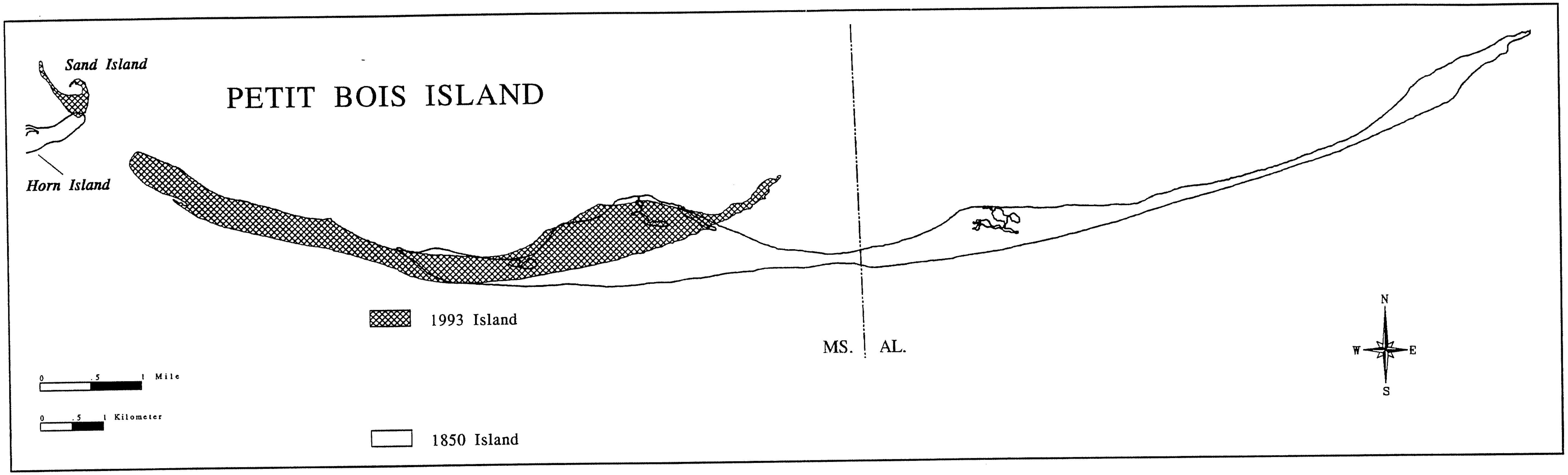


Petit Bois Island Historical Shorelines

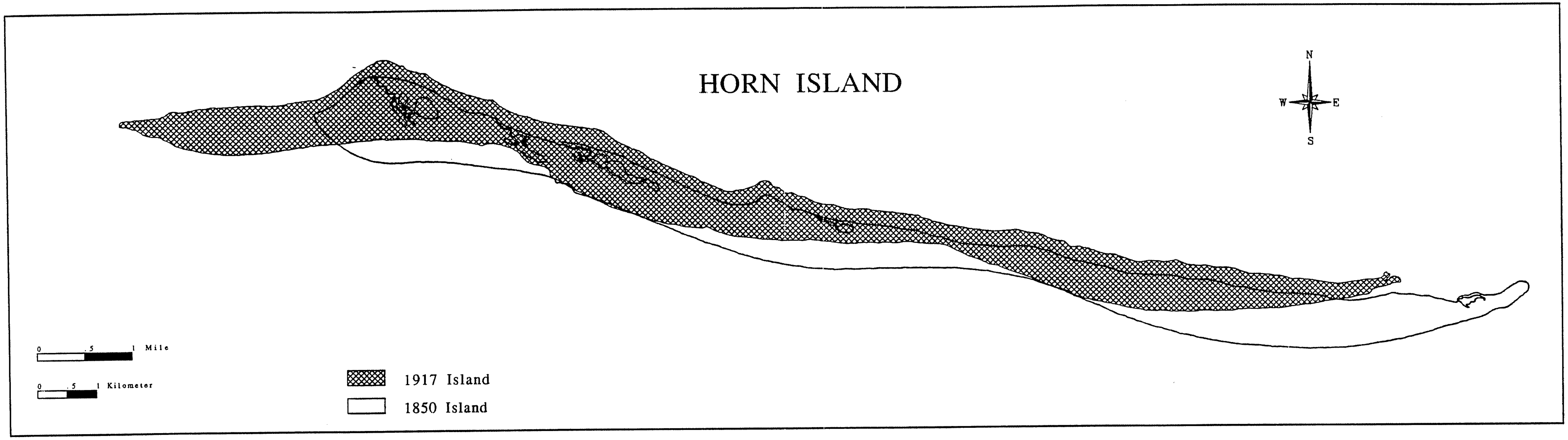


