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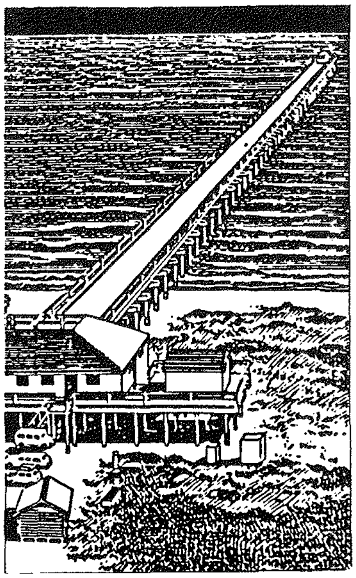

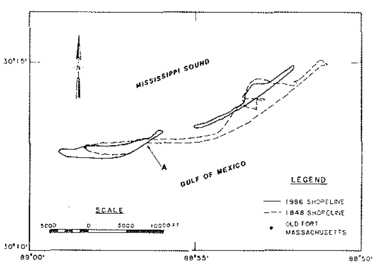

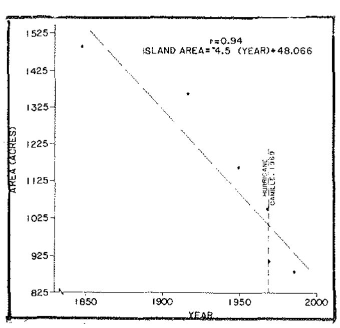

TECHNICAL REPORT CERC-89-1

GEOMORPHIC AND COASTAL PROCESS ANALYSIS FOR SHIP CHANNEL PLANNING AT SHIP ISLAND, MISSISSIPPI

by

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Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39181-0631

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Westward migration of Ship Island, Mississippi, has resulted in significant channel shoaling and increased maintenance dredging requirements of the Gulfport Harbor Ship Channel, requiring realignment of the channel to the west around the advancing island tip. The western island tip has migrated westward approximately 38 ft/year since 1848. The subaerial island area has decreased at the rate of 4.5 acres/year since 1948. As the Ship Island barrier system migrates westward, the gulf shoreline along the eastern end erodes, supplying sand to the advancing western tip.

Alternative channel alignments were studied as potential solutions to the shoaling problems caused by the island migration. An alignment passing 1,900 ft west of the island tip would allow approximately 50 years before the island tip reaches the channel edge, based on the 38 ft/year migration rate. This alignment is favorable according to the following criteria: construction and maintenance costs as a function of dredging requirements; channel navigability; siltation potential; and complexity of design and construction.

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PREFACE

This report is the result of a study conducted for the US Army Engineer District, Mobile (SAM), by the Coastal Engineering Research Center (CERC) of the US Army Engineer Waterways Experiment Station (WES). The study was conducted to provide supporting information to SAM for use in planning the Gulfport Harbor Improvement Project.

The study was conducted by Mr. Stephen C. Knowles and Ms. Julie D. Rosati, Coastal Structures and Evaluation Branch (CS&EB), Engineering Development Division (CD), CERC. The work was carried out under direct supervision of Ms. Joan Pope, Chief, CS&EB, and Mr. Thomas W. Richardson, Chief, CD, CERC; and under general supervision of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Chief and Assistant Chief, CERC. Mr. Darryl D. Bishop, CS&EB, provided drafting support with assistance from Mr. Perry Reed. Reviewers included Ms. Pope and Dr. Clifford L. Truitt, CS&EB, CERC; and Mr. Johnny Grandison, SAM. Field help was provided by Messrs. Bishop, Steve Underwood, Mark Hansen, and Mike Alexander. This report was edited by Ms. Shirley A. J. Hanshaw, Information Products Division, Information Technology Laboratory, WES.

Commander and Director during report publication was COL Dwayne G. Lee, EN. Technical Director was Dr. Robert W. Whalin.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4046.856	square metres
cubic yards	0.7645549	cubic metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
knots (international)	0.514444	metres per second
miles (US statute)	1.609347	kilometers
square miles	2.589988	square kilometres
square yards	0.8361274	square metres

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* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: C = (5/9)(F - 32). To obtain Kelvin (K) reading, use K = (5/9)(F - 32) + 273.15.

GEOMORPHIC AND COASTAL PROCESS ANALYSIS FOR SHIP CHANNEL PLANNING AT SHIP ISLAND, MISSISSIPPI

PART I: INTRODUCTION

1. Gulfport Harbor Ship Channel extends from Gulfport, Mississippi, across Mississippi Sound to the Gulf of Mexico, passing to the west of Ship Island (Figure 1*). During initial construction from 1901-1905, the channel alignment passed several hundred yards west of Ship Island which has been migrating westward throughout historic time, with erosion along the eastern end accompanied by accretion along the western end (Waller and Malbrough 1976). By the 1950's, the migration produced significant channel shoaling and increased maintenance dredging requirements of the channel. Shoaling exceeded maintenance dredging, requiring realignment of the channel around the advancing island tip. Improvements presently under study by the US Army Engineer District, Mobile (SAM), include deepening and widening the channel and possible channel relocation. SAM requested the US Army Engineer Waterways Experiment Station's Coastal Engineering Research Center (CERC) to study the island migration and channel and to assess engineering aspects of several proposed ship channel alignments. Results of this study will aid SAM in the preparation of the final Gulfport Harbor Ship Channel Improvement Design.

2. The study is divided into two areas of interest. The first section includes a summary of the physical environment of the study area and documents the coastal processes associated with island migration through an analysis of island morphologic change, bathymetric change, and wave refraction effects. The second section uses this information to determine relationships between coastal processes and various navigation channel alignments and potential dredged material disposal sites. This study will aid in the selection of a channel alignment which eliminates or minimizes island migration shoaling problems for the economic life of the project.

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* A table of factors for converting non-SI to SI (metric) units of measurement is presented on page 3.

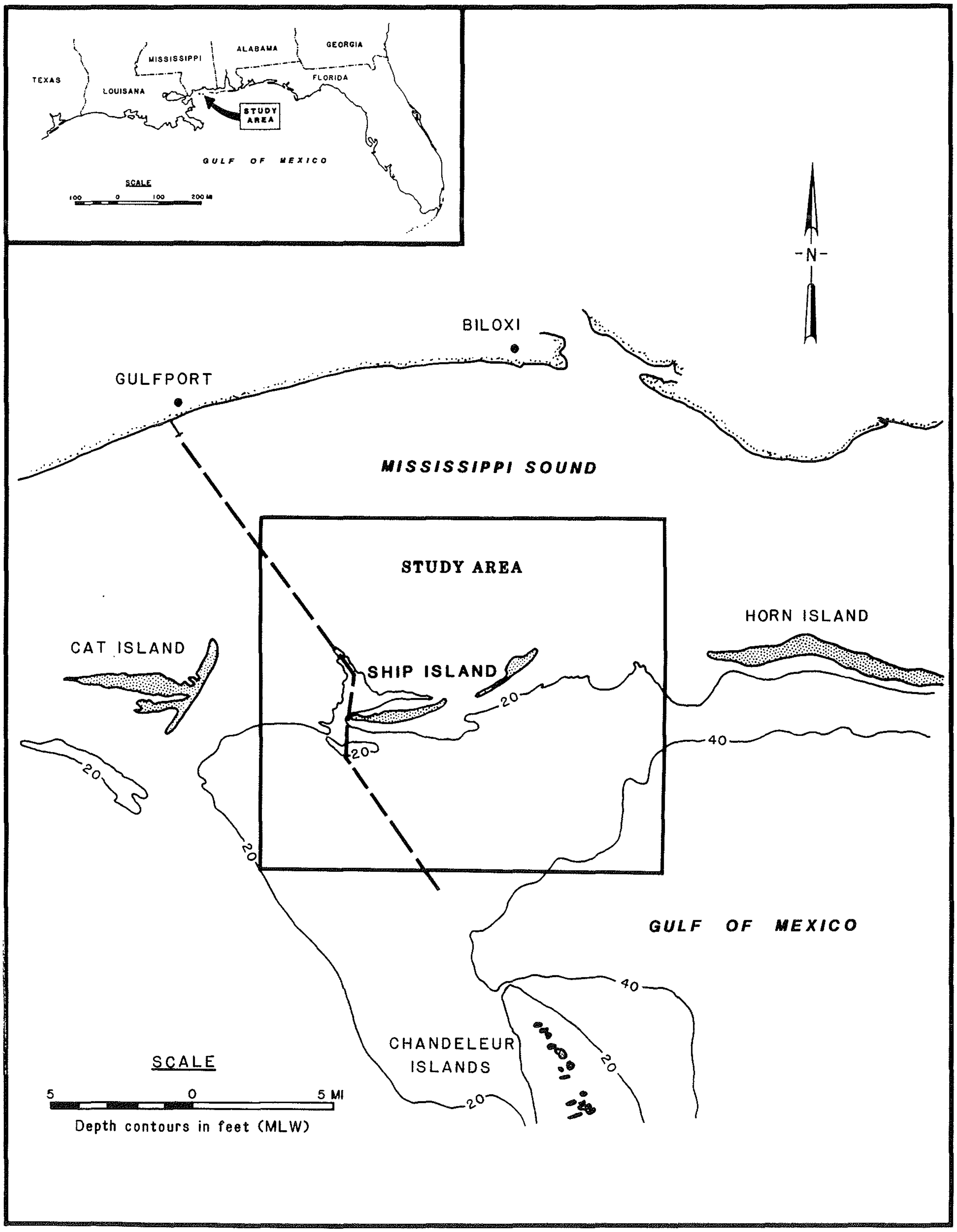

Figure 1. Location of study area

PART II: STUDY AREA

Geographical and Physical Setting

3. Cat, Ship, Horn, Petit Bois, and Dauphin islands form the southern boundary of Mississippi Sound along the northern Gulf of Mexico, within the Eastern Gulf Coastal Plain province. Breaching of Ship Island by Hurricane Camille in 1969 resulted in the formation of East and West Ship Island, which remain as two distinct islands today. Ship Island Pass and Little Dog Keys Pass are tidal inlets adjacent to Ship Island on the west and east, respectively. Mississippi Sound is a mostly unstratified brackish water body 81 miles long, 6.8 to 15 miles wide, and 820 square miles in area, which averages 9.7 ft in depth (Eleuterius and Beaugez 1979). Despite a diurnal tidal range of only 1.5 ft, the large area of the sound produces large tidal prisms at the inlets, where natural water depths may exceed 40 ft. Fetch and depth-limited waves within the sound average less than 1 ft in height (Jensen 1983).

4. The mainland coastal area is characterized by low relief beach ridge areas separated by drowned river valley estuaries. The sound shoreline varies from sandy beaches to marsh. The longest single artificial beach project in the US is located along the shores of Gulfport and Biloxi.

5. The barrier islands along the southern boundary of Mississippi Sound are similar in morphology to other barriers of the Gulf of Mexico coast. Mostly low relief, sandy areas with scattered dunes prevail, with interdune marsh and lagoon areas. However, unlike other barrier island chains, the back-barrier areas of Ship Island are void of fine-grained sedimentary environments. The relatively high wave energy of Mississippi Sound, compared with other back-barrier water bodies along the gulf coast, prevents deposition of fine-grained sediments or initiation of marsh habitat within the shallow-water areas behind the island. Past shoreline configurations, moderately well-developed beach profiles, and presence of well-developed bedforms indicate that significant sediment transport occurs along the sound shoreline of Ship Island, with a net westerly direction of transport.

6. Breaking wave heights along the gulf shoreline of Ship Island average about 3 ft.* Ship Island is protected from southerly to westerly Gulf

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* Unpublished Wave Information Studies (WIS) data.

waves by its location north of the Chandeleur Islands and east of the Mississippi River delta of Louisiana (Figure 1). Larger waves are produced by strong winds associated with winter cold fronts. Summers are characterized by relatively calm ocean conditions, although extreme waves may be produced by hurricanes during the summer and fall.

7. The climate at Ship Island is humid subtropical, with a mean annual temperature of about 68° F. The average annual rainfall is 60 to 65 in. Summers are hot and humid with occasional thunderstorms. Winters are cool with rain associated with passing cold fronts. Winds are predominantly northerly from September through February and southerly during the rest of the year. Table 1 summarizes annual wind conditions over Mississippi Sound.

Geological Characteristics

8. Holocene sediments in the study area consist of silt and clay transported into the sound by several rivers along the northern border. Salinity-induced flocculation of these sediments results in continuous infilling of the sound. Coarser, sand-sized sediments are found along the beaches and shallow-water areas of Ship Island. Medium sand sizes range from about 0.2-0.6 mm (2.32-0.74ϕ). These coarser sediments are transported by higher wave and current conditions. Well-developed dunes in many areas indicate that eolian sediment transport is also significant. The source of sand at Ship Island appears to be the mainland coast of Alabama (Otvos 1982). This sand is transported across the Mobile Bay ebb-tidal delta by the westerly littoral transport system, supplying sand to the westward migrating barrier island chain. The Holocene sediments overlie southerly sloping basal Miocene, Pliocene, and Pleistocene units (Figure 2).

9. Beach foreshore medians along the barrier beaches tend to be several tenths of a millimetre coarser on the sound shorelines than along the gulf shorelines. This textural inversion may be due to a winnowing of available fine sand from the sound-side beaches (Otvos 1982). The lower wave climate of Mississippi Sound, in comparison with the gulf, prevents transport of larger grain sizes, resulting in a coarse-grained lag deposit. Surface reconnaissance of Ship Island revealed a lack of any significant fine-grained depositional environments, due to the relatively high-energy conditions of Mississippi Sound, in comparison to other bays and lagoons. Even inner-island marsh

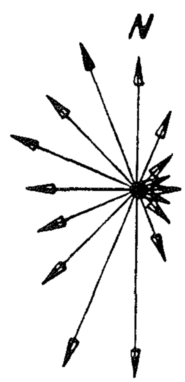
Table 1

Annual Wind Conditions Over Mississippi Sound

(from US Army Engineer District, Mobile 1984)

WIND SPEED (PERCENT OF TIME)

SPEED (KNTS) DIR.	1-3	4-6	7-10	11-16	17-21	22-27	28-33	34-40	41-47	48-55	>56
N	.9	2.1	4.2	2.6	.5	.1	.0				
NNE	.9	2.3	4.4	2.4	.5	.2	.0				
NE	1.0	2.1	3.0	1.2	.2	.1	.0				
ENE	.7	1.6	2.7	.9	.1	.0	.0	.0			
E	.5	1.5	2.9	1.2	.2	.0	.0				
ESE	.3	.9	3.5	2.6	.4	.1	.0				
SE	.4	1.0	3.3	2.2	.4	.0					
SSE	.4	1.3	3.9	2.6	.5	.1	.0				
S	.5	1.4	3.3	1.8	.3	.1	.0				
SSW	.3	.8	2.0	1.4	.2	.0	.0		.0		
SW	.2	.6	1.3	.6	.1	.0					
WSW	.1	.5	.9	.4	.1	.0					
W	.3	.7	1.0	.3	.1	.0					
WNW	.2	.5	.8	.4	.2	.0	.0				
NW	.3	.5	.9	.7	.2	.0					
NNW	.4	.7	1.5	1.2	.4	.1	.0	.0			
CALM								Total Calm % = 6.6			
	7.2	18.6	39.7	22.5	4.4	.9	.2	.0	.0		



WIND DIRECTION (PERCENT OF TIME)

ALL

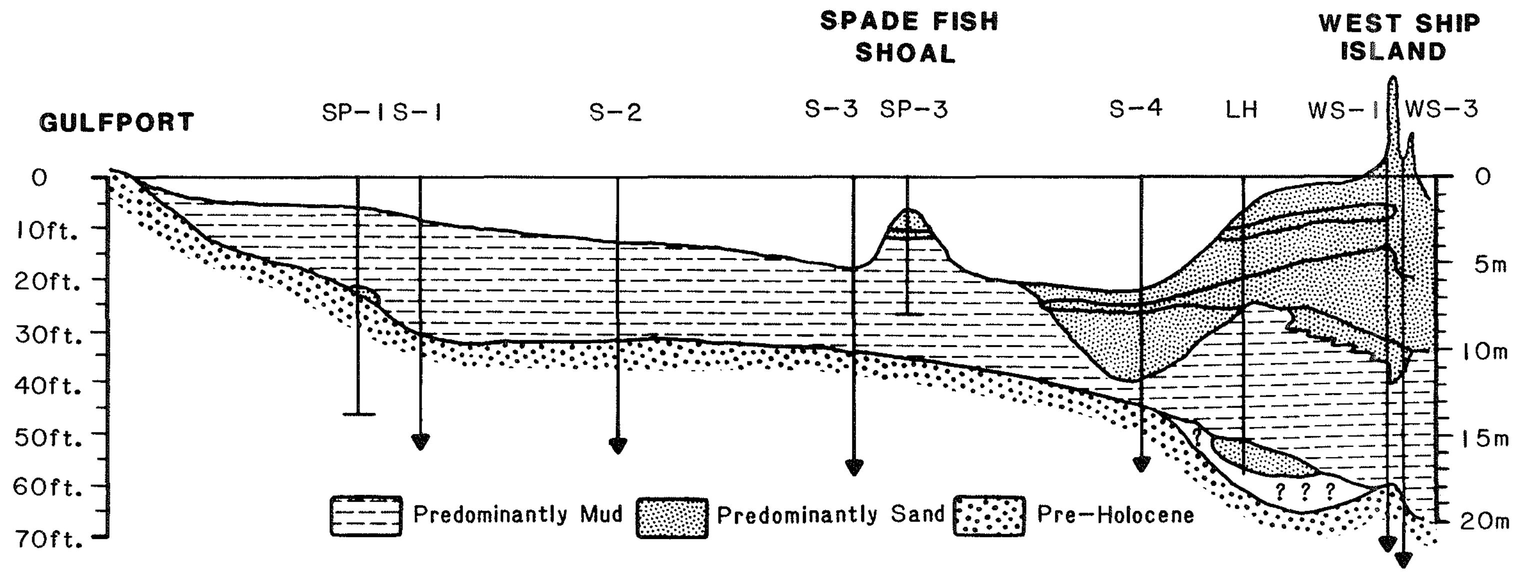


Figure 2. Stratigraphy of Ship Island and Mississippi Sound (after Otvos 1982)

areas are dominated by sandy sediments. The lack of fine-grained deposition at Ship Island is unlike most barrier island systems, where fine-grained deposition dominates typically low-energy, back-barrier areas. Figure 3 illustrates the distribution of surface geomorphic zones at Ship Island.

10. Analysis of 1986 aerial photography reveals a well-developed beach-ridge and swale topography along both East and West Ship Island. Along West Ship Island, the ridges are oriented west to east, attributed to the historic westerly littoral transport along this coast. Along East Ship Island, beach ridges are oriented northwesterly to southeasterly, and northerly to southerly, oblique to the present shoreline, indicating variable directions of sediment transport in the past. This variability may have been caused by a change in wave refraction effects, wave climate, or a combination of both factors. Past storm breaches may also be a cause of the variable beach ridge orientations.

Gulfport Harbor Ship Channel

11. Gulfport Harbor Ship Channel was first authorized for 19-ft depths by congressional action in 1899 (Table 2). At that time, dredging was not necessary south of central Mississippi Sound since the authorized depth existed naturally. Through the years, increases in channel widths and depths have been made to accommodate larger vessels (Table 2). Presently proposed improvements would involve increasing the entrance channel dimensions to 400 × 38 ft and 300 × 36 ft across Mississippi Sound.

Tropical Storms

12. Effects of a single hurricane may surpass several years of average conditions in a coastal area (Hayes 1978). From 1871 to 1978, 67 tropical storms and hurricanes passed within 100 nautical miles of Mississippi Sound (Eleuterius and Beaugez 1979). The eye of one of the most severe hurricanes in historic time, Camille in 1969, passed to the west of Ship Island landfalling in Bay St. Louis, Mississippi. Top winds exceeded 200 mph, and ocean waves reached heights of 45 ft. A storm surge of 22.6 ft was recorded at Pass Christian, Mississippi. Ship Island was inundated, and a new tidal inlet was formed, informally called "Camille Cut" today. Other major hurricanes passed near Ship Island in 1893, 1916, and 1926.