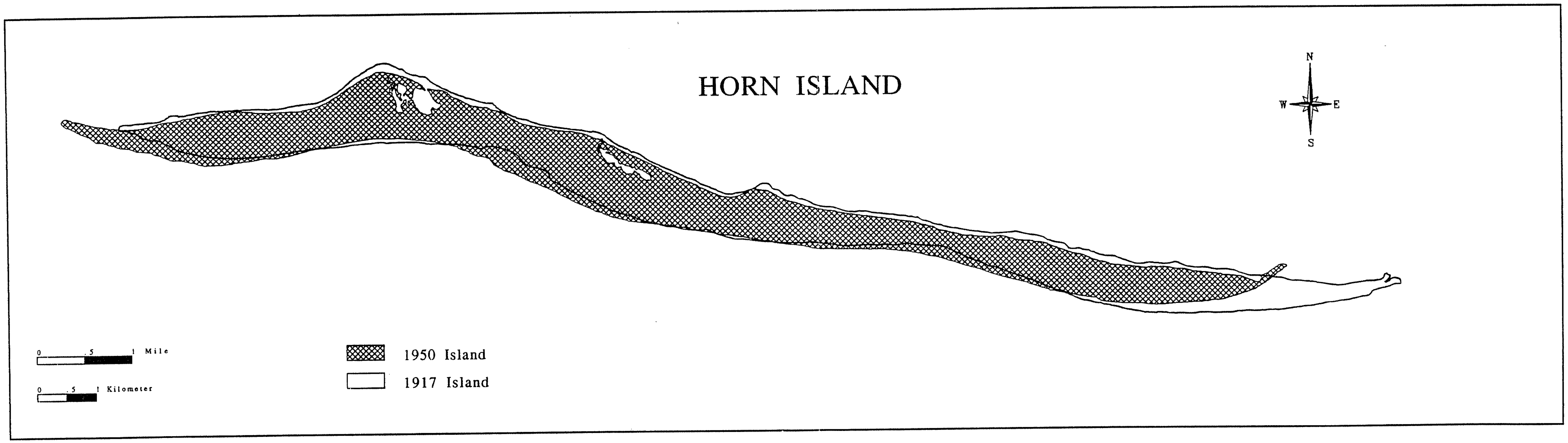


Petit Bois Island Historical Shorelines

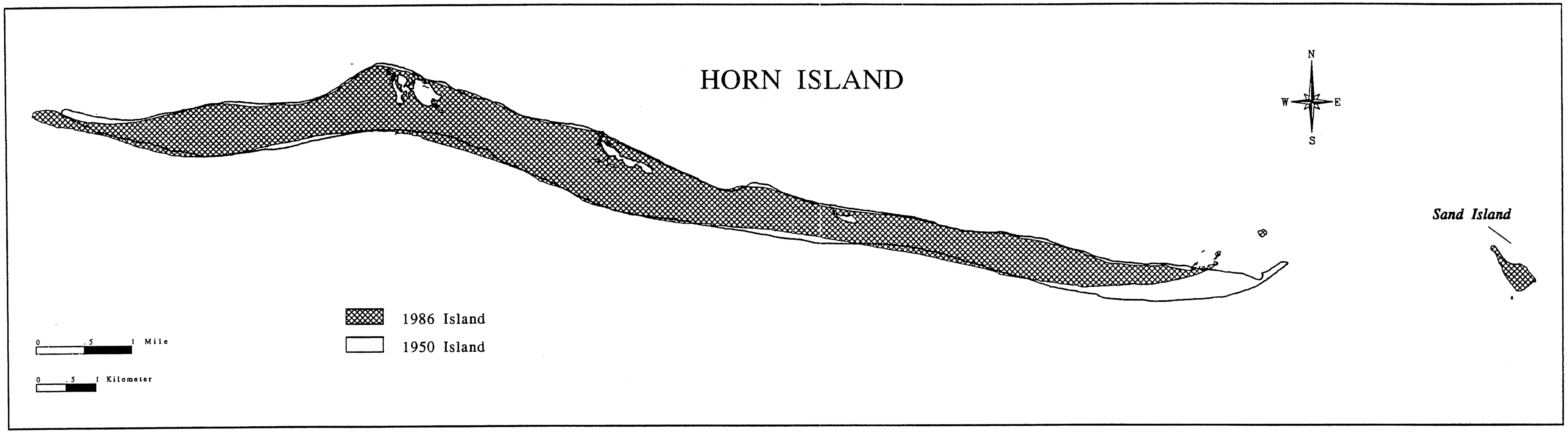


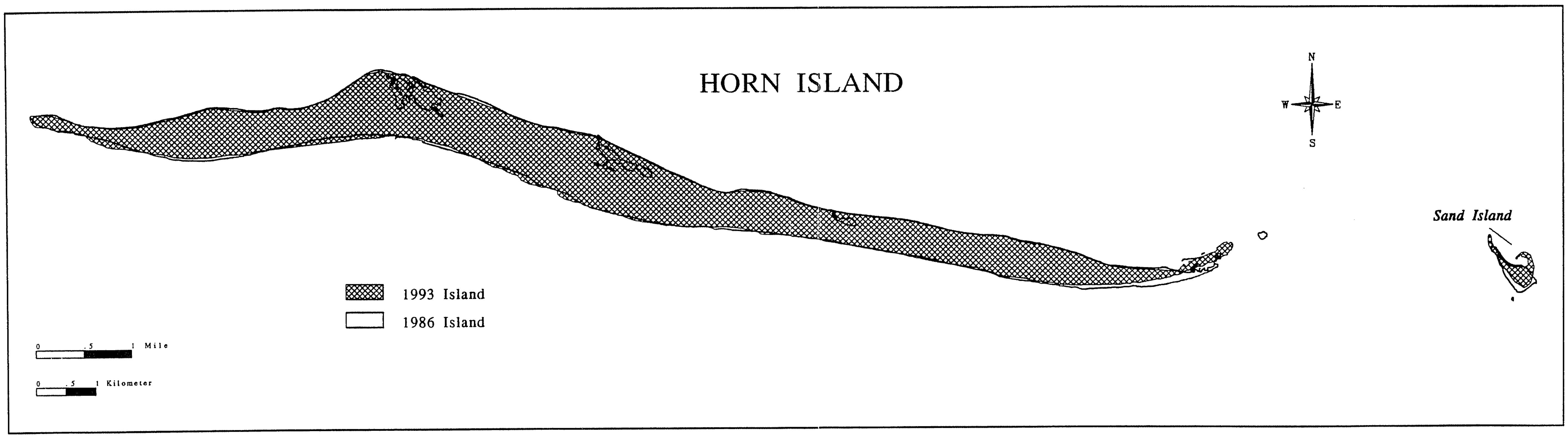
Petit Bois Island Historical Shorelines



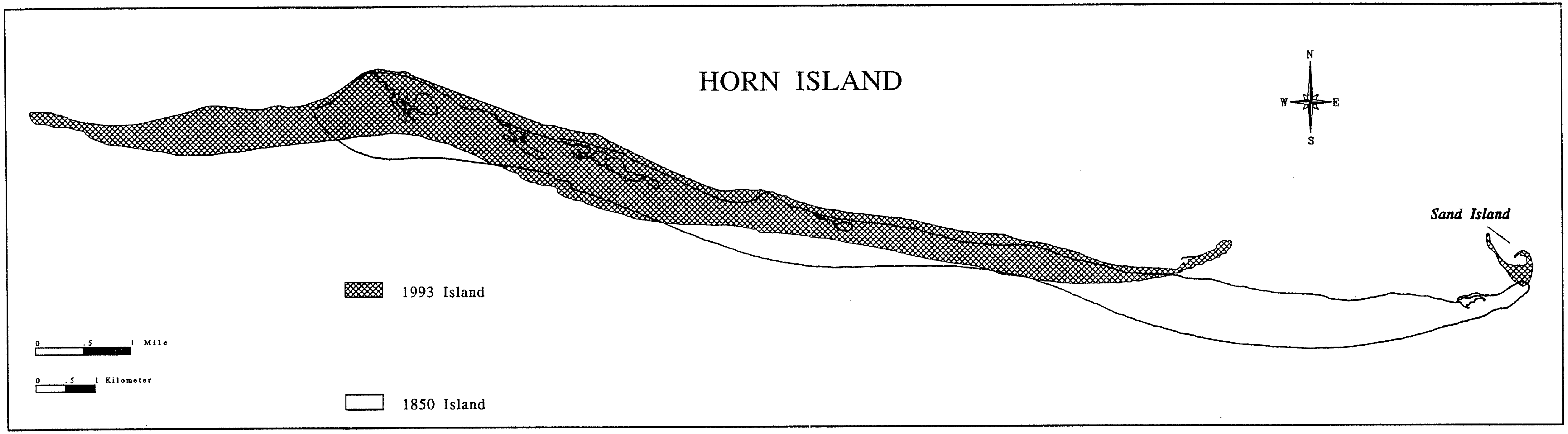