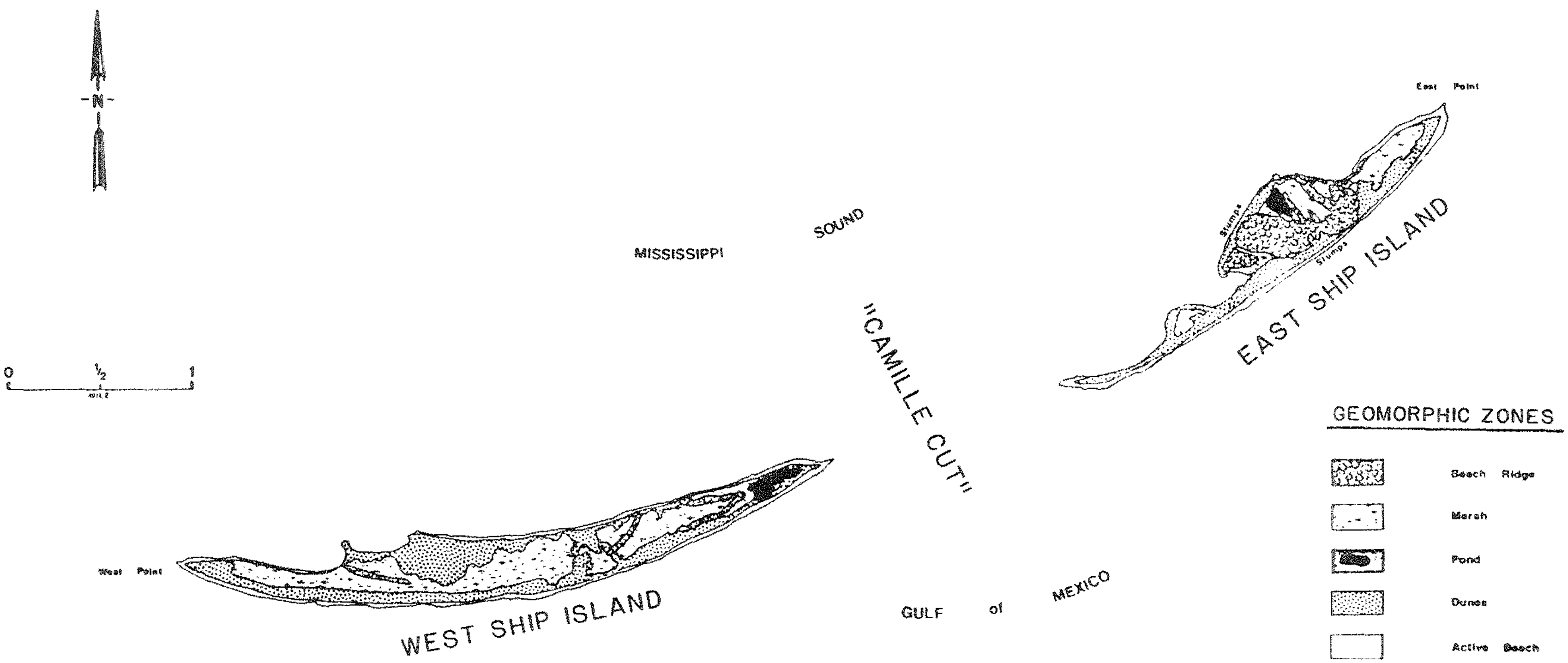


Figure 3. Surface sedimentary environments at Ship Island (after Waller and Malbrough 1976)

Table 2

History of New Work Dredging of Gulfport Harbor and Ship Channel

(after US Army Engineer District, Mobile 1984)

Design, ft	Approval*	Construction years
19 × 1,320 × 2,640	3 Mar 1899, H. Doc. 120, 55th Cong., 3d Sess.	1901-1905
19 × 300	3 Mar 1899, H. Doc. 120, 55th Cong., 3d sess.	1901-1903
26 × 300	27 Feb 1911, H. Doc. 2, 60th Cong., 1st sess.	1900-1921
26 (basin)	23 Jul 1930, H. Doc. 692, 69th Cong., 2d sess.	1932-1934
26 × 220	23 Jul 1930, H. Doc. 692, 69th Cong., 2d sess.	1932-1934
27 × 300	23 Jul 1930, H. Doc. 692, 69th Cong., 2d sess.	1932-1934
30 (basin)	30 Jun 1948, H. Doc. 112, 81st Cong., 1st sess. modified 3 Jul 1958	1949-1950
30 × 220	30 Jun 1948, H. Doc. 112, 81st Cong., 1st sess.	1949-1950
32 × 300	30 Jun 1948, H. Doc. 112, 81st Cong., 1st sess.	1949-1950

* House Document (H. Doc.), Congress (Cong.), Session (sess.)

PART III: DATA ANALYSIS

13. Historic National Ocean Service (NOS) hydrographic surveys were the principal source of data used for this study. Supplemental information was obtained from US Geological Survey (USGS) topographic maps, aerial photography, and a previously published study of historic shoreline position change. Beach profiling and vibracoring conducted by CERC supplied some additional information. These data sources and their uses in this study are listed in Table 3.

NOS Surveys

14. The earliest hydrographic survey which could be used for analysis was conducted in 1848 and included a map of the shoreline. This survey was conducted with lead lines or rods along transects located by survey stations on Ship Island and the mainland. Depths greater that 18 ft were recorded to the nearest 1/4 fathom (1.5 ft). An additional survey conducted during 1854-1855 covered areas east of the 1848 survey. Data from these two surveys were combined to form one data set.

15. The next complete hydrographic survey of the area was conducted in 1917, and it included a shoreline map. The shoreline was not mapped with the same detail as the earlier surveys, but it did allow for comparison of morphologic change.

16. The hydrographic survey conducted during 1967-1968 included another shoreline map but excluded most offshore areas. Passage of Hurricane Camille in 1969 caused significant bathymetric changes to the Ship Island area, resulting in a resurvey in 1970. Only areas adjacent to Ship Island were resurveyed to depths of about 20 ft. This limited survey supplied valuable information concerning the effects of Camille.

Other Data

17. A topographic map of Ship Island was made in 1950 by the USGS and photo-revised in 1970. These two maps provided additional shoreline configurations and island topographic information. A limited hydrographic survey conducted by SAM in 1986 supplied the most recent bathymetric data for use in

Table 3

Data Used in This Study

Type	Source	Number	Date	Scale	Use
Hydrographic survey	NOS	H-194	1848	1:20,000	Bathymetry, shoreline map
Hydrographic survey	NOS	H-430	1854	1:20,000	Bathymetry
Hydrographic survey	NOS	H-489	1855	1:20,000	Bathymetry
Hydrographic survey	NOS	H-4000	1917	1:40,000	Bathymetry, shoreline map
Hydrographic survey	NOS	H-4021	1917	1:40,000	Bathymetry, shoreline map
Topographic map	USGS	N/A	1950	1:24,000	Topography, shoreline map
Hydrographic survey	NOS	8924	1967-1968	1:20,000	Bathymetry
Hydrographic survey	NOS	H-8971	1968	1:20,000	Bathymetry, shoreline map
Hydrographic survey	NOS	H-9004	1970	1:20,000	Bathymetry
Hydrographic survey	NOS	H-9103	1970	1:20,000	Bathymetry
Topographic map	USGS	N/A	1970	1:24,000	Topography, shoreline map
Hydrographic survey	SAM	N/A	1986	1:20,000	Bathymetry
Aerial photos	NOS	8621-8634	3/6/86	1:20,000	Shoreline map
Island profiles	CERC	N/A	5/87	N/A	Topography
Island migration rates	*	N/A	N/A	N/A	Island migration data
Vibracores	CERC	N/A	1986	N/A	Sediment characterization

* Waller and Malbrough (1976).

this study. A 1986 color air-photo set purchased from NOS provided the most recent island shoreline configuration. Additional topographic data in the form of island profiles were collected by CERC in May 1987. Vibracores from Ship Island were also collected at that time to provide general sedimentological information.

Data Precision and Accuracy

18. Accuracy of horizontal positioning during the 1848-1855 survey was dependent on the positioning of triangulation stations in relation to the location of survey boats (Dedrick 1983). Areas close to Ship Island or the mainland probably were accurate to within a few yards, with decreased accuracy far from shore. Depths were recorded to the nearest 1.5 ft during the 1848-1855 survey, with uncertain accuracy. The ability to tie the field data with a common datum is also uncertain. Today, NOS supplies measured depths to the nearest 1 ft, with an accuracy of ±0.2 ft.* Reliable control to common datums is also used, allowing good comparison with other surveys from the same area.

19. In addition to the unknown accuracy of the earliest surveys, a rise in worldwide sea level has been occurring, necessitating additional corrections to the 1848-1855 and 1917 surveys. The 1967-1968, 1970, and 1986 surveys are all adjusted to the most recent tidal epoch, which began in 1961. Corrections for sea-level rise were not necessary for these surveys. However, significant rise in sea level has occurred since 1850, and corrections were necessary for both the 1848-1855 and 1917 surveys. The nearest location along the northern Gulf of Mexico coast in which a sea-level rise estimate has been calculated through the use of annual tide measurements is Pensacola, Florida, 100 miles to the east of Ship Island. The rate of sea-level rise at Pensacola is 0.008 ft/year. A value of 0.01 ft/year was used at Ship Island to accommodate subsidence effects associated with proximity to the Mississippi River delta. Relative sea-level change recorded by tide-gage measurements at Biloxi, Mississippi, from about 1900 to 1960, confirms that this estimate is fairly accurate (US Army Corps of Engineers (USACE) 1973).

20. Several changes in the designation of geographic north have been made since the earliest survey was conducted. The 1848-1855 and 1917 surveys

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* Personal communication, J. Hubbard, National Ocean Service, 1987.

were adjusted to the present coordinate system by subtracting the appropriate degrees of latitude and longitude from the coordinates printed on the original hydrographic sheets. Both horizontal and vertical datum adjustments used in this study are listed in Table 4.

Table 4

Horizontal and Vertical Datum Adjustments

Survey Date	Latitude	Longitude	Depth, ft
1848-1855	-0.001667	-0.022980	+1.09
1917	-0.000074	-0.000209	+0.44
1967-1968	0.000000	0.000000	0.00
1970	0.000000	0.000000	0.00
1986	0.000000	0.000000	0.00

Digital Database Creation

21. Bathymetric data from hydrographic surveys were converted into x-y-z coordinates with a Calcomp 9000 digitizer. After appropriate data corrections were made, these data were then converted to state plane x- and y-coordinates and z-elevation/depth values relative to mean low water (mlw). Shoreline position x- and y-coordinates were considered to be at zero elevation, mean sea level (msl), although most shorelines are mapped as mean high water (mhw) positions. Because of the small tidal range in the study area, and shoreline locations on relatively steep profile positions, horizontal error associated with this assumption is only a few yards. Analysis of topographic maps and island profiles indicates that the average island elevation is about +5.0 ft mlw. Because topographic information was not available on many surveys, +5.0 ft was assigned to all coordinates within the shoreline boundaries, regardless of the survey date or position on the island. Actual topographic variation on Ship Island ranges from near msl within the inter-island ponds, to over +15 ft in some dune areas. Combining data from hydrographic and topographic surveys produced data sets covering five time periods; 1848-1855, 1917, 1967-1968, 1970, and 1986. Only the first two periods covered the area of analysis (Figure 1). Offshore areas were not surveyed after 1917. However, significant morphologic change in offshore areas greater than 30 ft deep is not expected to occur in the time frame of this study. The

critical area of interest, the west end of Ship Island and adjacent channel (Figure 1), was surveyed during all periods, permitting detailed analysis of temporal changes in that area.

Methods of Analysis

Three-dimensional analysis

22. ASCII coded data sets were analyzed with Raytheon Corporation's CPS-1 computer software. CPS-1 transforms randomly positioned x-y-z data into uniformly gridded x-y-z data. A piecewise least squares algorithm of random x-y-z values assigns a z-value to each grid node. Grids created for each survey date were used to create bathymetric contour maps. Bathymetric change between surveys was also analyzed with the use of CPS-1. Specific areas can be designated for volumetric analysis with CPS-1. This feature permits volume quantification within polygons above and below specified elevations, allowing estimation of dredging volumes necessary to achieve specified navigation channel length, width, and depth. Grid cells used in this study were 333 ft on a side, assuring detail of gridded data comparable to original survey data.

Two-dimensional analysis

23. Shorelines from the hydrographic surveys and topographic maps were digitized separately from the bathymetric data, allowing separate plots of shoreline positions. General morphologic change analysis could be conducted from these plots. The shoreline data bases could also be analyzed by CPS-1 to obtain island area statistics. Island area data were also collected by planimetering the west end of Ship Island. These data were used to document the increase in area of the west end of Ship Island through time.

PART IV: GEOMORPHIC ASSESSMENT

Island Morphologic Change

24. Figures 4-10 illustrate island morphologic changes which have occurred at Ship Island since 1848. In 1848, the gulf shoreline had a general northeasterly to southwesterly arcuate configuration (Figure 4). A significant embayment was present along the west-central gulf shoreline (Figure 4a). This embayment may have been caused by a storm breach sealed by littoral sediment transport. A wide section of island along the eastern sound shoreline contained an inner island "bay" (Figure 4b). Narrow spit sections extended northeast and west of this wide section, connecting with another wide island section. These two wide island sections form the nuclei of what are today called East and West Ship Island.

25. By 1917, significant recession of the gulf shoreline had occurred across the eastern two-thirds of the island (Figure 5). The northeast spit had retreated and the west island tip had advanced, with beach accretion along the west gulf shoreline. The gulf-side embayment (Figure 4a) had lost most of its definition, and the sound-side "bay" (Figure 4b) had partially shoaled. The central narrow island section had transgressed landward, presumably through overwash processes during storms.

26. The 1950 shoreline map reveals the presence of a breach in the center of the island (Figure 6). This breach may have formed during a hurricane which passed near Ship Island in 1926 (USACE 1973). The gulf shoreline continued to erode along the eastern two-thirds of the island from 1917-1950. The northeasterly spit had not retreated to the west significantly but did transgress landward more than 1,000 ft. The west spit continued to migrate westward, actually changing its long-axis orientation from nearly northwest to almost due west. Infilling of the inner island "bay" continued, producing a sound-side embayment.

27. By 1968, the inlet present in 1950 had sealed (Figure 7). Only the eastern third of the island showed significant gulf-side erosion. Both the northeast and western spits advanced several hundred feet, with continued landward transgression of the northeast spit. Most of the sound shoreline remained in the same position as in 1950.