Horn Island Historical Shorelines

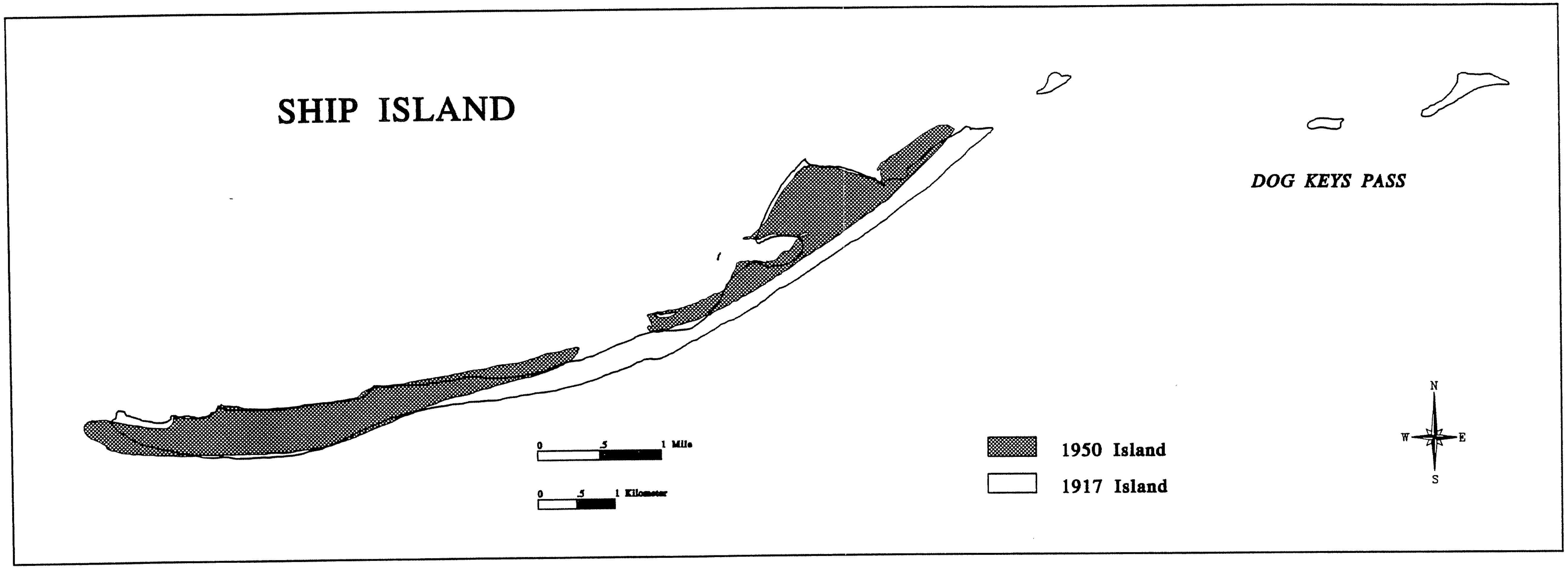


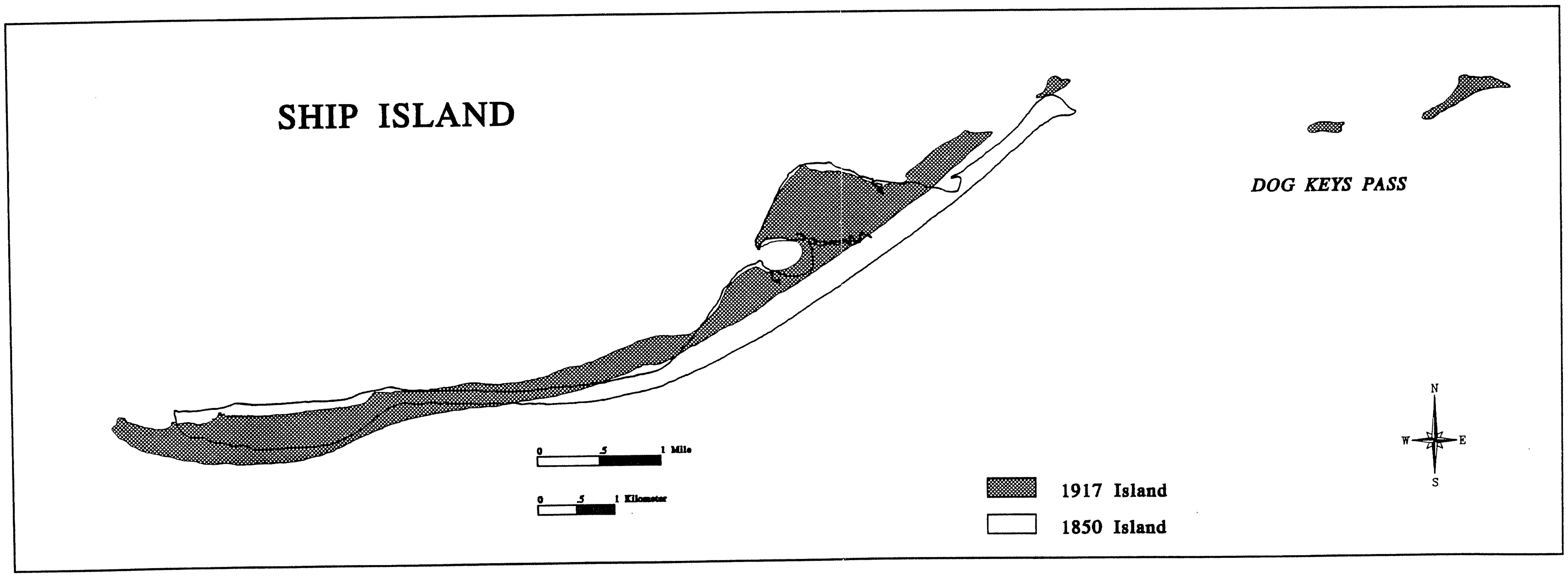


Horn Island Historical Shorelines