28. Hurricane Camille opened an inlet at Ship Island during its passage

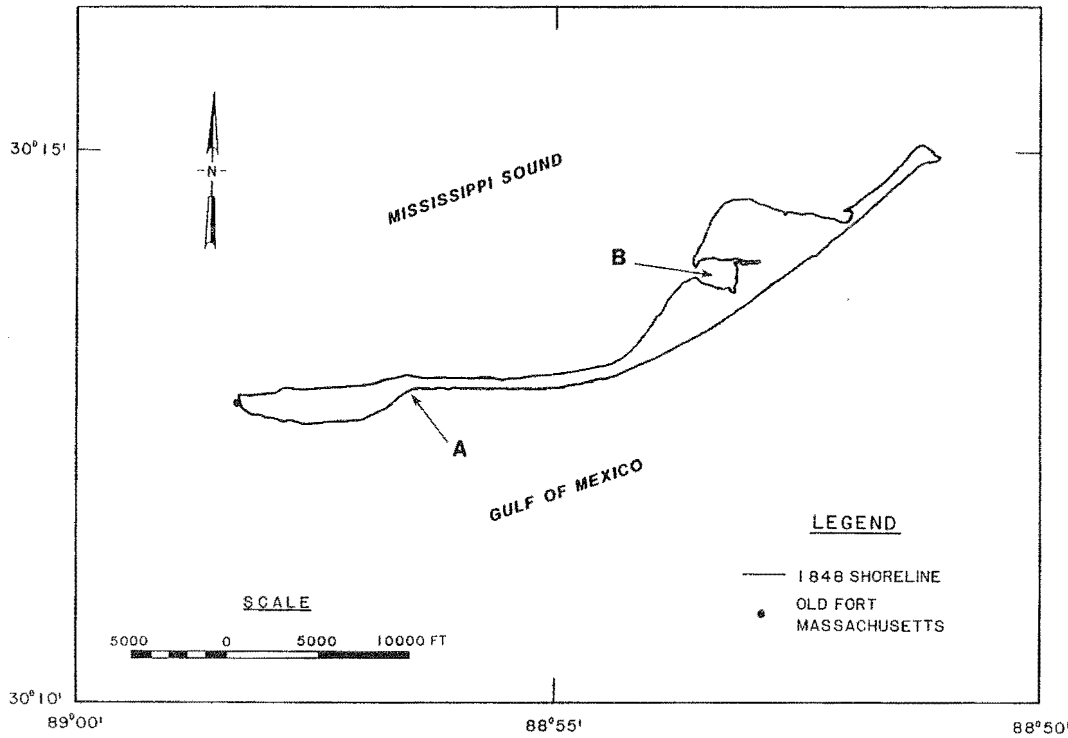

Figure 4. Ship Island, 1848

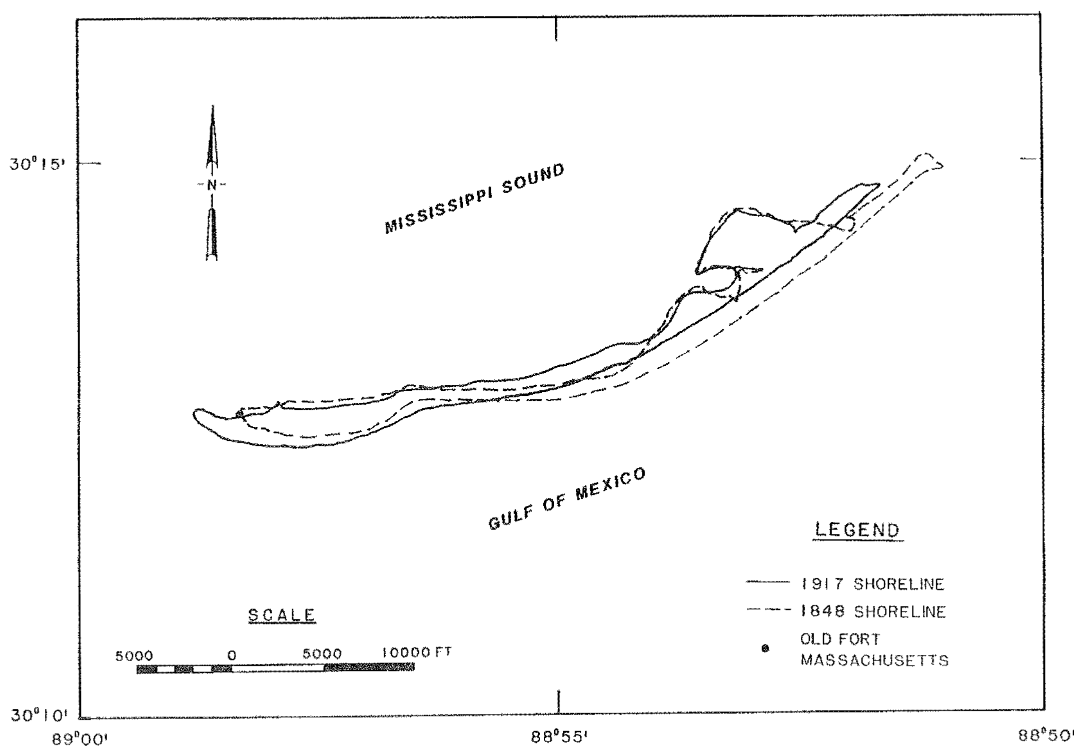

Figure 5. Morphologic change at Ship Island, 1848-1917

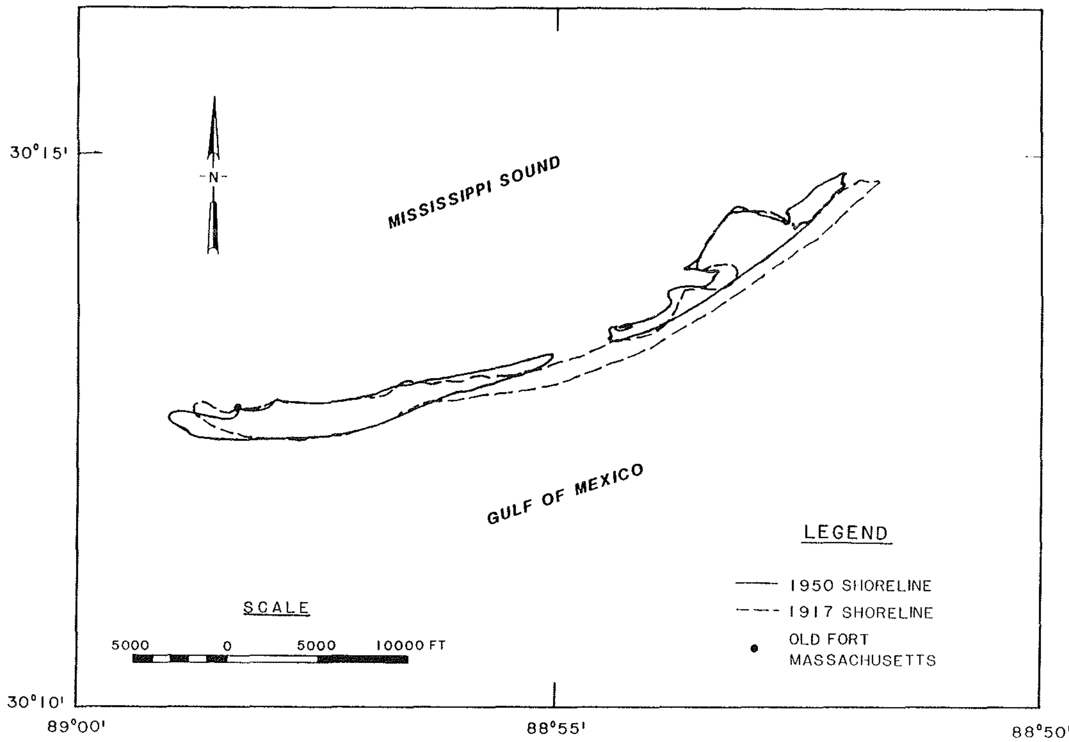

Figure 6. Morphologic change at Ship Island, 1917-1950

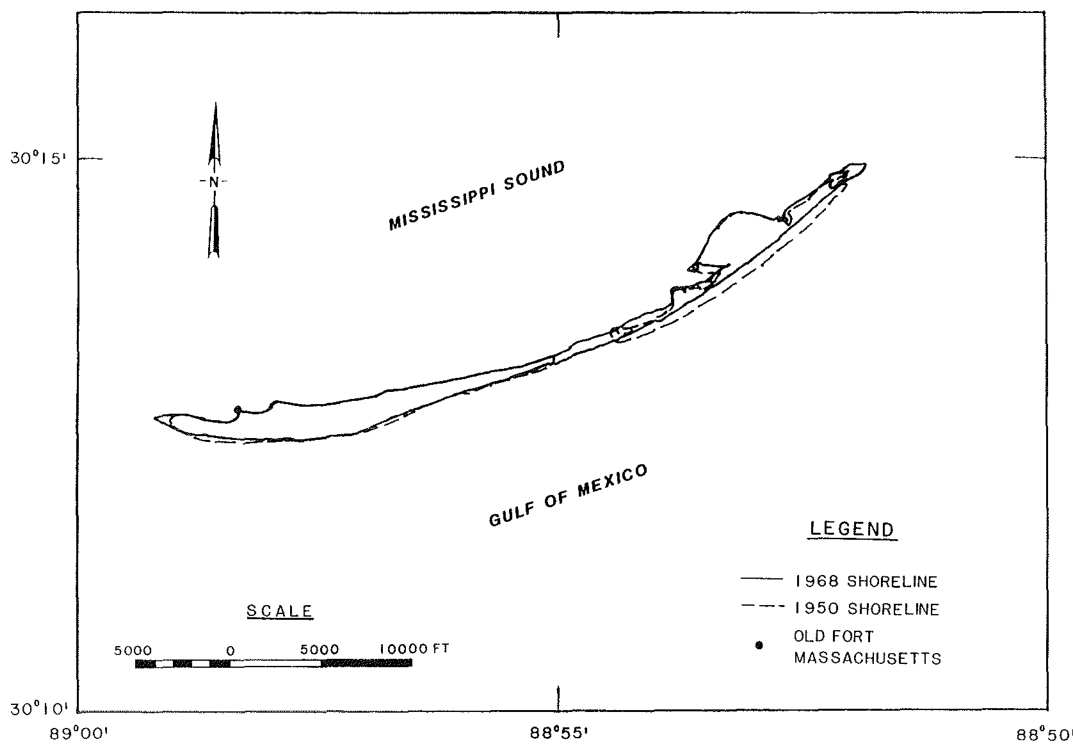

Figure 7. Morphologic change at Ship Island, 1950-1968

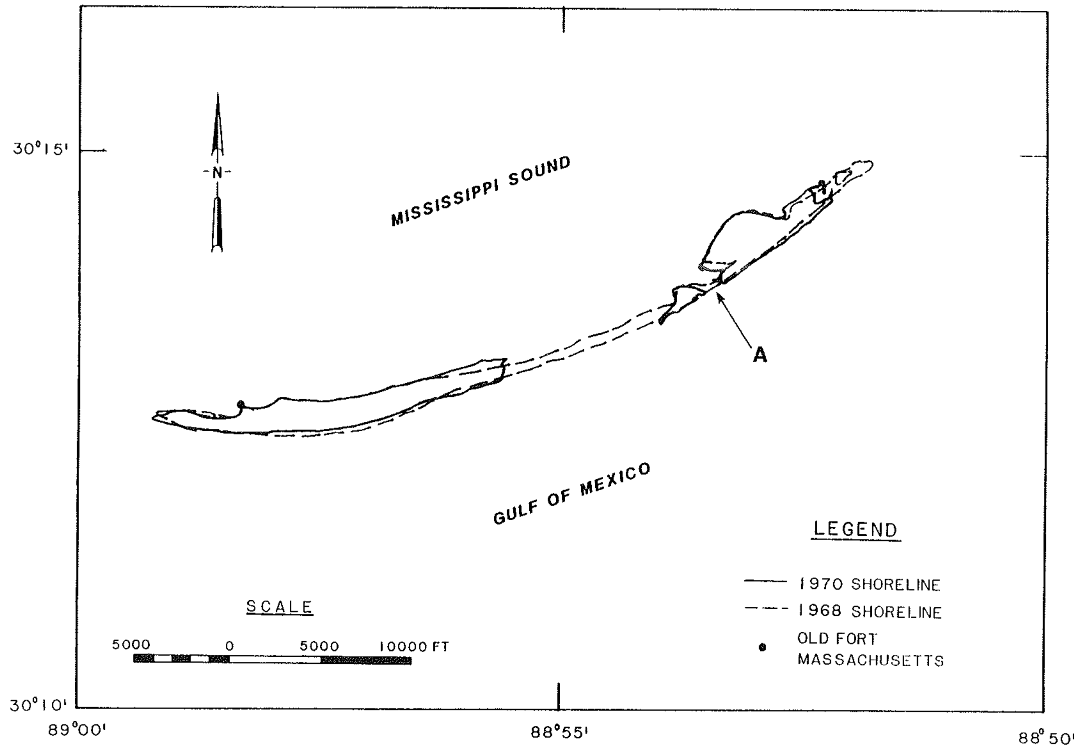

Figure 8. Morphologic change at Ship Island, 1968-1970

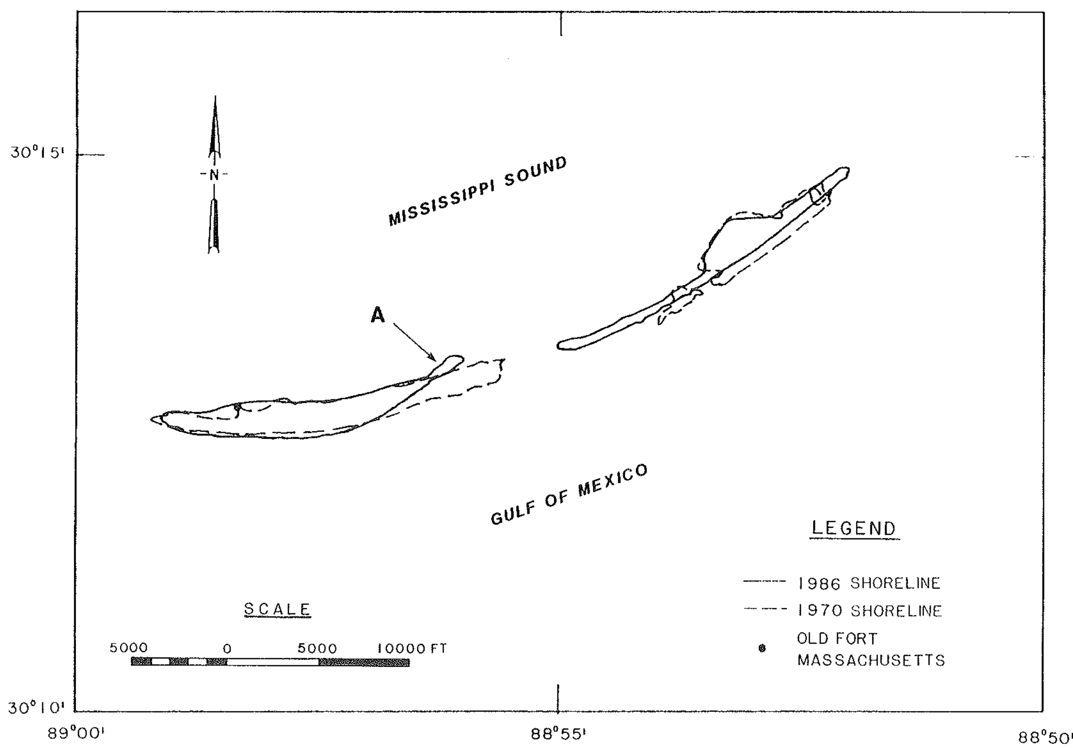

Figure 9. Morphologic change at Ship Island, 1970-1986

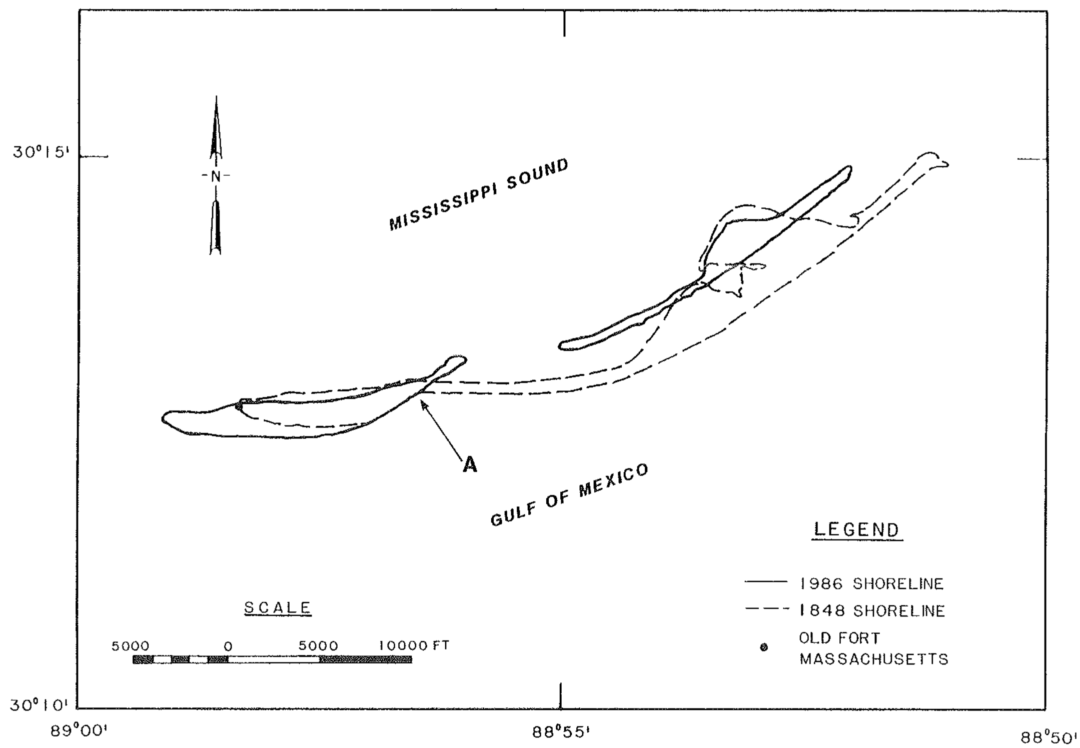

Figure 10. Morphologic change at Ship Island, 1848-1986

in 1969 (Figure 8). A small breach also formed adjacent to the remnant inner island "bay" (Figure 8a). Although the gulf shoreline position changes do not appear as great as illustrated in Figures 5-7 (considering these changes represent a 2-year time period and most likely a single storm event), the rate of change is very significant. The western spit shifted from a slightly northwestly to a more westerly orientation, with additional westward migration. The northeast spit was almost completely eroded by Camille.

29. The 1986 map (Figure 9) shows that the inlet formed by Camille has narrowed and migrated westward. The 1986 hydrographic survey indicates the inlet is deeper than when it first formed. The gulf shoreline of East Ship Island has continued to erode. New spits extend toward the northwest and southwest from the wide section of East Ship Island. The west tip of West Ship Island has retreated, probably as a result of dredging the adjacent ship channel. Profile adjustment along the edge of the channel may have resulted in retreat of the shoreline. Significant accretion occurred in the Old Fort Massachusetts area, some attributed to beach nourishment with dredged material from the channel. The inlet has developed a slight updrift offset morphology. Along the West Ship Island gulf shoreline, a local reversal in the net

westerly littoral transport may be present on the downdrift west side of the inlet, producing the northwesterly orientation of the spit adjacent to the inlet (Figure 9a).

30. Figure 11, a comparison of the 1848 and 1986 shorelines, dramatically illustrates changes visible in the sequential maps (Figures 5-9). The large island area loss due to erosion of the eastern gulf shoreline is apparent in this figure. It is interesting to note that the embayment in the gulf shoreline in 1848 (Figure 10a) became an apparent axis of rotation for the east end of West Ship Island. The west side of the embayment reveals no significant change in shoreline position. The stability of this area may be due to the presence of more resistant subsurface strata. Barrier island morphology and development are often influenced by antecedent topography or subsurface stratigraphy. Subsurface data are not presently available from the east end of West Ship Island to verify this hypothesis. Although the sequential maps do not show much erosion of the sound shoreline, Figure 10 illustrates that significant erosion has occurred along the sound side of the wide portions of East and West Ship Island. Presence of tree stumps exposed along

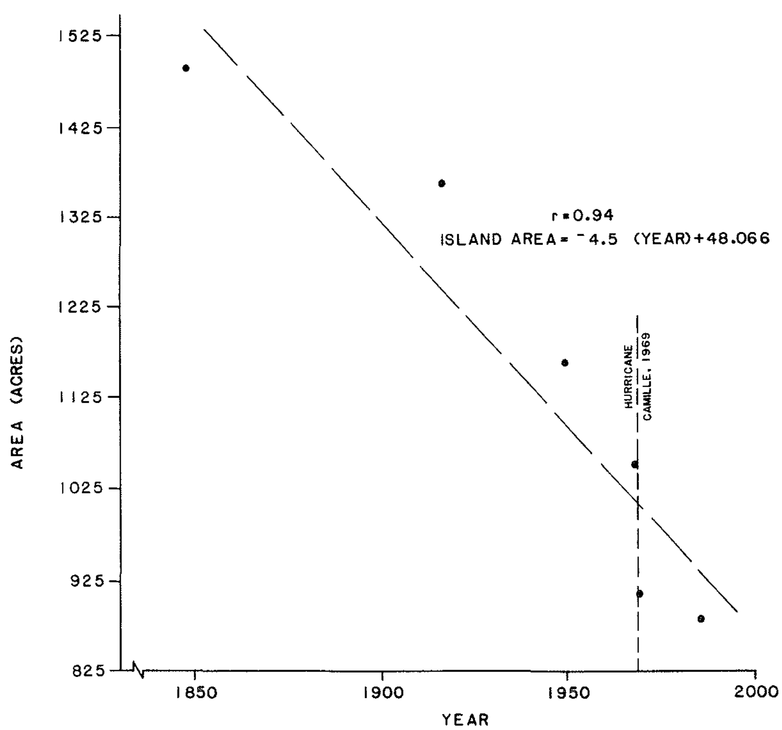

Figure 11. Ship Island subaerial area change, 1848-1986

the gulf and sound beaches of East Ship Island attest to the severity and extended history of erosion.

31. It appears that East and West Ship Island may now be functioning as two distinct barrier islands, separated by a reasonably well-developed tidal inlet. East Ship Island appears to be anchored by the old, wide island area, with changes occurring to the spits on either side. West Ship Island appears to be migrating westward as an independent island, with sand supplied from erosion of East Ship Island.

32. Although accretion of the west tip of Ship Island has occurred through time, it is obvious from analysis of Figures 4-10 that a net loss of subaerial island area has occurred due to erosion. Figure 11 illustrates this progressive loss of total island area. Linear regression of the island areas through time reveals that over 4.5 acres of land has been eroded per year since 1848, although the actual history of erosion has occurred in stair-step fashion, with large area losses attributed to major storms followed by periods of lesser erosion. The maximum rate of area loss is attributed to Hurricane Camille, with 138 acres of erosion occurring between 1968 and 1970. Minimum rates of area loss occurred from 1848-1917 and 1970-1986 when less than 2 acres per year were eroded.

Bathymetric Change

33. Bathymetric maps were prepared for five time periods: 1848-1855, 1917, 1967-1968, 1970, and 1986. Comparison of the bathymetric maps reveals deposition and erosion trends in the study area. These trends were further emphasized by the construction of bathymetric change maps. Grids representing bathymetric data from each survey period were compared with the use of a CPS-1 feature. The output grids were then contoured at 5-ft intervals to illustrate major areas of deposition and erosion. Highly irregular contours were eliminated from the plots by two-dimensional, symmetric smoothing of the grids prior to contouring.