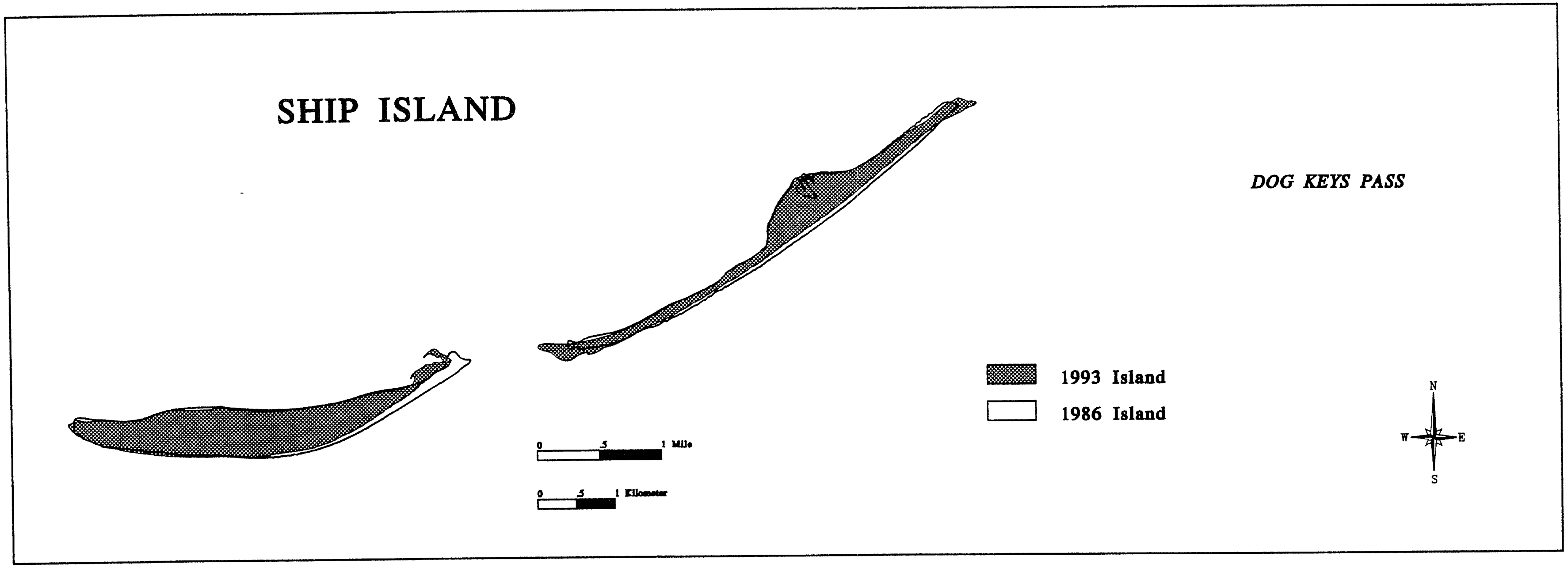


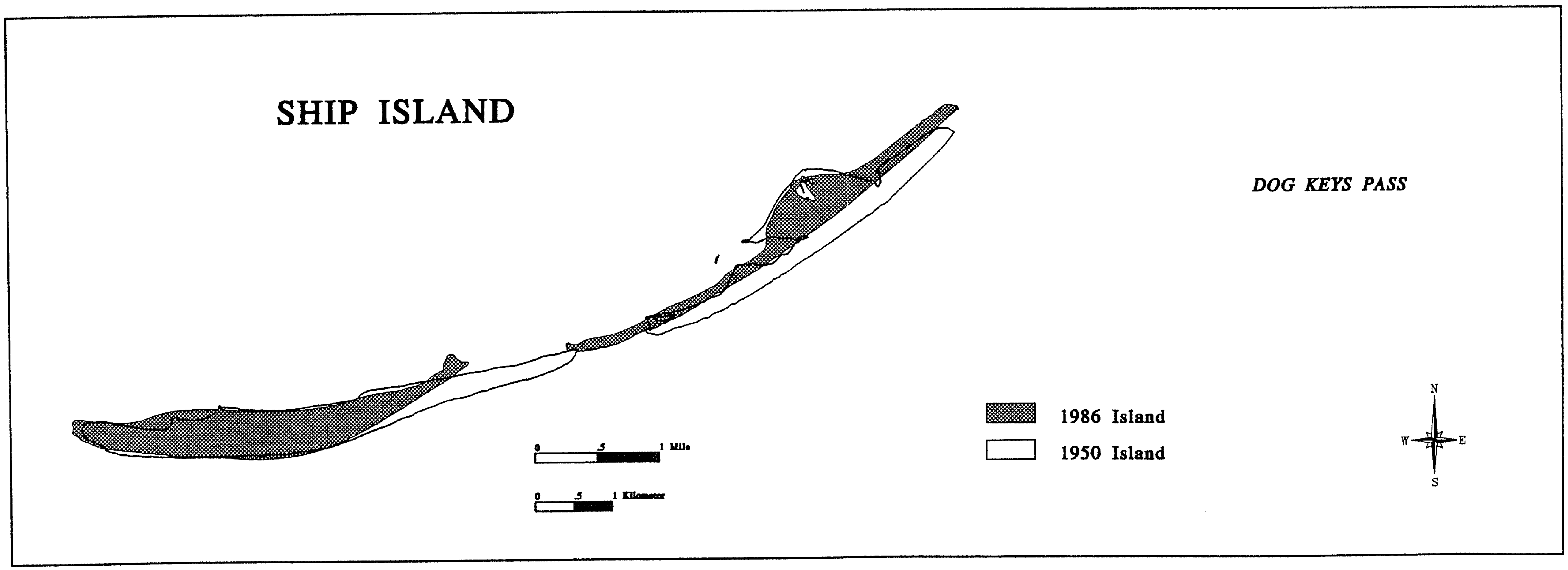
Horn Island Historical Shorelines