Bathymetry: 1848-1855

34. The earliest bathymetric survey revealed the shallow, low relief of Mississippi Sound, with depths generally between 15 and 20 ft within the study area (Figure 12), contrasting with the deeper, higher relief tidal inlet and Gulf of Mexico areas where depths exceed 35 ft. A seaward bulge in the -20

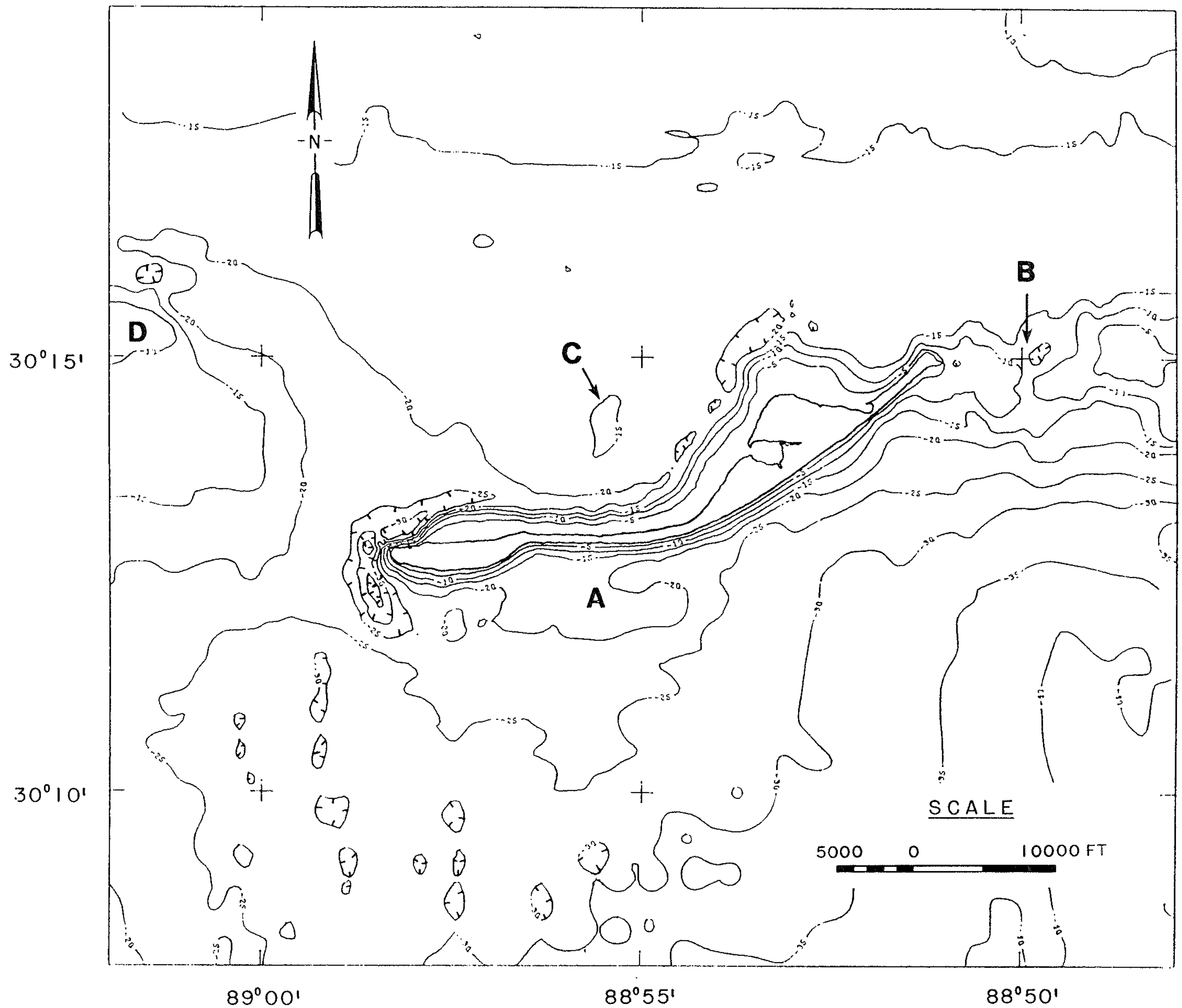

Figure 12. Bathymetry of study area, 1848-1855

and -25 ft contours was present in front of the gulf shoreline embayment (Figure 12a), which would have caused a focusing of wave energy in that area, a possible factor in the formation of the embayment. This bathymetric bulge is called Loggerhead Shoal on later nautical charts. A subtle inletlike feature was present east of Ship Island (Figure 12b). A slightly deeper channel crossed this shallow-water area, and a seaward deflection of the contours was present on the gulf side, suggesting ebb-current effects. Other bathymetric features present during this time include a slight bathymetric high (Figure 12c) called Walker Shoal on later charts. The cause of this feature is unknown, but it may be related to storm surge flow through breaches formed in the center of Ship Island. The other bathymetric feature is presently named Spade Fish Shoal (Figure 12d), and it seems to be related to coastal processes associated with Cat Island, west of Ship Island (Figure 1).

Bathymetry: 1917

35. By 1917 the subtle inlet feature of 1848-1855 east of Ship Island had developed a classic inlet morphology, with a well-developed central channel and ebb-tidal shield (Figure 13a). The channel exceeded 25 ft in depth. This inlet is called Little Dog Keys Pass on later charts. Westward migration of the west island tip caused the adjacent tidal channel to also migrate to the west.

36. Bathymetric changes which occurred from 1848 to 1855 and in 1917 are illustrated in Figure 14. Bathymetric change maps presented in this study were contoured from grids which consisted of elevation differences between surveys. As with the bathymetric maps, the grids were smoothed prior to plotting. Five-foot contours were used to illustrate only major deposition and erosion areas. Positive contours indicate deposition; negative contours indicate erosion. The development of Little Dog Keys Pass is indicated by the deposition and erosion contours near the eastern boundary of the study area (Figure 14a). Elongate north to south erosional contours indicate scouring of the inlet throat. Arcuate depositional contours to the south represent development of the ebb shield. Farther west, island and shoreface erosion is indicated by the large northeasterly to southwesterly trending area of erosional contours (Figure 14b). Overwash deposition is apparent along the central island section and the northeast spit area (Figure 14c). The most significant deposition occurred at the west island tip due to island migration (Figure 14d). Corresponding migration of the tidal channel produced the area of

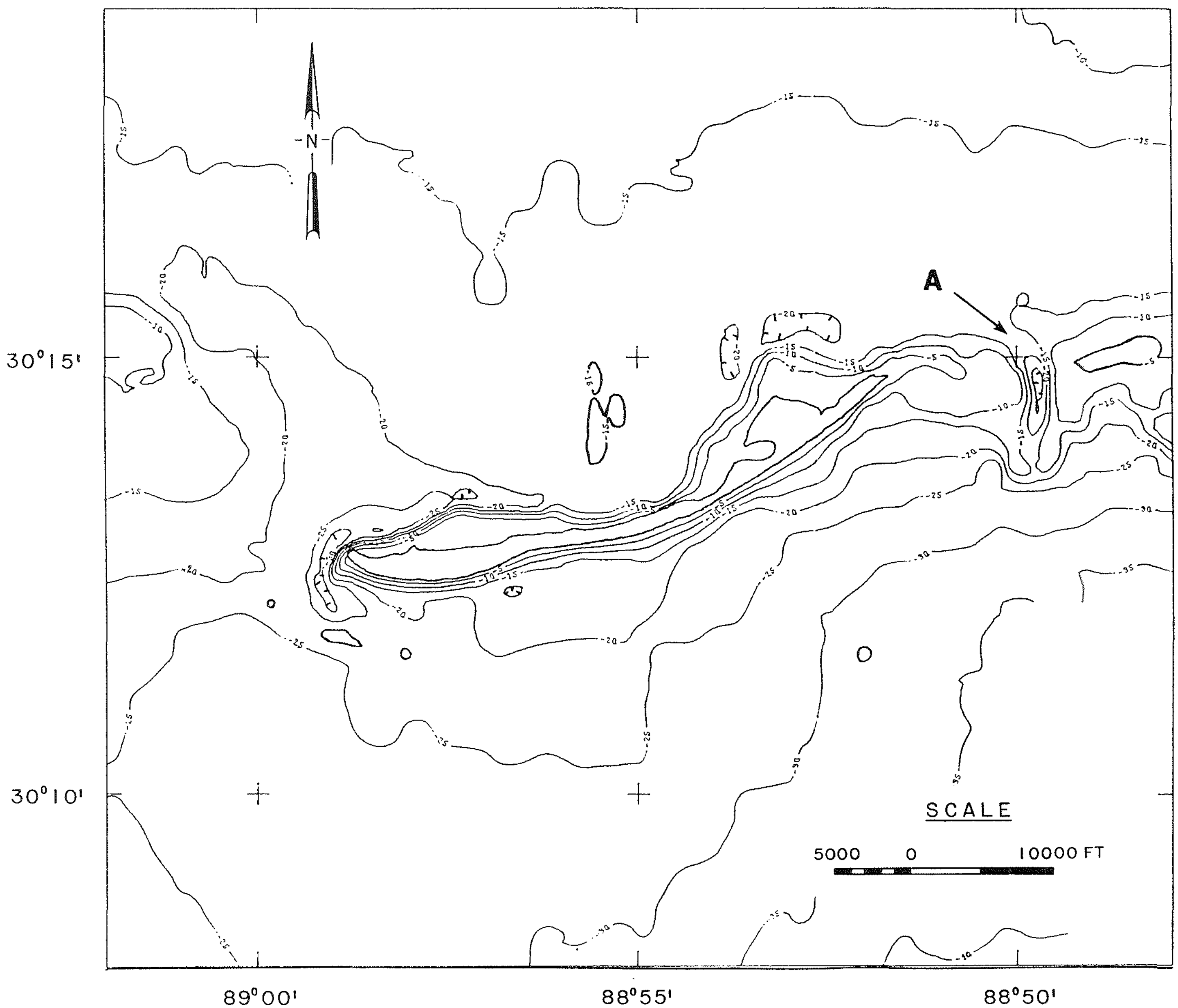

Figure 13. Bathymetry of study area, 1917

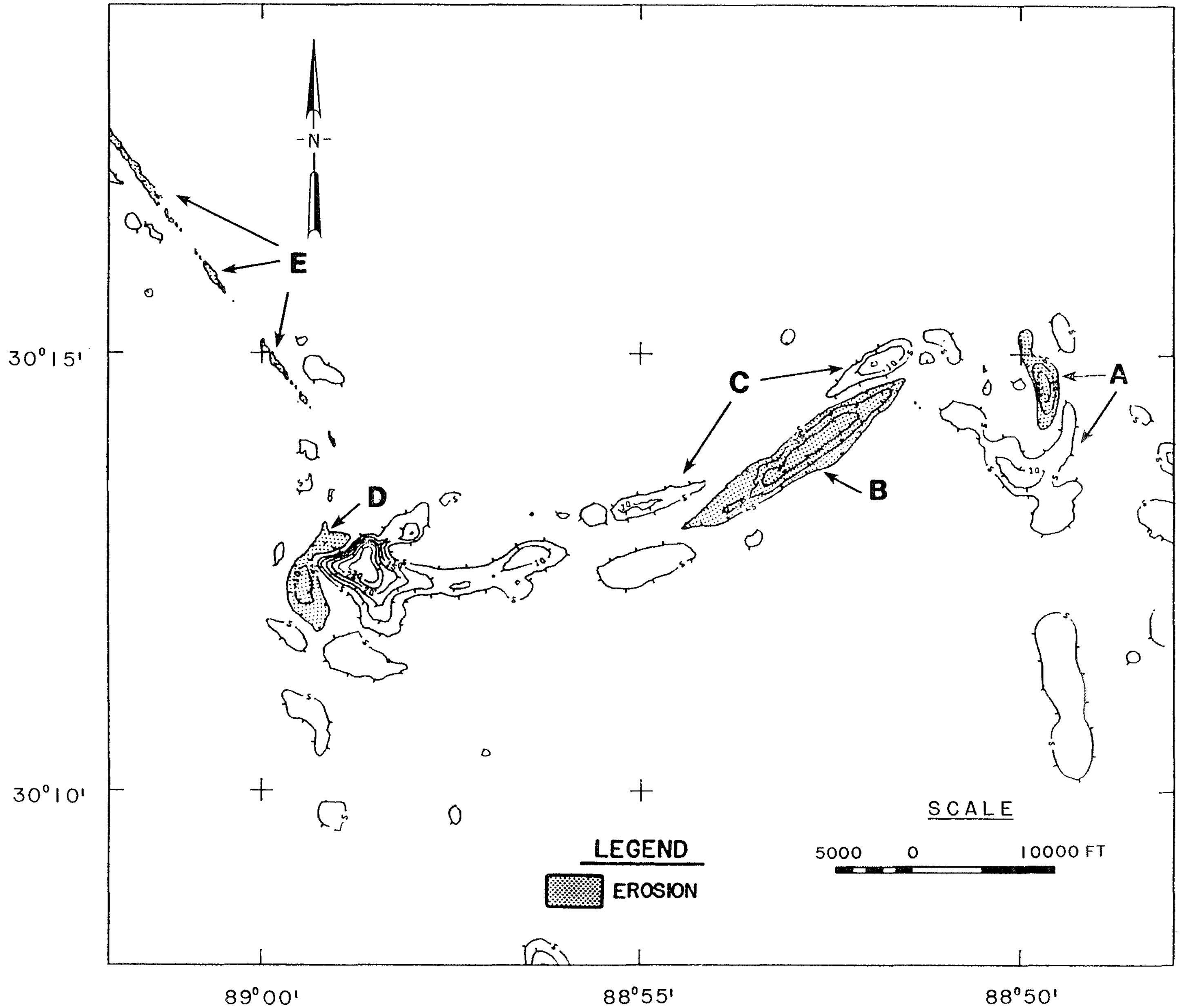

Figure 14. Bathymetric change, 1848-1855 to 1917

erosional contours. It is interesting to note that the Gulfport navigation channel (Figure 14e) did not appear on the bathymetric contour map but is expressed on the bathymetric change map. Apparently the dimensions of the channel were too small to influence the bathymetric contours drawn by CPS-1, but due to the lack of major change other than channel construction in Mississippi Sound, the channel presence was revealed in the change map.

Bathymetry: 1967-1968

37. Little Dog Keys Pass experienced further development by 1967-1968 (Figure 15). The main channel and ebb shield were better defined, and the channel had developed a greater bend (concave to the west). Two marginal channels had also developed across the shoal to the west (Figure 15a). Unfortunately, offshore areas and the shoreface of central Ship Island were not surveyed in 1968. Continued migration of the west island tip caused further migration of the tidal channel. By 1968 the Gulfport ship channel was significant enough to be revealed by the 5-ft bathymetric contouring scheme used in these figures. The 1917 to 1967-1968 bathymetric change map is similar to the previous one, with erosion along the shoreface of eastern Ship Island, deposition/erosion at the west island tip, and continued overwash deposition along the central island-sound shoreline (Figure 16). Deposition along the southwest side of the Little Dog Keys Pass ebb-tidal shield also occurred (Figure 16a).

Bathymetry: 1970

38. The passage of Hurricane Camille in 1969 opened a new inlet through the center of Ship Island (Figure 17). Other than some scouring of the channel along the west island tip and better definition of the small tidal channels across the shoal near Little Dog Keys Pass (Figure 17a), the new inlet was the only major bathymetric change which occurred between 1968 and 1970. However, this major change (inlet formation) occurred during the passage of a single storm which probably caused the other changes as well. The bathymetric change map illustrates the volumetric loss attributed to the new inlet (Figure 18). The area of greatest change is actually from comparison of 1917 and 1970 survey data due to lack of data in that area from the 1968 survey. Other than the inlet formation, contouring at 5-ft intervals did not indicate any other significant areas of bathymetric change between 1967-1968 and 1970.