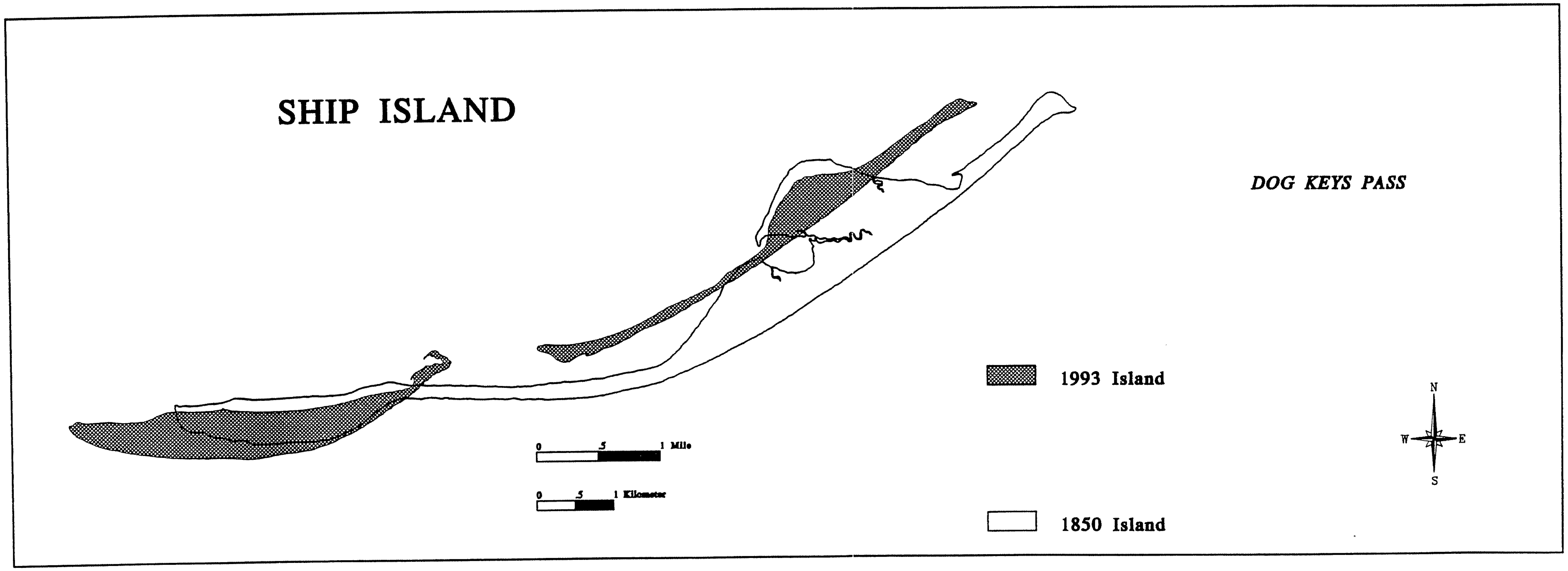


Ship Island Historical Shorelines

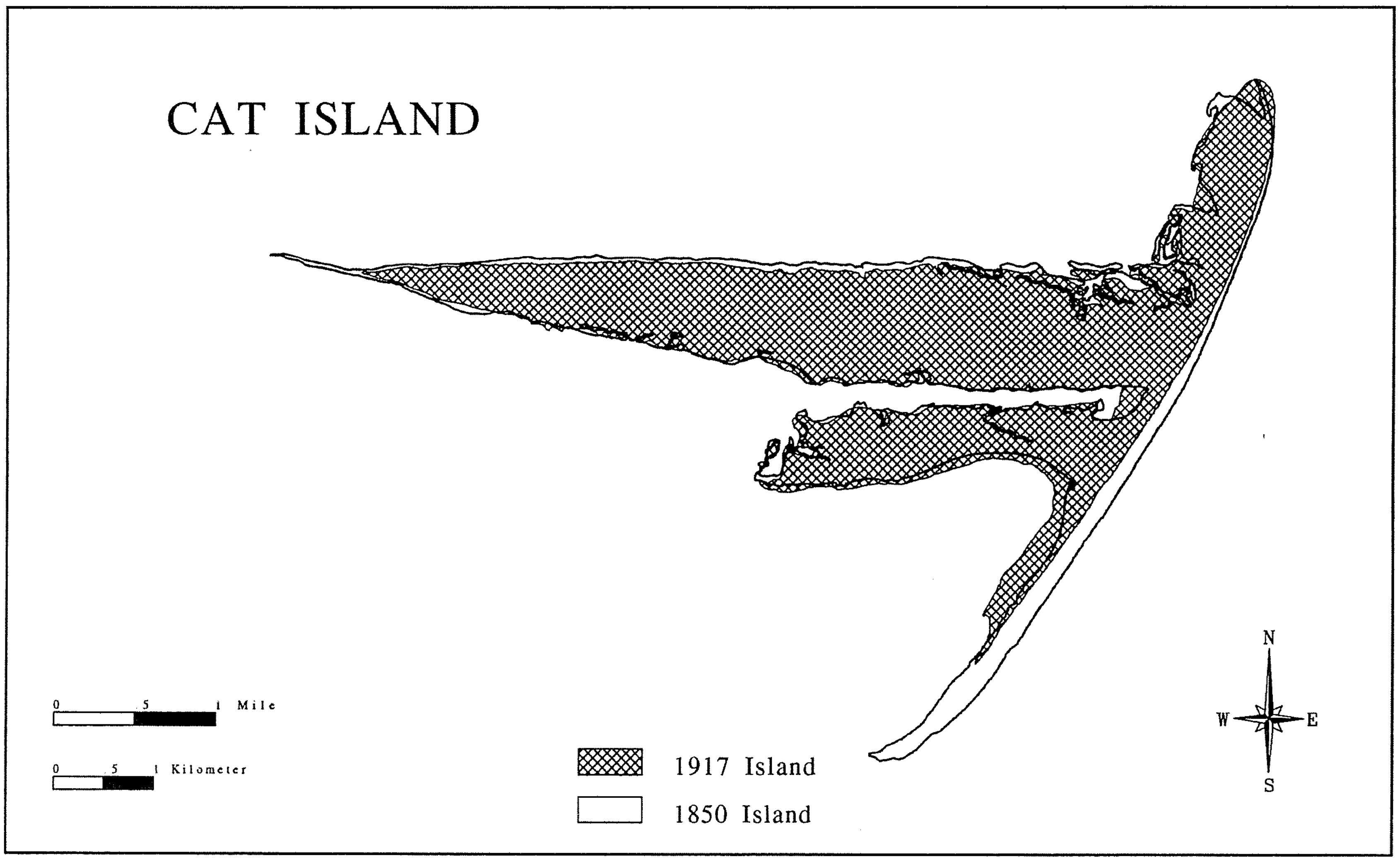


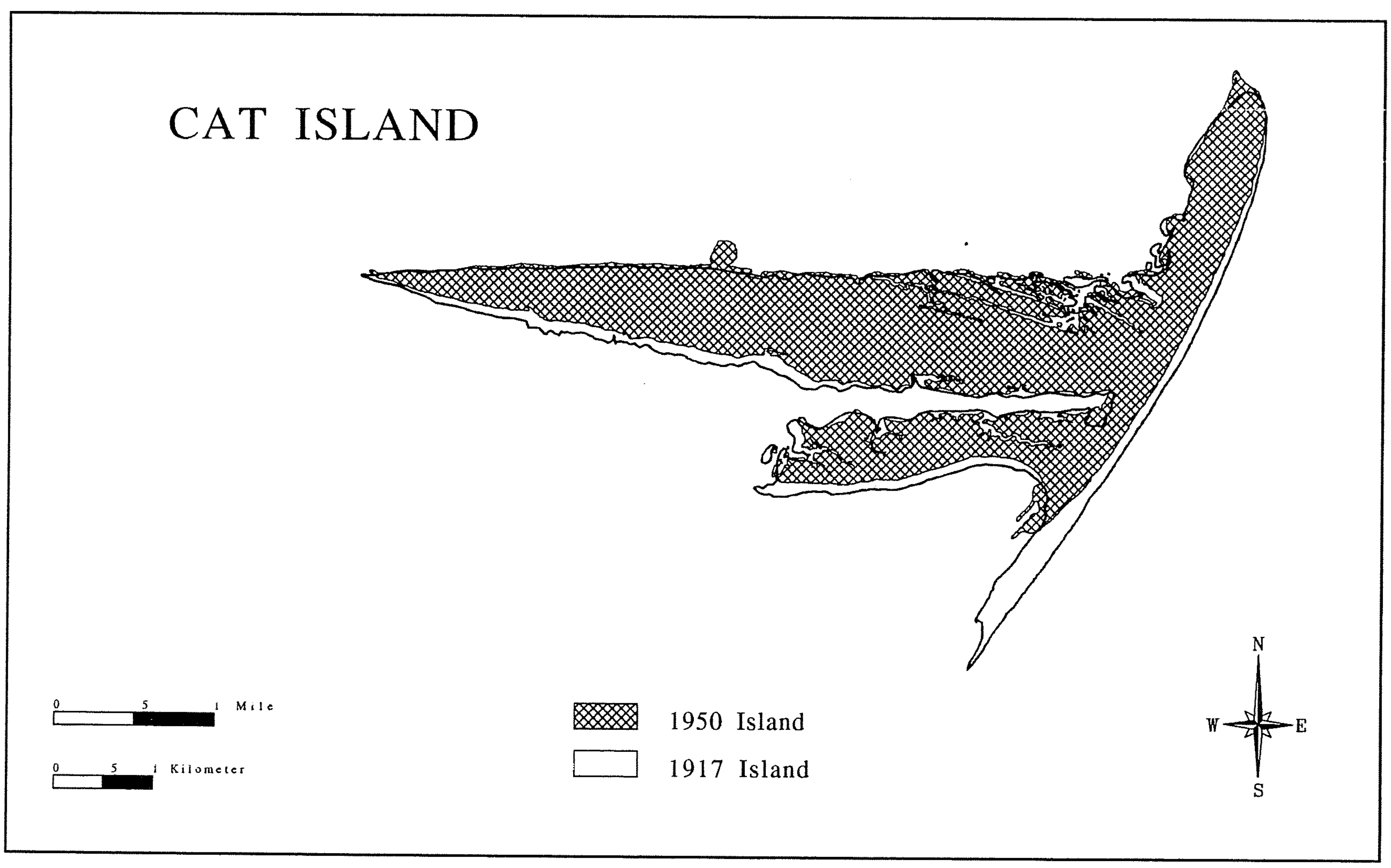


Ship Island Historical Shorelines

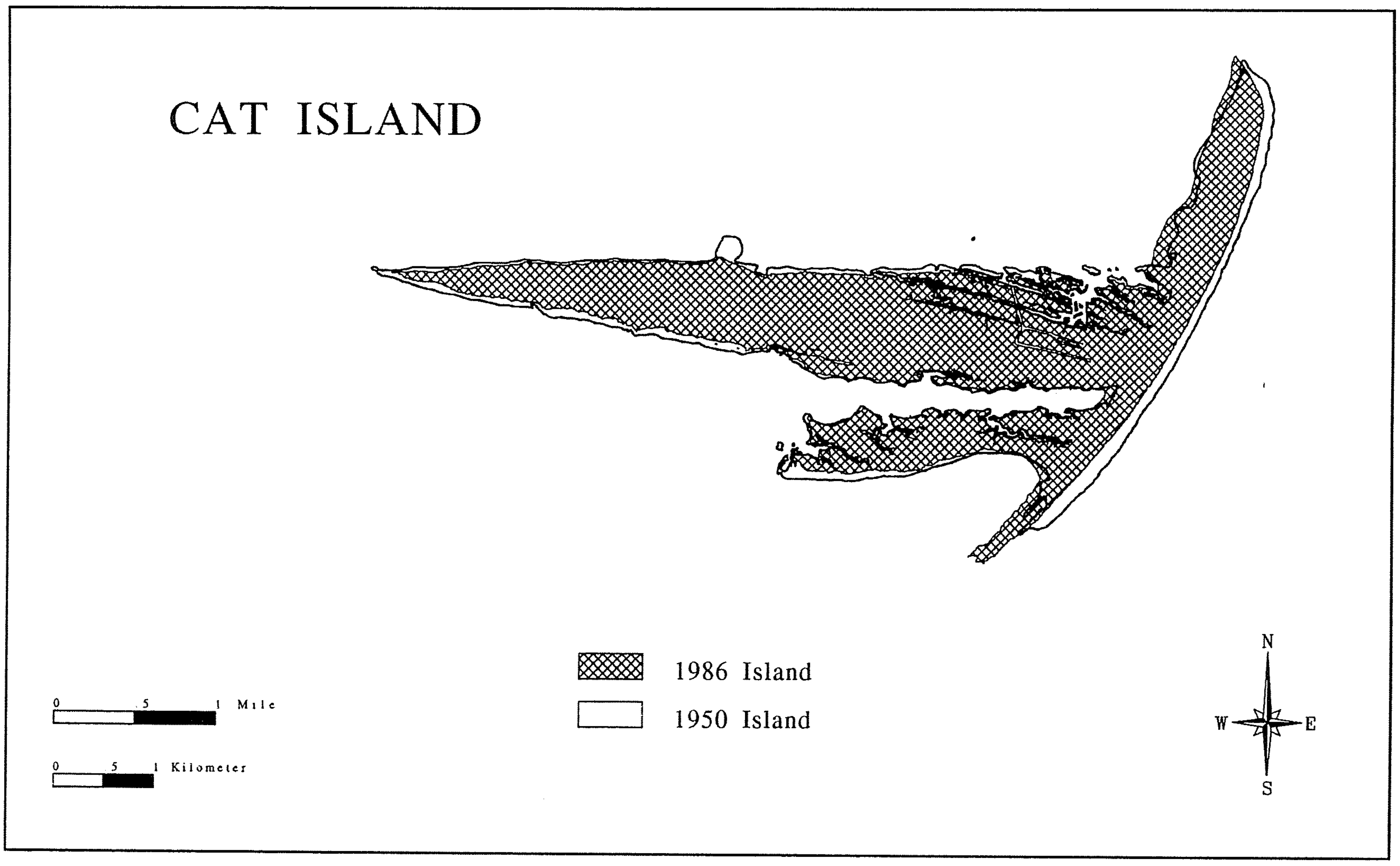