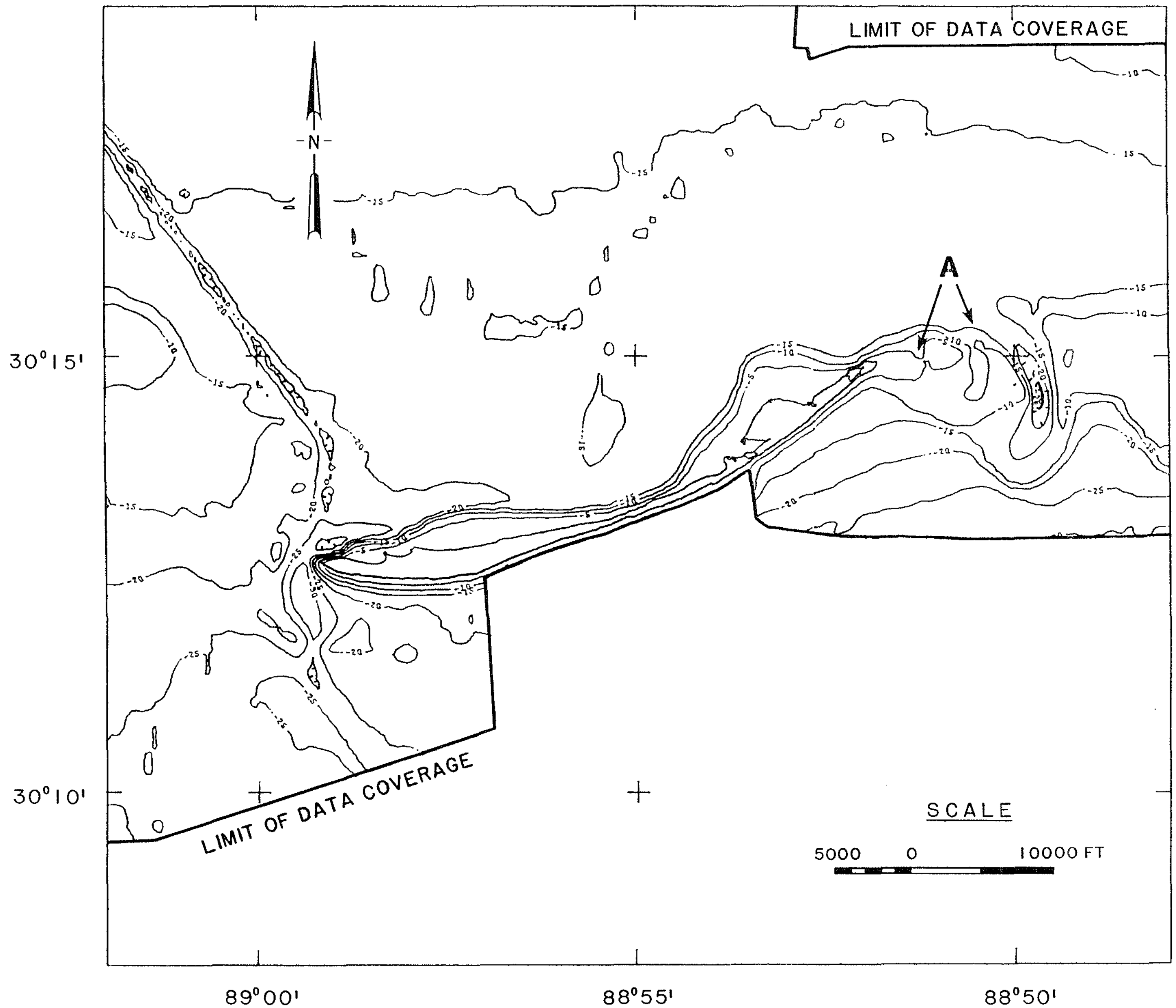

Figure 15. Bathymetry of study area, 1967-1968

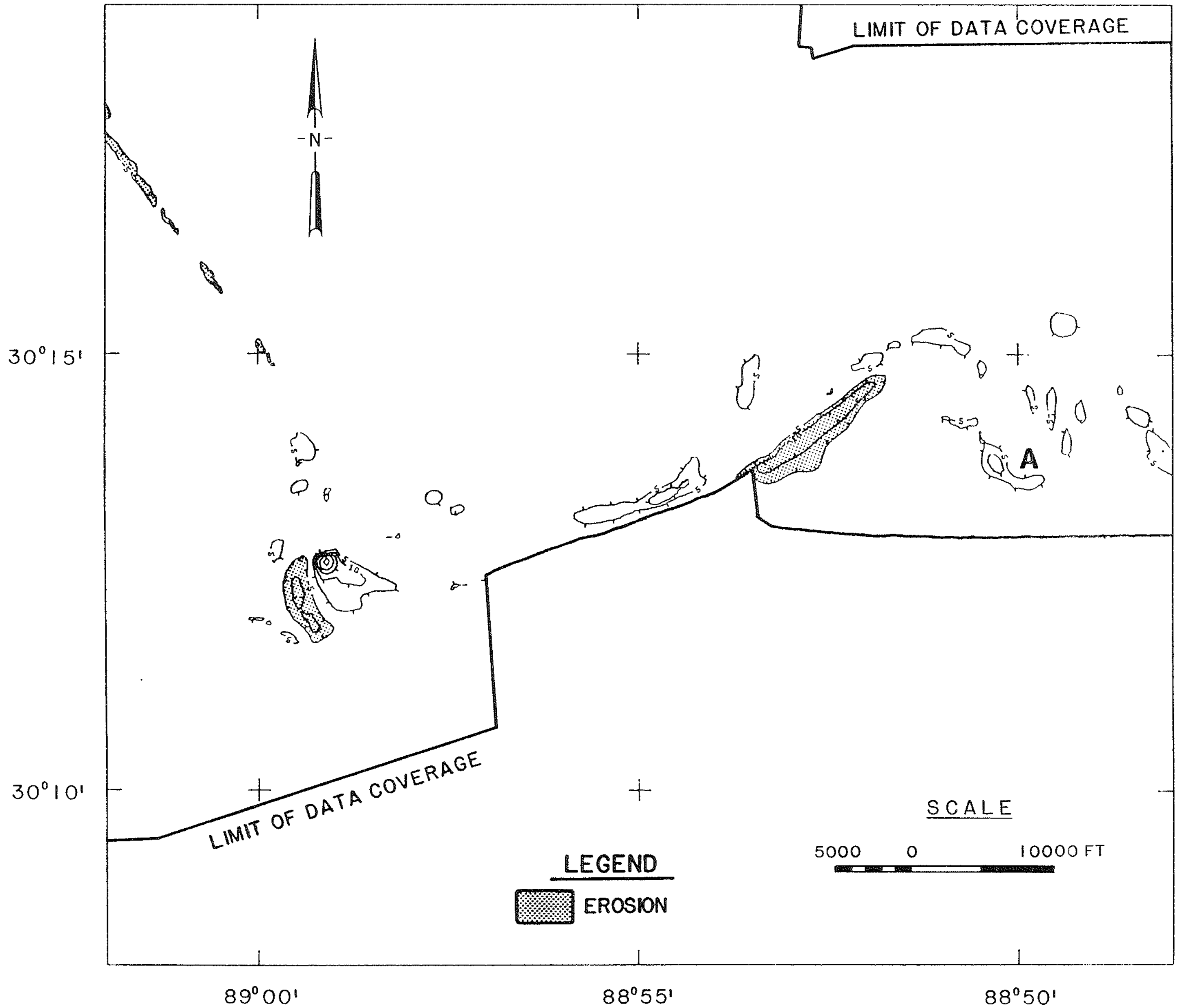

Figure 16. Bathymetric change, 1917 to 1967-1968

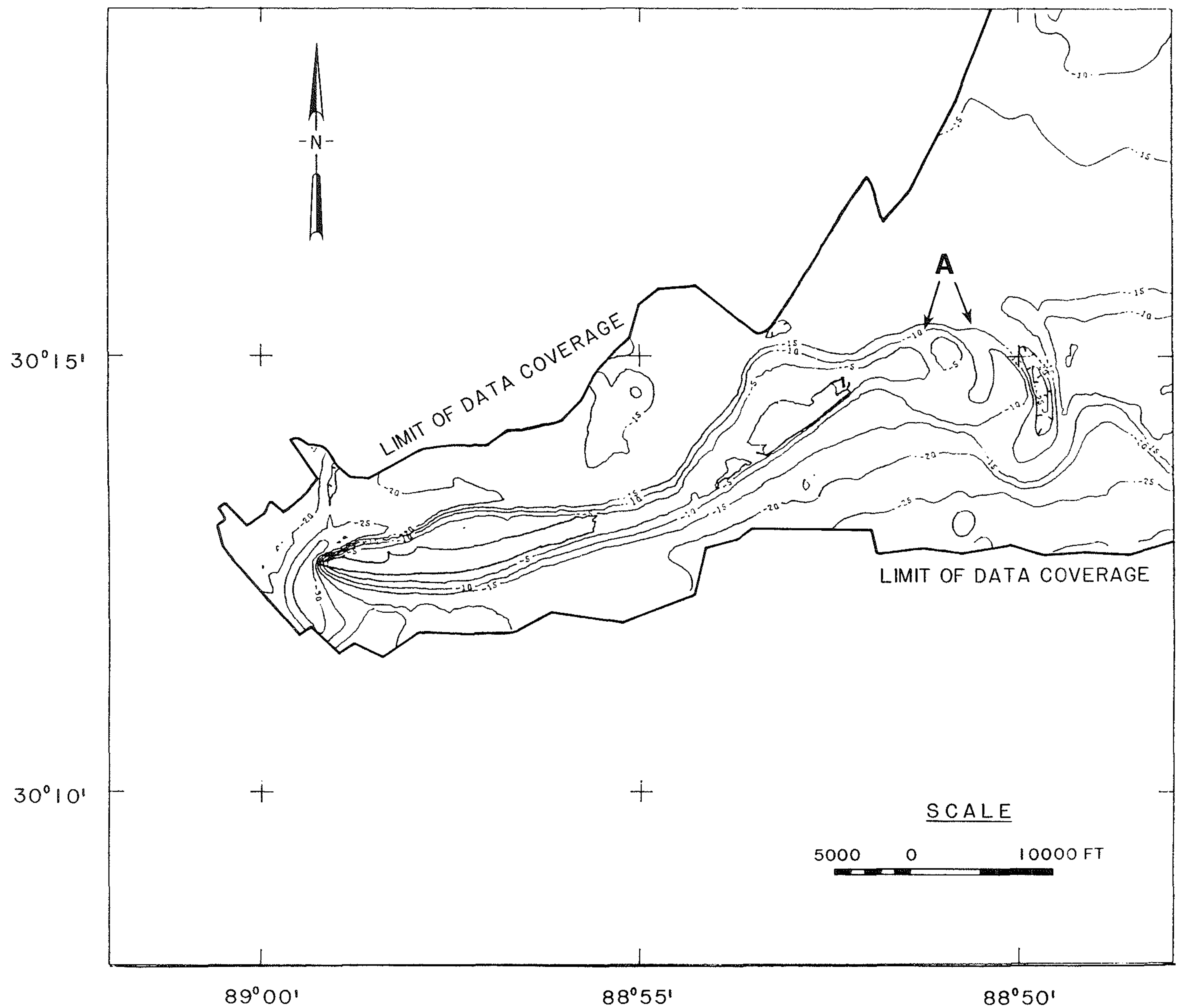

Figure 17. Bathymetry of study area, 1970

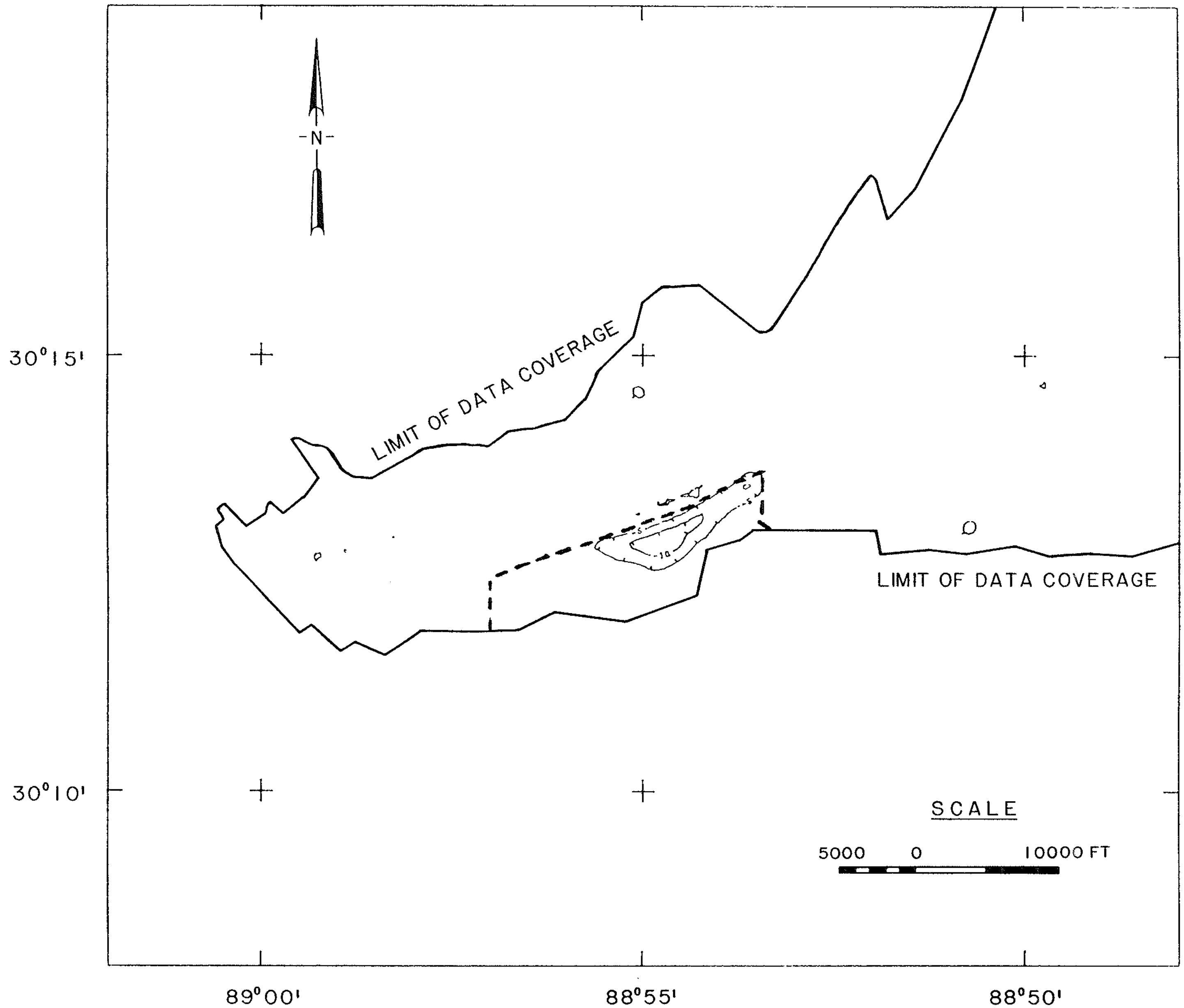

Figure 18. Bathymetric change, 1967-1968 to 1970 (area within dashed line represents change from 1917-1970)

Bathymetry: 1986

39. A limited bathymetric survey conducted in 1986 by SAM reveals further changes in the local bathymetry (Figure 19). Natural deepening of Camille Cut is evident from this figure. The channel along the west island tip and areas farther west had also deepened. These trends are revealed by the erosional contours on the 1970-1986 bathymetric change map (Figure 20). Some accretion also occurred at the western island tip.

Morphologic Change Analysis

40. It is evident from analysis of the bathymetric change maps that the most active processes at Ship Island involve erosion of East Ship Island with westerly transport to West Ship Island where deposition occurs at the edge of Ship Island Pass. This process results in the westerly migration of the west island tip into the channel, causing migration of the channel itself. Linear regression analysis of the rate of migration of the west island tip, measured by Waller and Malbrough (1976), with additional data provided by this study, indicates a migration rate of 38 ft/year (Figure 21).

41. Figure 22 summarizes the coastal processes influencing the present behavior of Ship Island. The main tidal flow passes through Ship Island Pass, although Camille Cut appears to be more dominant than when it first opened in 1969. The main littoral transport direction is westerly along the gulf shoreline with local reversals along the eastern ends of East and West Ship Island, due to local wave refraction and tidal current effects. Net littoral transport appears to be westerly along the sound shoreline of West Ship Island, as evidenced by shoreline morphology visible on maps. Such indicators were not evident along the sound shoreline of East Ship Island. The headland formed by the landward bulge along the sound side of East Ship island may produce a local divergence in littoral transport. Sand waves and other bottom features visible in the 1986 aerial photographs, and beach morphologies, indicate that sediment transport is quite active along the entire sound shoreline of both East and West Ship Island.

42. Analysis of historic changes in bathymetry and island morphology has been used to reconstruct regional changes which have occurred as well as to make some predictions of future changes. The predictions are speculative due to limited subsurface information. Figure 23a depicts a possible past