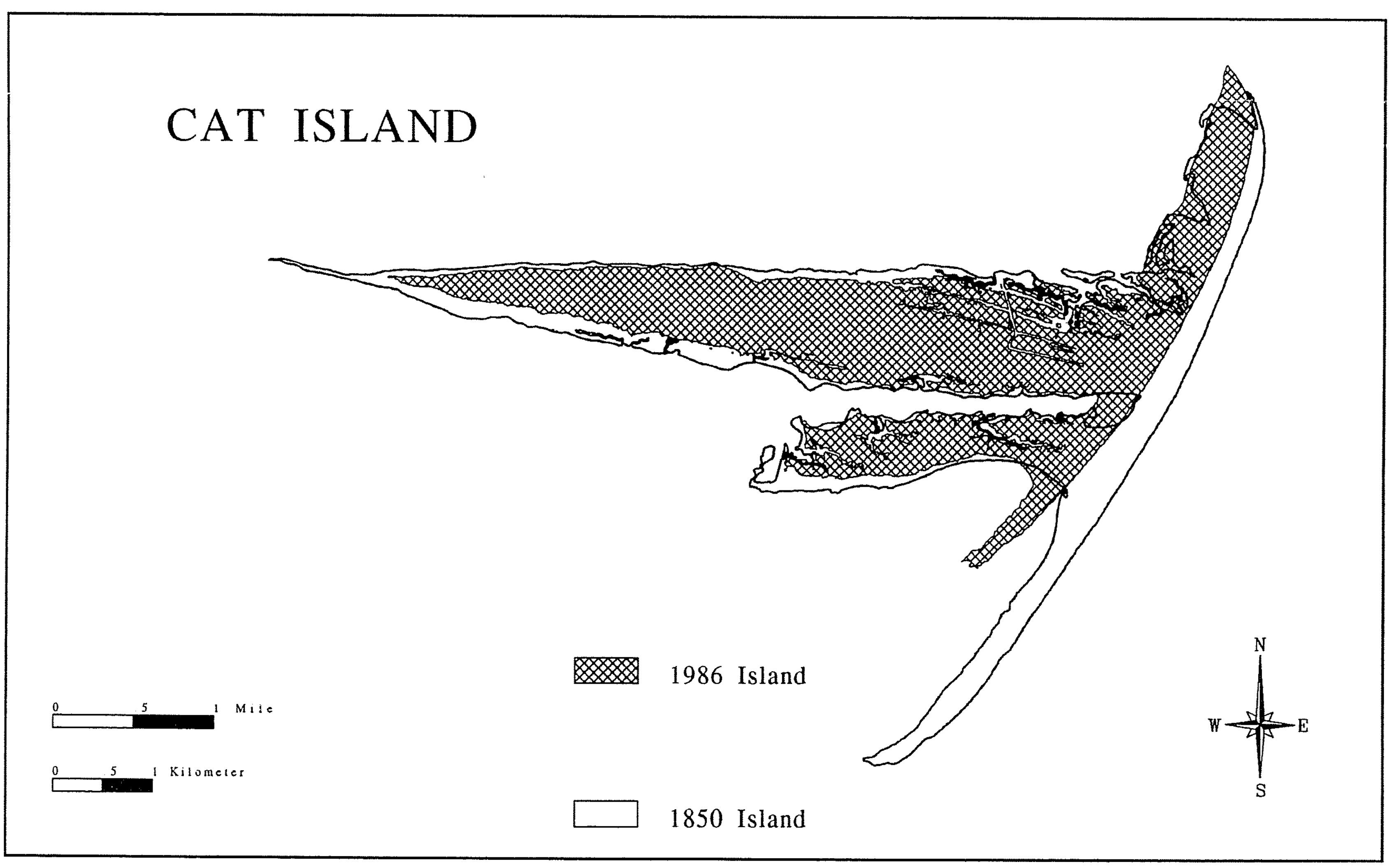
Ship Island Historical Shorelines





Cat Island Historical Shorelines





Cat Island Historical Shorelines