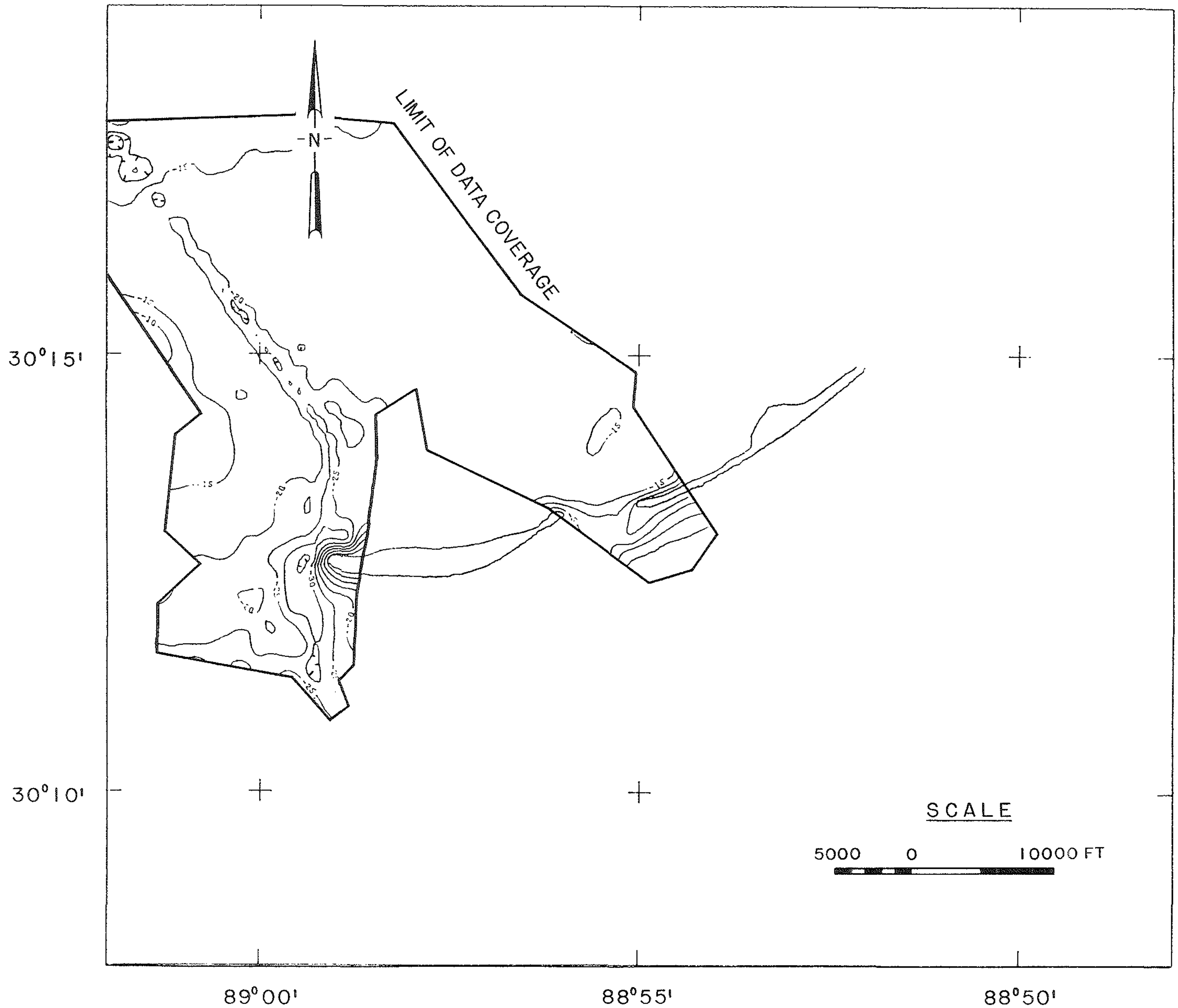

Figure 19. Bathymetry of study area, 1986

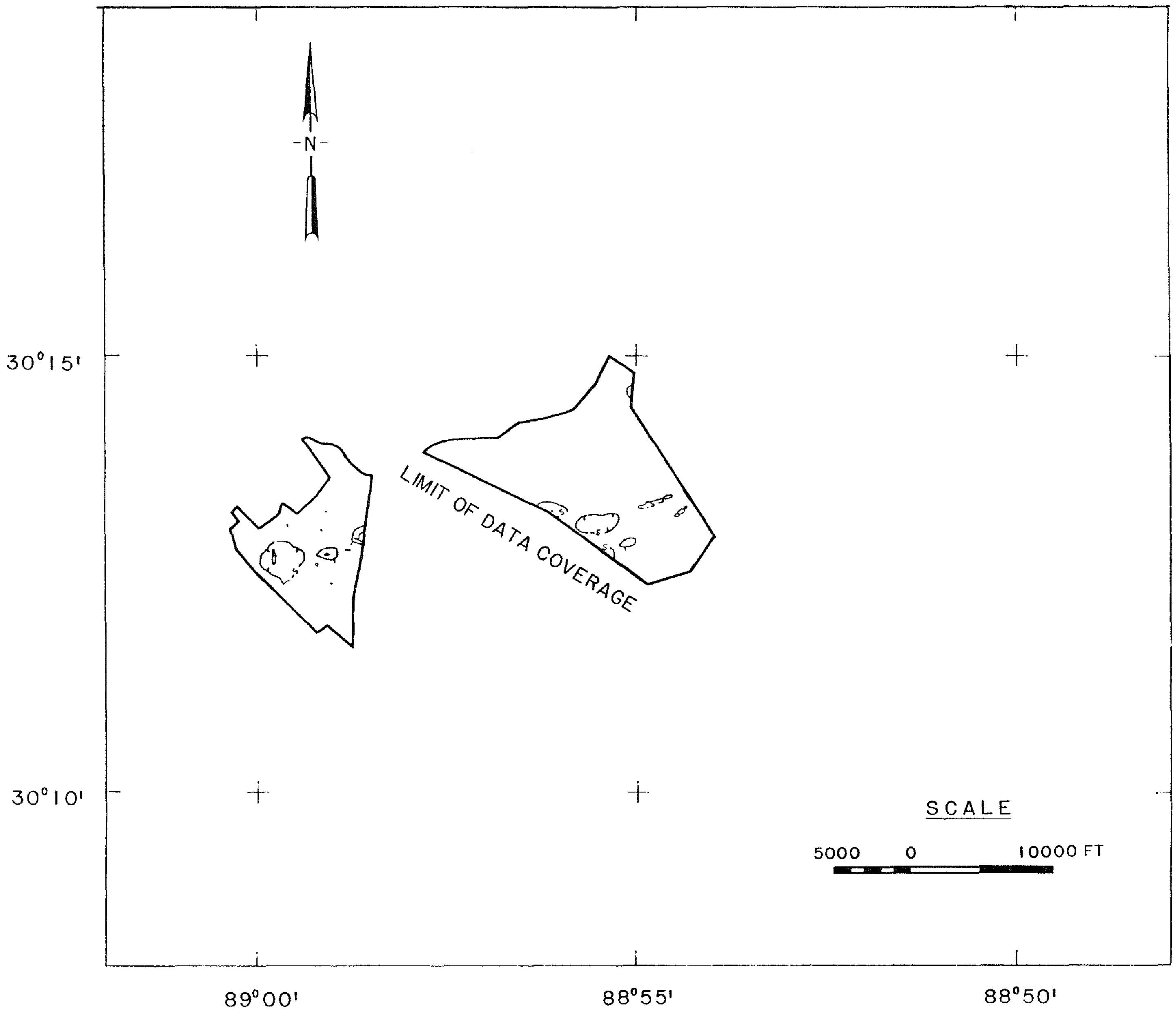

Figure 20. Bathymetric change, 1970-1986

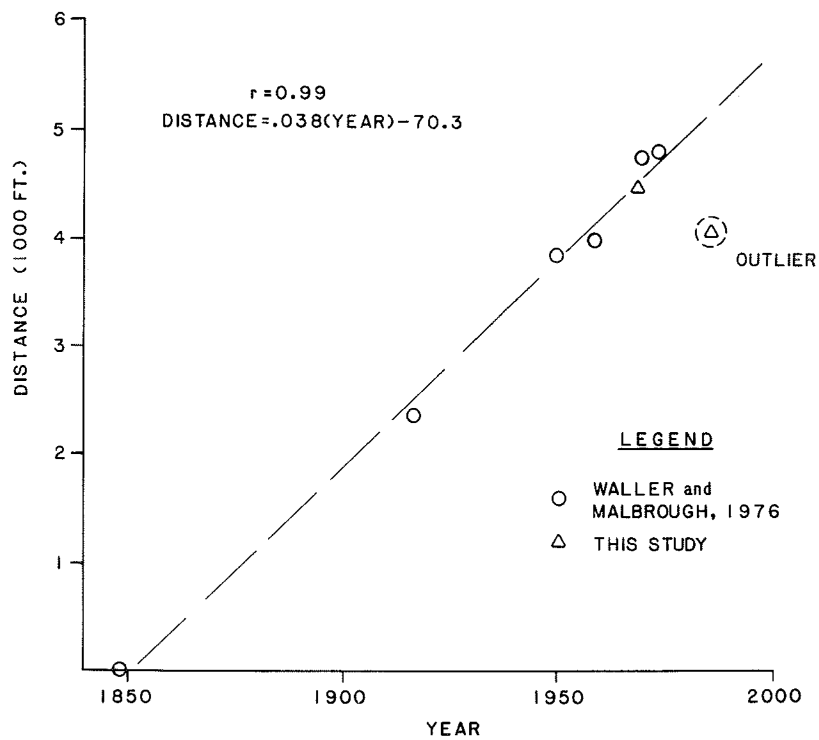

Figure 21. Migration of west point of Ship Island, 1848-1986

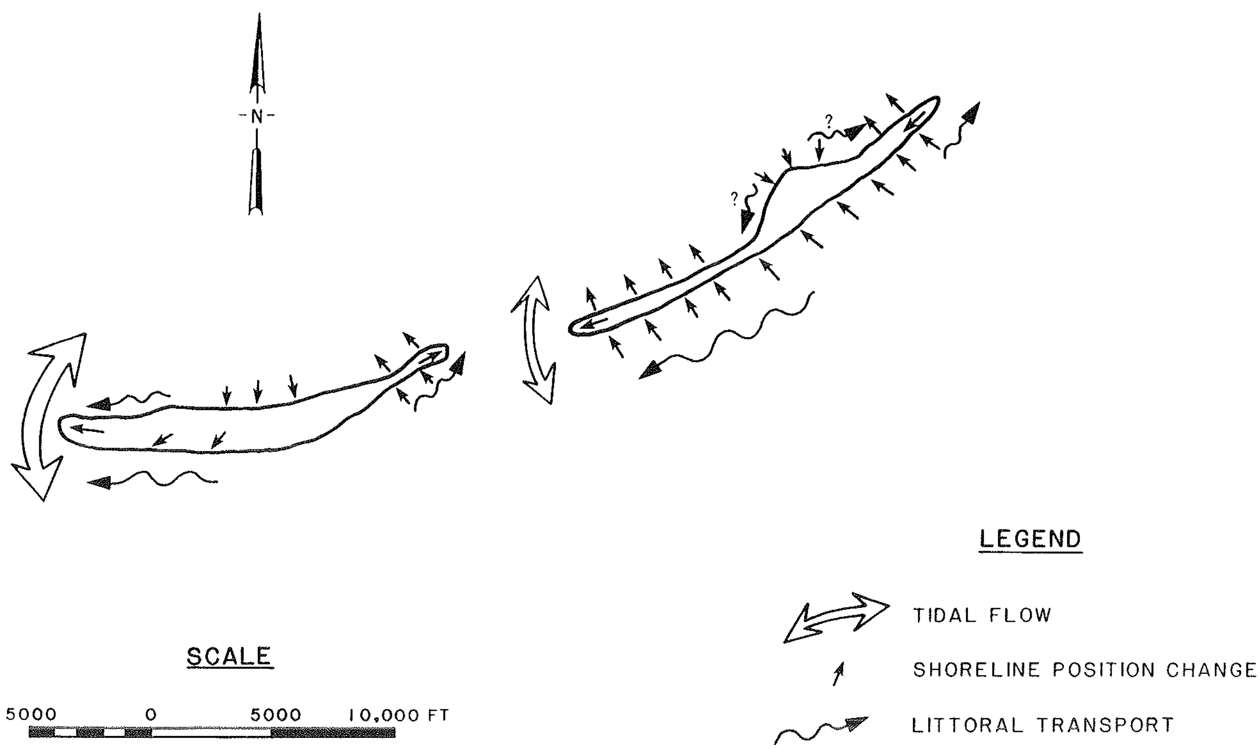

Figure 22. Schematic summary of coastal processes at Ship Island

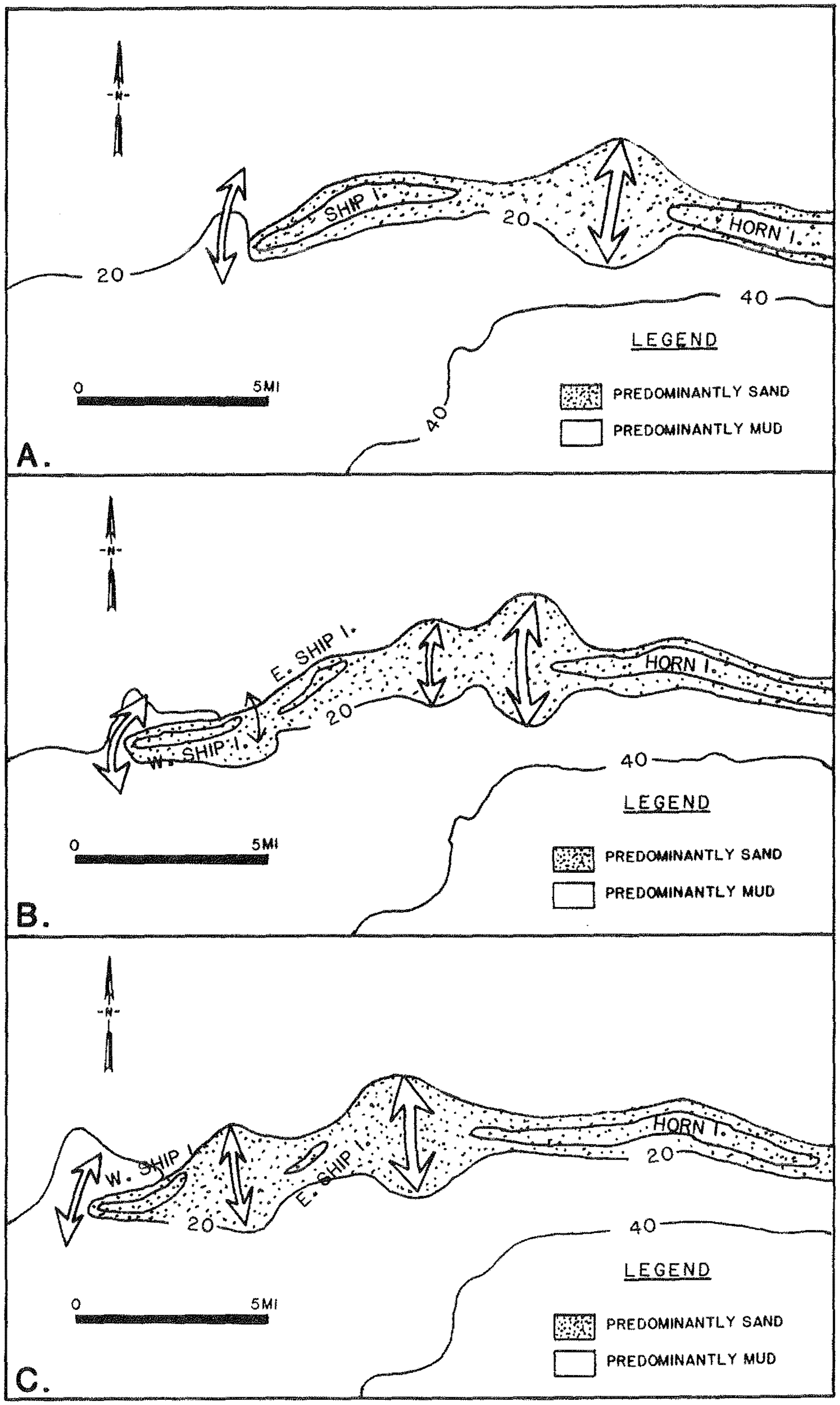

Figure 23. Hypothetical geomorphic evolution of study area

configuration of Ship Island and Horn Island. Both islands are situated along the -20 ft contour, with major channels adjacent to both. The barrier islands and associated tidal-inlet systems are composed of predominantly sandy sediments, overlying and surrounded by predominantly muddy sediments of Mississippi Sound and the Gulf of Mexico. Figure 23b depicts the present configuration. Horn Island and associated Dog Keys Pass have migrated westward to their present positions. Little Dog Keys Pass has formed farther west. Ship Island has migrated southwesterly across the upper continental shelf, forming a seaward bulge in the previous bathymetric configuration. Southwest island migration has caused Ship Island Pass to migrate westward also. The barrier island sand package has migrated farther west. Littoral sand is lost from the system through channel filling as Ship Island migrates westward. In the future, West Ship Island may behave as a barrier island separate from East Ship Island, with Camille Cut becoming a major tidal inlet (Figure 23c). West Ship Island may also continue to rotate to a more northerly orientation as it migrates west. Ship Island Pass may lose tidal prism to Camille Cut inlet, and East Ship Island may all but disappear unless significant sand is transported from the east. Finally, Little Dog Keys Pass may become the major inlet west of Horn Island as the whole barrier system migrates westward.

PART V: LITTORAL TRANSPORT ANALYSIS

43. Littoral transport is the movement of sedimentary material in the littoral zone by waves and currents. Most of the shoaling presently occurring within Ship Island Pass is attributed to littoral transport of sand from the littoral zone of Ship Island. A major portion of this study was conducted to document temporal and spatial changes in direction and amount of littoral transport through two principal methods. First, a comparison of the volumetric changes of the west end of Ship Island through time was performed. This analysis provided estimates indicative of littoral transport rates of the quantities of material shoaling into Ship Island Pass. The second analysis involved use of a numerical wave refraction model. The model characterized nearshore breaking wave heights, periods, and directions which result from transformation across offshore and nearshore bathymetry. The wave data from this model were then used to calculate temporal and spatial variation in littoral sediment transport. Final values alone could only be used for qualitative purposes. However, littoral shoaling estimates calculated from volumetric analysis were used to provide a quantitative framework in which to interpret the numerical results.

Volumetric Calculation of Littoral Shoaling Rates

44. Data grids consisting of depth change between survey periods were used to calculate volumetric changes along the west end of Ship Island. A schematic cross section of the west end of Ship Island illustrates the logic behind this analysis (Figure 24). Sediment transported to the island end is deposited in the channel as the island migrates to the west (Figure 24), along with westward migration of the channel. By comparing the volume changes which occurred between surveys at the west end of Ship Island, rates of littoral shoaling could be calculated. The volumes represent a combination of both gulf- and sound-side transport. The volumes do not necessarily represent littoral transport rates because all of the sediment may not be trapped at the edge of the island. However, the quantities measured do provide good estimates of the amount of material shoaling into Ship Island Pass. These amounts are approximately equal to the average annual quantity of material which would have to be dredged to maintain Ship Island Pass in its present position, which

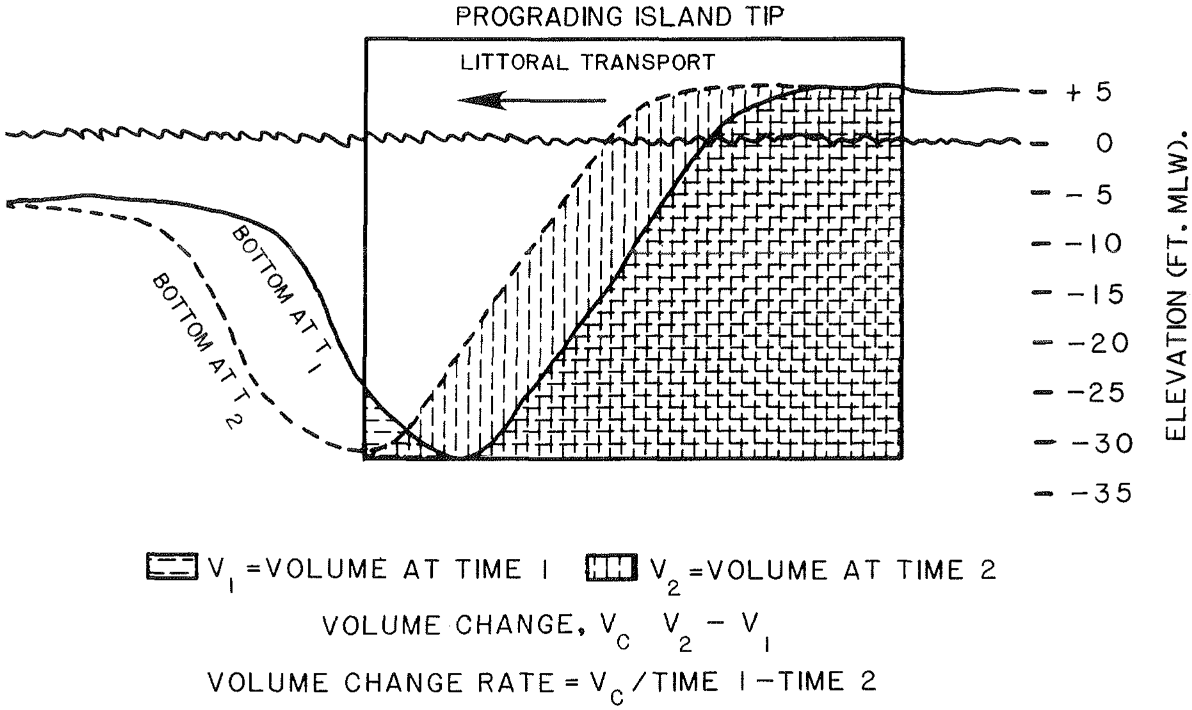

Figure 24. Calculation of littoral shoaling rate

is currently the same position as the Gulfport Ship Channel.

45. Table 5 lists net volume changes calculated for five comparative time intervals used in this study. Due to dredging effects after 1950, the volumetric change rate for the first time period is the best estimate of littoral shoaling. The subsequent periodic channel maintenance dredging removed sediment which would have accumulated at the island tip. The result is a decrease in calculated rates of growth. However, because dredging only removed part of the transported sediment, the island tip volume continued to increase but at a much slower rate. The dredging effects prevent volumetric estimation of littoral transport rates after 1917.

Table 5

Volumetric Change at the West End of Ship Island

Period	No. of Years	Net Volume Change 1,000 cu yd	Volumetric Change Rate 1,000 cu yd/year
1848-1917	69	10,979	159
1917-1968	51	3,625	71
1968-1970	2	-238*	-119*
1970-1986	16	806	50
1968-1986	18	734	41

* Indicates effects of Hurricane Camille in 1969.

46. Temporal changes in the subaerial area of the west island tip correlate well with the volumetric change rate trend depicted in Table 5. Volumetric growth of the island is accompanied by an increase in subaerial island area. The two trends should correlate, assuming relatively uniform bathymetry occurred adjacent to the west end of Ship Island. If the bathymetric configuration remains approximately constant through time, constant sediment accumulation should produce a constant rate of island area increase. The bathymetric maps (Figures 12, 13, 15, 17, and 19) indicate that the bathymetric configuration at the west tip of Ship Island has remained fairly constant, indicating that island area change should correlate with volumetric change. To eliminate the effects of local shoreline position change on area measurements, eastern limits of area measurements were advanced westward for later periods. Three eastern limits were chosen lying on longitude lines of 88°58', 88°58'30", and 88°59' (Figure 25). Figure 25 illustrates the area rate of change per year for these three boundaries. Curves A and B indicate that rates of island area increase were relatively constant until 1950 when dredging began affecting both volumetric and island area change rates. This relatively constant increase in island area until 1950 indicates that the 159,000-cu-yd/year rate of volumetric increase for the period 1848-1917 probably continued until about 1950. The pronounced decrease in rate of island area increase after 1950 is illustrated in curves A and B (Figure 25). The third data set (Figure 25, Curve C) had its eastern boundary too far west for area measurements from 1848 and 1917 maps. Curve C shows that even after 1950 a relatively steady growth of the island occurred, with a slight drop off after 1970. The area west of 88°58' in 1986 plots closely to the trend of area increase experienced between 1848 and 1950. This increase in area is a function of substantial sound-side accretion in recent years, partly attributed to beach nourishment with dredged material, and does not appear to represent the typical downdrift sediment-transport-related accretion recorded in earlier surveys.

47. The purpose of the volumetric and subaerial island area measurements was to estimate the littoral transport rate along the gulf shoreline at Ship Island. The net littoral transport rate at Perdido Pass, Alabama, has been estimated at 200,000 cu yd/year to the west (US Army Engineer District, Mobile 1954). This location is about 80 miles east of Ship Island, along a more exposed section of coast, where transport rates are probably higher than

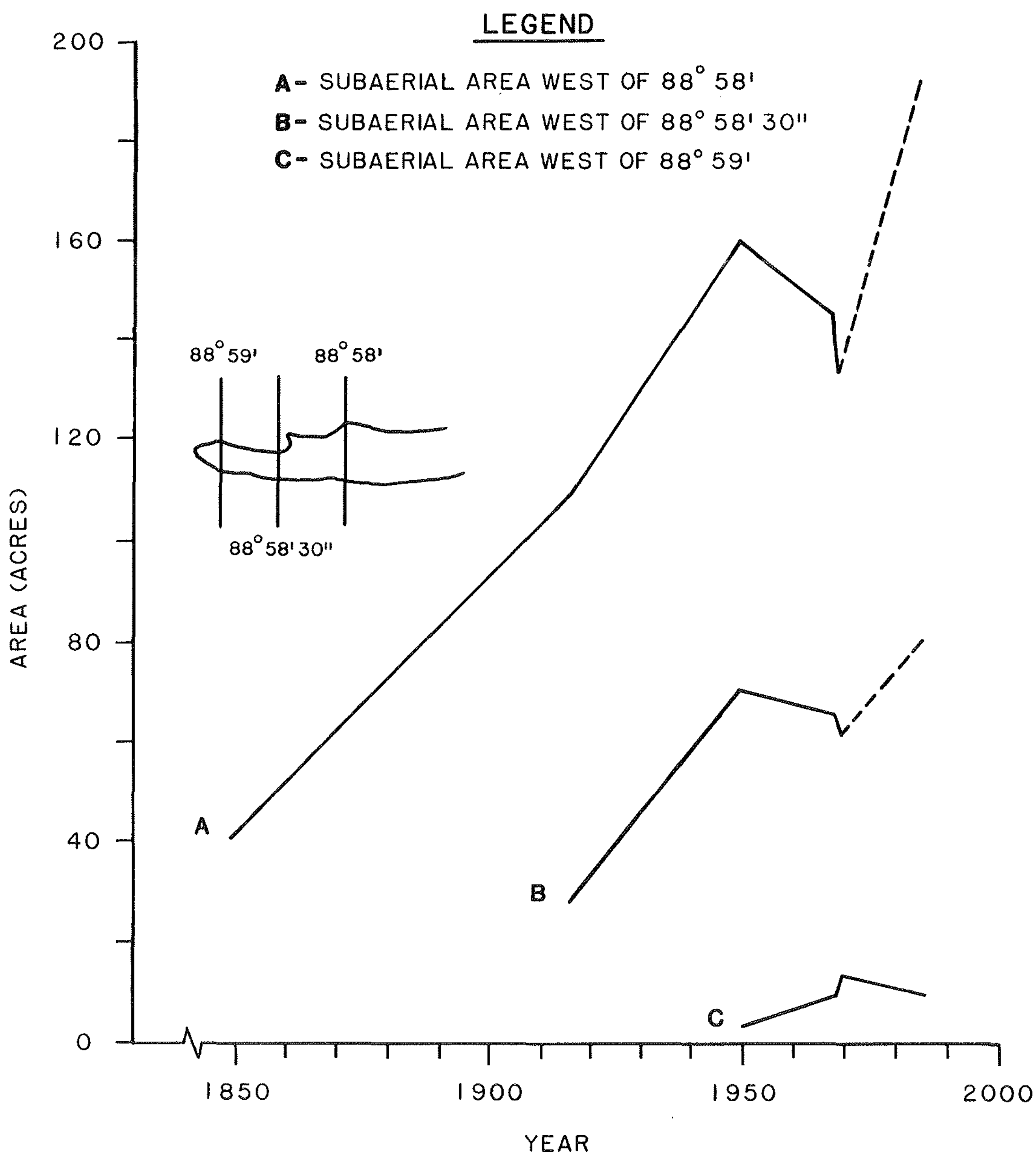

Figure 25. Area change of west point, Ship Island, 1848 to 1986

those at Ship Island. The value of 159,000 cu yd/year calculated for Ship Island appears to be a reasonable estimate of littoral transport based on comparison with the rate at Perdido Pass.

Numerical Wave Refraction and Sediment Transport Analysis

48. Wave refraction across the bathymetry seaward of Ship Island and resulting sediment transport rates on the gulf shoreline were predicted using the Regional Coastal Processes Numerical Modeling System (RCPWAVE), a linear

wave propagation model for engineering use (Ebersole, Cialone, and Prater 1985). The purposes of this phase of the study were: (a) to determine the extent and nature of wave refraction across the study area; (b) to predict the historical variation in total potential sediment transport rates; and (c) to predict the alongshore variation in magnitude of potential sediment transport along the length of the island.

49. RCPWAVE was used in this study to predict linear wave propagation for three periods: 1848-1855, 1917, and 1967-1968. These periods were chosen because of corresponding extensive bathymetric coverage seaward of Ship Island, although the 1967-1968 data lacked coverage of some offshore areas. Data from the 1917 survey were used to fill in these gaps. RCPWAVE predicts wave height, angle, breaker index, and wave number at each computational grid cell in a given bathymetric grid. For the Ship Island simulation, grid cells were chosen to be 360 × 360 ft in size, with 85 to 115 cells in the onshore/offshore direction (depending on the extent of data coverage for a particular period), and 204 cells in the alongshore direction. The bathymetric and shoreline data grid systems generated with CPS-1 earlier in the study were rotated 17 deg to make the offshore depth contours roughly parallel to the alongshore grid axis. Input for the model includes (a) number and size of the grid cells; (b) height, period, and angle of the deepwater waves to be run in the model; and (c) bathymetry at every node of the finite difference grid.

50. Five wave conditions representing a typical year of Gulf of Mexico waves were run in the model. The wave data were statistically reduced from a 20-year summary of WIS data at Gulf of Mexico station 26 in approximately 85 ft of water. The WIS data indicated that northerly wave approach occurred 40 percent of a typical year; therefore, the five wave conditions used in the model were assumed to occur only 60 percent of a year (Table 6). The wave

Table 6

Equally Weighted Deepwater Wave Conditions Used in RCPWAVE*

Wave Condition No.	Significant Height, ft	Peak Period sec	Peak Angle deg
1	5.7	7.1	43.0 E
2	3.8	4.0	30.0 E
3	2.5	5.6	23.0 E
4	2.7	4.0	8.0 E
5	2.7	4.0	-21.0 W

* Occur 60 percent of a year.

angles in Table 6 are relative to the alongshore grid axis. An angle of zero indicates a wave crest approaching parallel to the grid axis; positive wave angles indicate wave crests approaching from the east; and negative wave angles indicate wave crests approaching from the west.

51. The extent and nature of wave refraction within the study area were qualitatively observed using a plot of wave height and angle (wave ray) at each computational grid cell. Because refraction was not noticeable for most of the representative wave conditions, the wave condition with the most significant refraction, wave condition No. 1, has been presented for the 1848-1855, 1917, and 1967-1968 bathymetries in Figures 26, 27, and 28, respectively. In all three figures $H_o = 5.7$ ft, $T = 7.15$, and $\theta_o = 43$ deg. These refraction diagrams should represent the "worst case" wave refraction for the typical wave conditions considered. Wave rays are not plotted after waves have broken.

52. The figures indicate that, in general, refraction on the gulf side of Ship Island does not result in any significant focusing of the waves on a particular area for any period considered. However, wave heights appear to be largest in the vicinity of the asterisks for the 1848-1855 and 1917 periods. There are significant changes in wave height and angles at the eastern side of each plot in the vicinity of Little Dog Keys Pass. These changes probably result because of the large changes in depth over a small distance. The 1968 plot shows a decrease in wave height in the present ship channel, which is probably because of the increase in depth as the waves propagate over the channel. Generally, it appears as if wave focusing due to refraction should not be a serious consideration for channel location.

53. Variation in the rate of potential sediment transport through time was evaluated at Ship Island by using estimated breaker heights and angles in Equations 4-39 and 4-49 from the Shore Protection Manual (SPM) (1984). These equations predict potential sediment transport, i.e., the quantity of sediment that could be transported if an infinite supply of sediment were available. The breaker heights and angles were estimated by using RCPWAVE-predicted heights and angles one cell offshore from breaking. The waves were then "marched" shoreward until the breaking height-to-water-depth ratio was reached (SPM equation 2-72a). Breaking angles were estimated using Snell's Law (SPM equation 2-78a). The dimensionless coefficient K used in SPM equation 4-49 which relates the longshore energy flux factor to the immersed weight

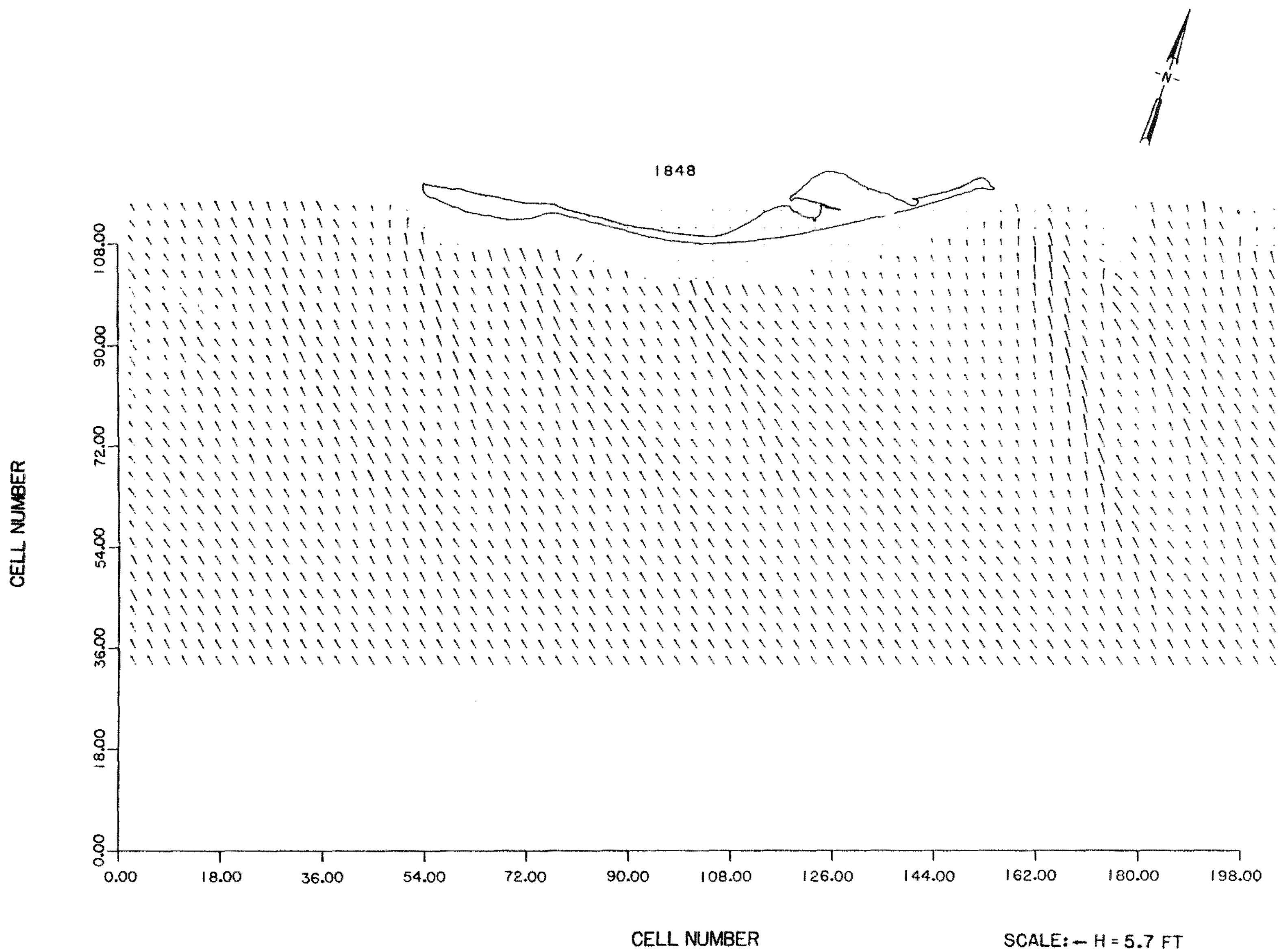

Figure 26. Wave ray distribution at Ship Island, 1949-1955

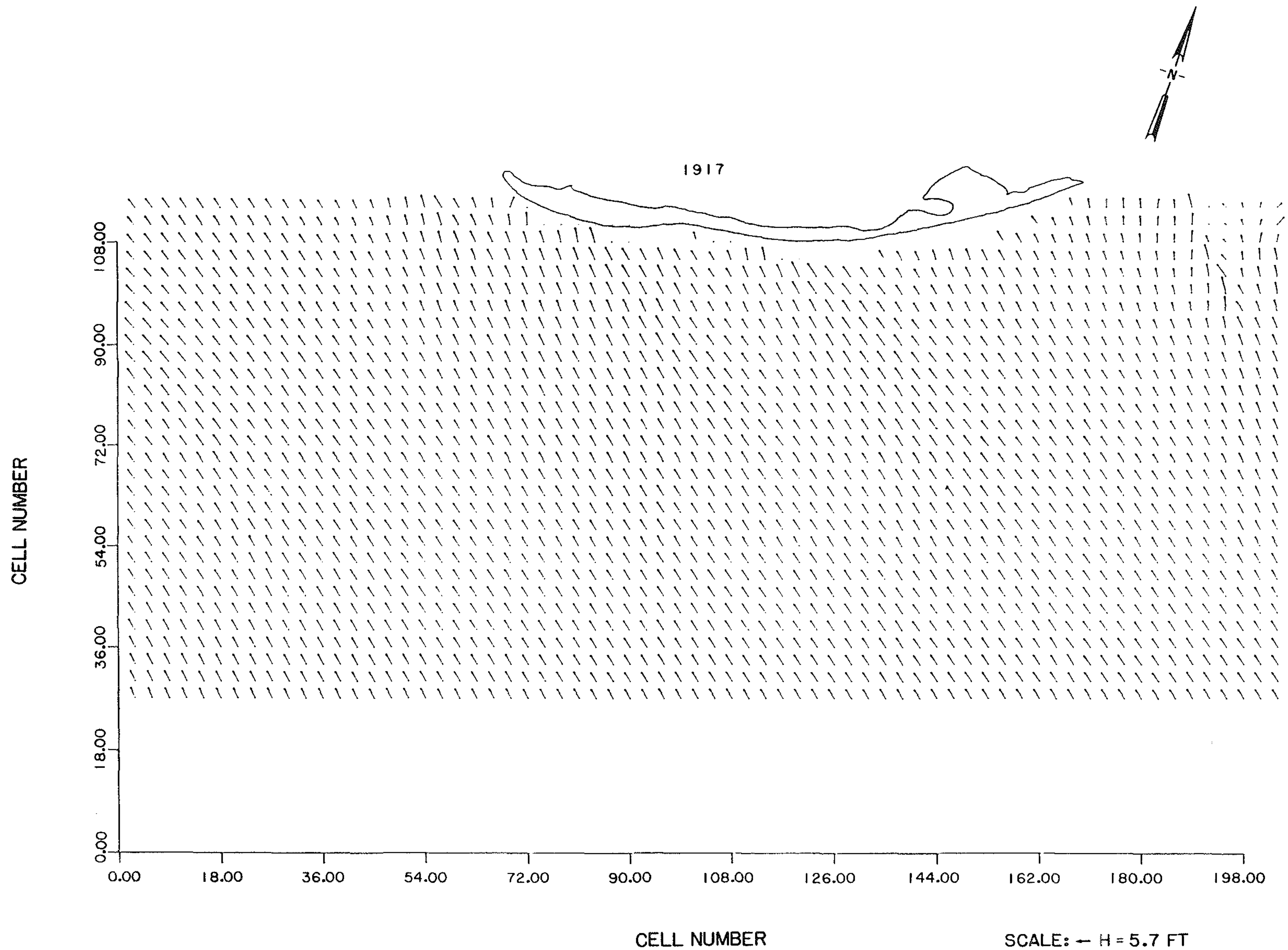

Figure 27. Wave ray distribution at Ship Island, 1917

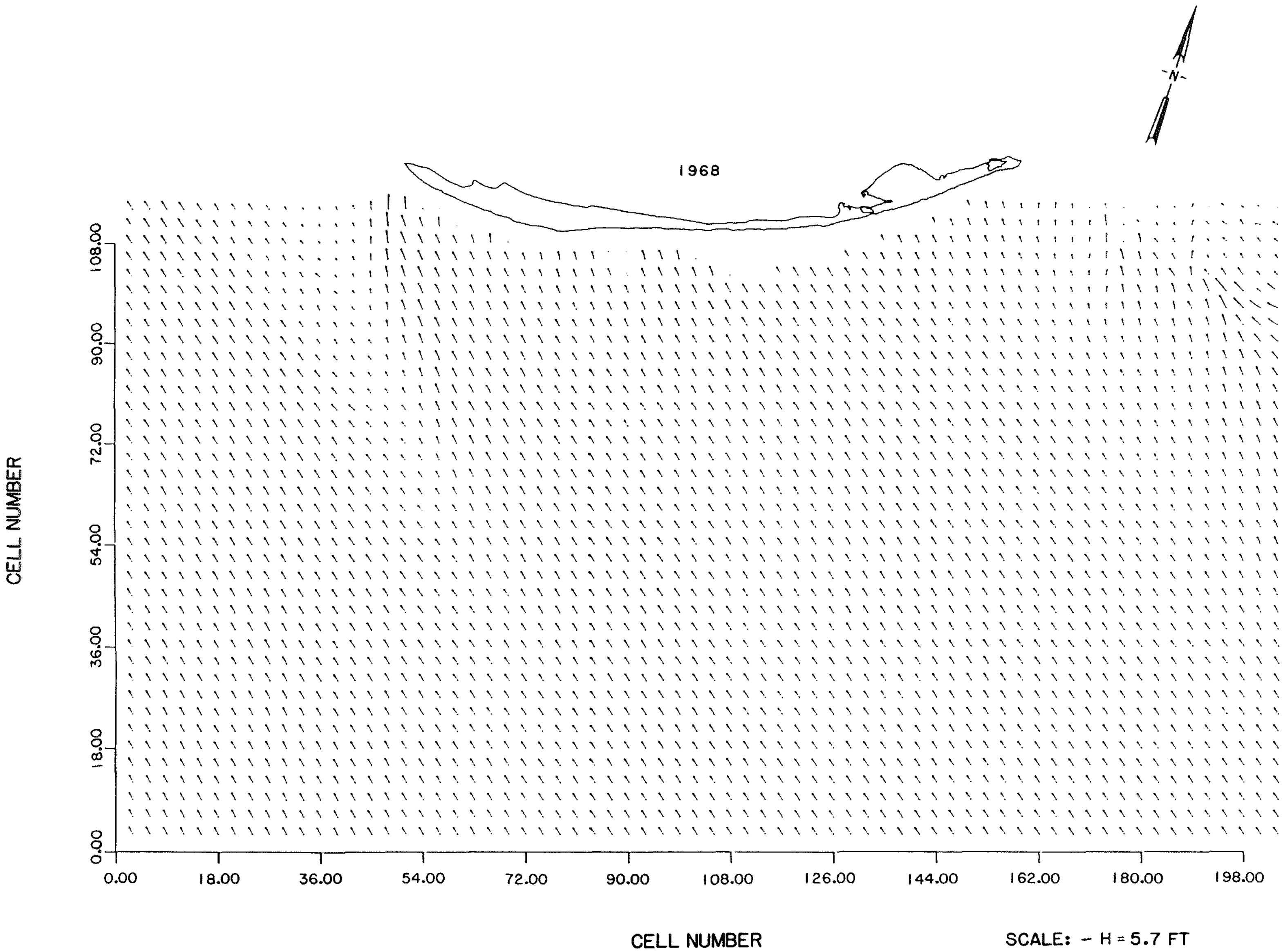

Figure 28. Wave ray dsitribution at Ship Island, 1967-1968

transport rate of sediment was empirically calculated from field data. The coefficient K was calculated for Ship Island using the littoral transport rate estimated from volume changes for the 1848-1855 to 1917 period. A calculation of sound transport rates using wave heights and angles from Mississippi Sound station 14 (Jensen 1983) and linear wave theory indicated that quantities of potential sediment transport calculated for the sound side were minimal in comparison with gulf-side quantities. Therefore, it was assumed that the shoaling rate for 1848-1917 (159,000 cu yd/year) primarily represented transport along the western gulf shoreline of Ship Island. By using the predicted transport values for the five westernmost cells along the Ship Island shoreline, the constant K was found to be K = 0.0277 , much lower than the SPM-suggested value of K = 0.39 . The low value of K is probably because RCPWAVE, using linear wave theory, does not incorporate frictional losses as incoming waves refract and shoal; therefore, predicted breaking wave heights and angles are larger than would naturally occur. The values of sediment transport for each wave condition and period are presented in Table 7. The average potential transport rate for each period along the entire gulf shoreline of Ship Island is presented in the bottom row of Table 7. The higher potential sediment transport along the west tip of Ship Island is most likely due to the sharp angle of the shoreline relative to the dominant wave approach angle.

Table 7

Predicted Potential Sediment Transport Rates*

Wave Condition No.	Transport Rate for Indicated Period 1848-1855	1917	1967-1968
1	313,000	374,000	339,000
2	86,000	98,000	95,000
3	32,000	33,000	31,000
4	13,000	14,000	10,000
5	-29,000	-32,000	-34,000
Average Q	83,000	97,000	88,000

* Adjusted for 40 percent calm period per year; measurements in cubic yards per year.

54. The predicted sediment transport rates indicate that there may have been an overall slight increase in potential sediment transport through time. However, this increase is slight and within the accuracy of the model, bathymetry, wave data used in the model, and equations used to predict the rate.

55. Variation and magnitude of potential sediment transport along the length of Ship Island were calculated and plotted for each period (Figure 29). The 1968 shoreline has been drawn at the top of the figure for reference. Several characteristics of each period are illustrated: sediment transport along the island for each period peaks in the center of the island, with lower transport rates at the western end and lowest rates at the eastern end. Reversal in direction of sediment transport occurred at the east end of Ship Island during 1848-1855 and 1917. The central peak in transport indicates a tendency for wave energy to be highest at the center of the island, which most likely contributed to the formation of Camille Cut during Hurricane Camille. Potential sediment transport rates along the western end of the island appear to have decreased from 1848-1855 to 1967-1968 (Figure 29). This decrease may be due to increased protection from wave approach as the island migrated westward. However, the 1967-1968 data set was incomplete, and there are many assumptions regarding numerical estimation of potential sediment transport. The temporal trends of potential sediment transport estimated with RCPWAVE and the value estimated from volumetric analysis indicate a range of littoral sediment transport at the western tip of Ship Island from approximately 122,000 to 159,000 cu yd/year. An average of these two values, 140,000 cu yd/year will be used for additional analyses in this study.

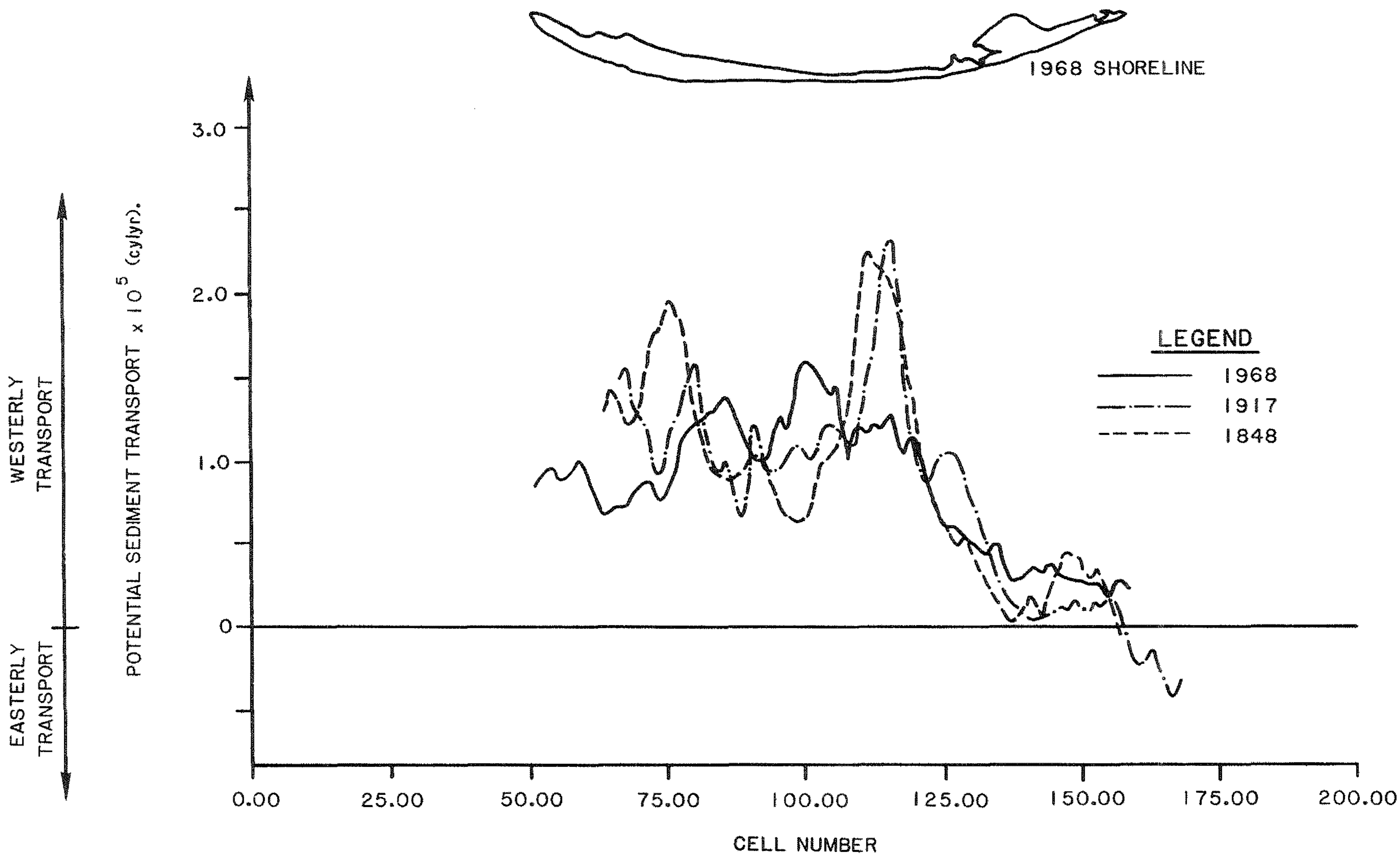

Figure 29. Potential sediment transport distribution along Ship Island; 1848-1855, 1917, and 1967-1968

PART VI: CHANNEL ALIGNMENT EVALUATION

56. Proposed improvements to the Gulfport Harbor Ship Channel authorized for study involve widening the entrance channel through Ship Island Bar to 400 ft and across Mississippi Sound to 300 ft. The channel across the open gulf and entrance area would be deepened to 38 ft. Within the sound the channel would be deepened to 36 ft. The principal goal of this study is to determine the relationships between littoral transport at Ship Island and several possible channel alignment configurations. Five general alignments selected for study have characteristics which address the problems associated with the westward migration of Ship Island.

57. Three alignments extend from the present bend in the entrance channel at the edge of the Ship Island Pass outer bar (markers "13" and "14") to a point approximately 1,900 ft west of the -30 ft contour adjacent to the island tip. The west end of Ship Island is expected to migrate 1,900 ft west during the next 50 years, based on the long-term trend of 38 ft/year (Figure 21). Each of these three alternatives would therefore delay channel shoaling problems associated with island migration for approximately 50 years. Uncertainties associated with the subaqueous island development indicate a possible range of 30-63 years. The first of these three alignments, "A," continues at a constant bearing until intersection with the original channel alignment farther north (Figure 30). Alignment "B" follows the same path as "A" until a point west of Ship Island, where it changes bearing to due north, until intersection with the original channel alignment (Figure 31). The third of these westerly diverted alignments, "C," also extends to the same point 1,900 ft west of Ship Island, but it changes to a northeasterly bearing until intersection with the original channel alignment (Figure 32). Alignment "C" incorporates the westward channel diversion while utilizing as much of the existing channel alignment as possible, requiring a minimum amount of new dredging.

58. The original alignment of the Gulfport Ship Channel was also analyzed and designated as alignment "D" (Figure 33). This alignment would effectively straighten the channel bend caused by migration of Ship Island. Furthermore, it would take advantage of the existing length of channel already dredged but would involve extensive construction dredging adjacent to the west tip of West Ship Island, as well as high annual maintenance dredging

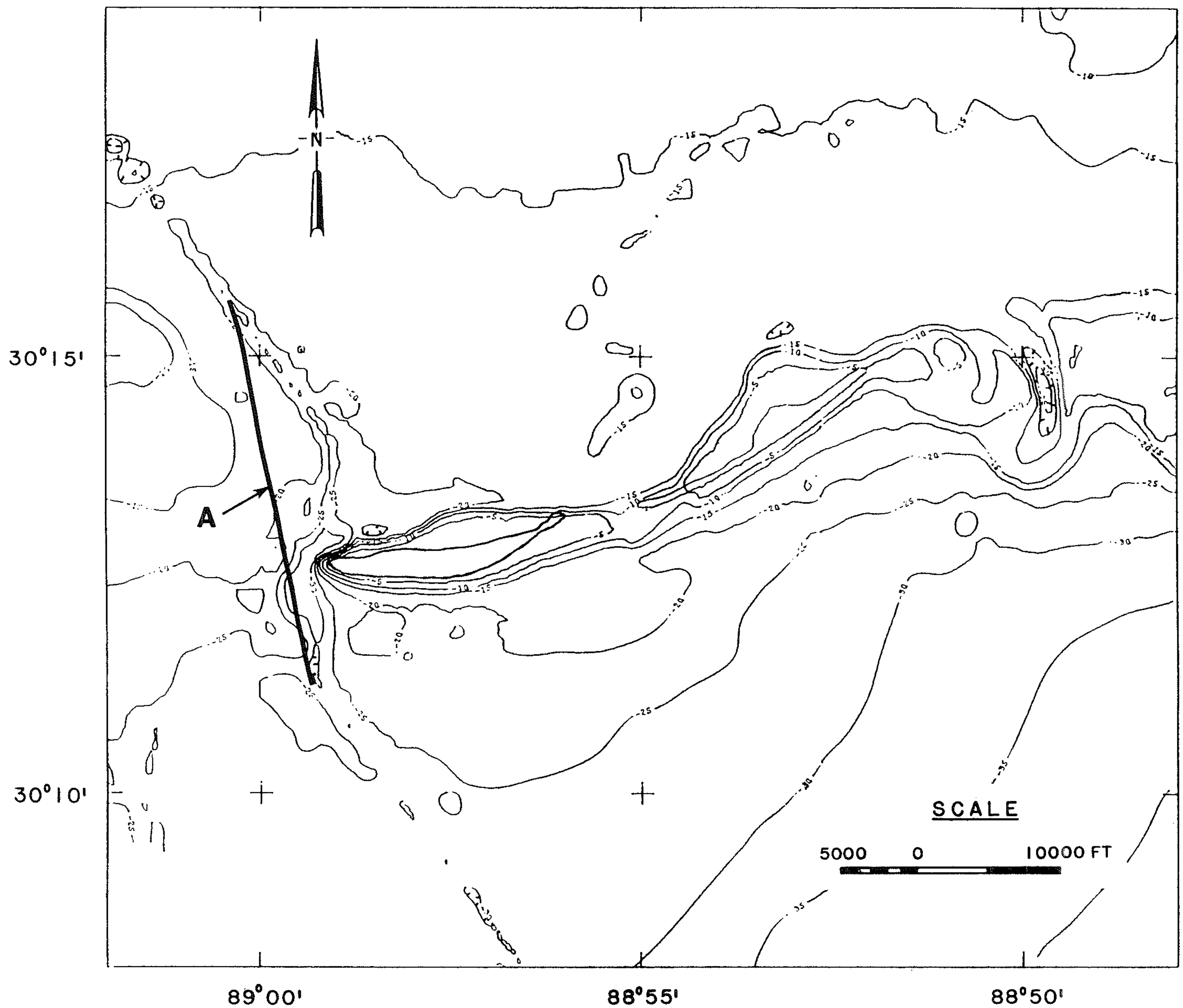

Figure 30. Channel alignment configuration "A"

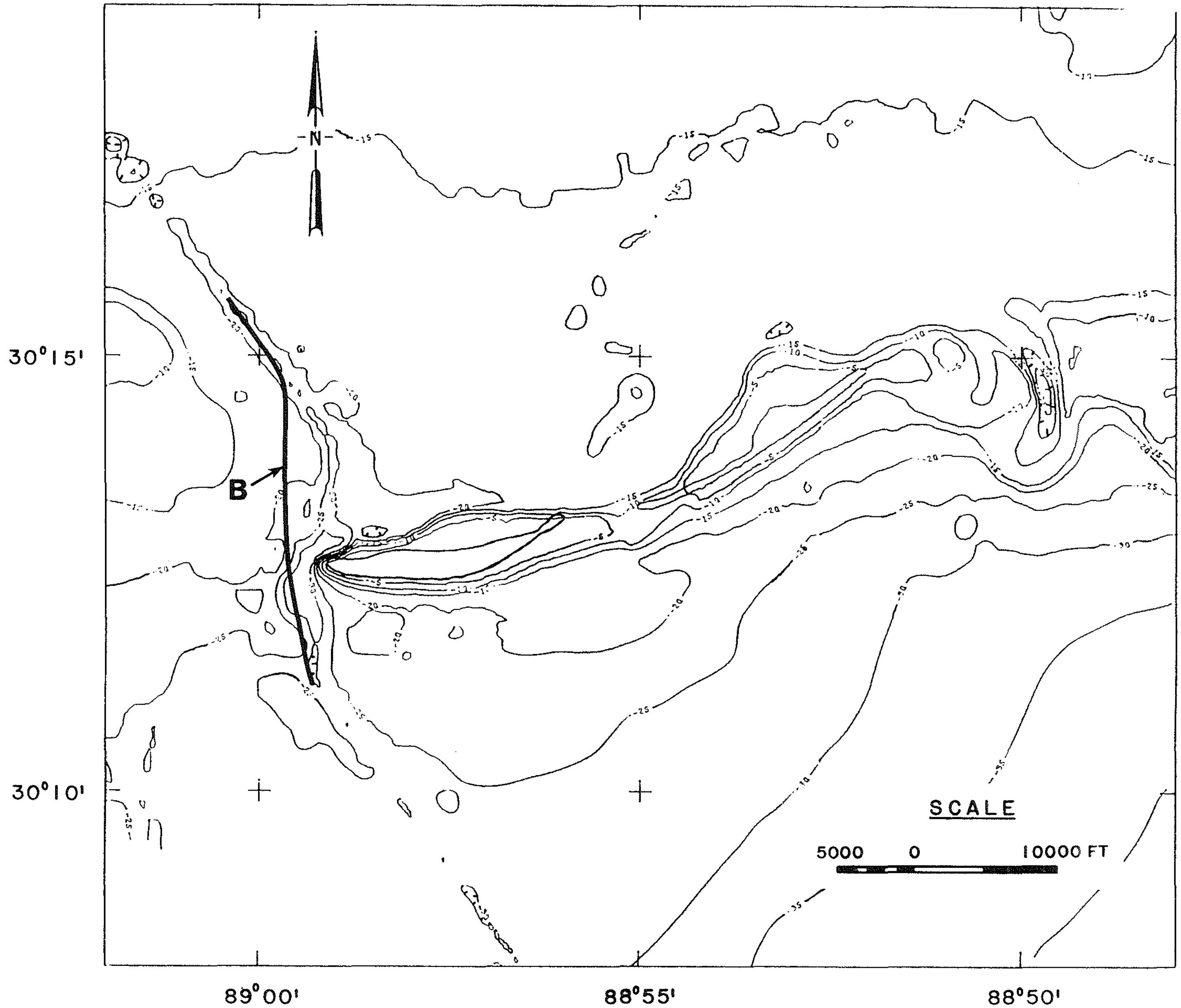

Figure 31. Channel alignment configuration "B"

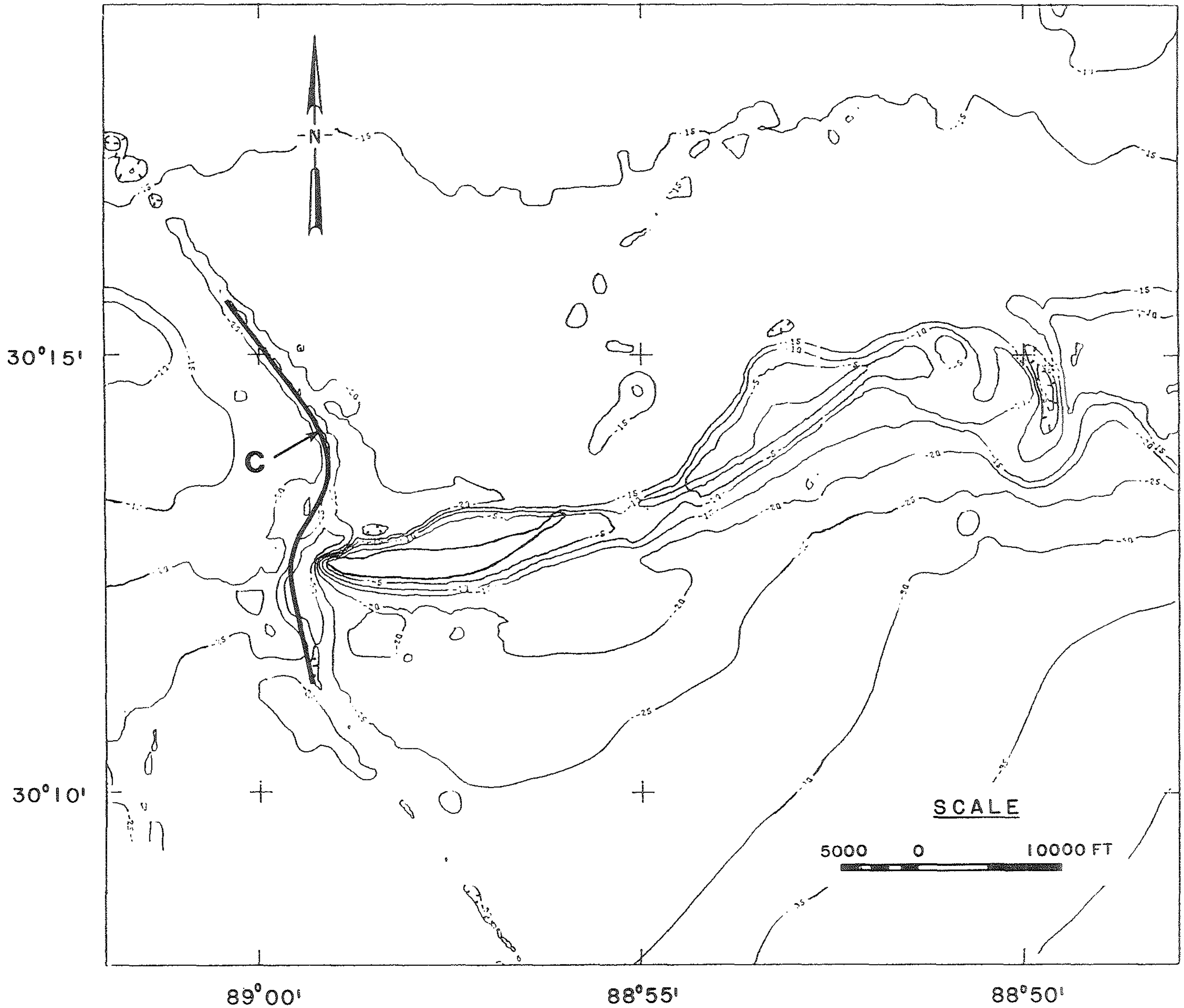

Figure 32. Channel alignment configuration "C"

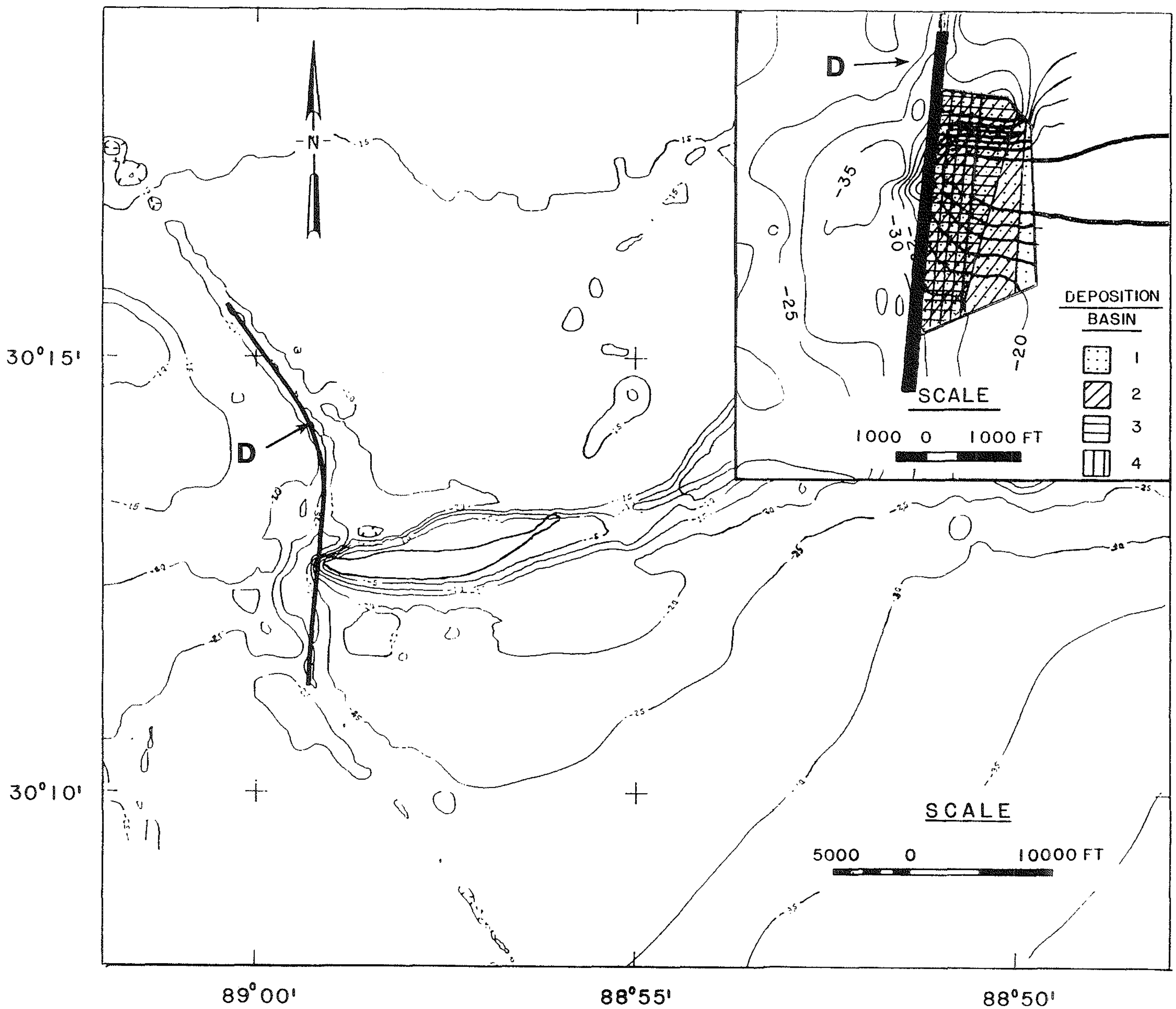

Figure 33. Channel alignment configuration "D" and deposition basin configurations 1-4

associated with the migration of Ship Island.

59. A fifth channel alignment was analyzed to assist in determining the feasibility of relocating the ship channel across Mississippi Sound behind Ship Island, and out into the Gulf of Mexico through Camille Cut (Figure 34). This alignment would require the most construction dredging, but it could possibly be justified if long-term maintenance dredging associated with the island migration could be avoided.

Dredge Volume Analysis

60. Dredge volumes necessary to construct each of the five channel configurations were calculated through the use of the CPS-1 software. The 1986 hydrographic survey conducted by SAM was used as the base level for dredge volume estimates, except for alignment "E," where a composite bathymetric grid of 1986, 1970, 1968, and 1917 data was used. This composite was necessary because the 1986 survey did not cover many areas in which alignment "E" would be constructed. One-on-four side slopes were included with the project channel widths and depths. Criteria from EM 1110-2-1613 (USACE 1983) were used to determine channel widths at turns, based on a design vessel with a 100-ft beam and one-way traffic. The five channel configurations should not be considered engineering designs. They are approximations of channel layouts for construction volume comparisons only. Actual channel design would need to consider also detailed navigability and environmental aspects which were beyond the scope of this study. Additionally, dredge volumes would depend on precise, final design specifications and up-to-date bathymetry.

61. Table 8 summarizes the construction dredging volumes estimated for each channel configuration. Alignments "A" and "B" are very similar in total area and volume of dredging. The bend in "B" to a northerly bearing increases the overall channel area, but because the distance required to intersect the original channel alignment is less, total construction dredging requirements are less than for alignment "A" (Figures 30 and 31). Although alignment "C" requires the greatest area of dredging of the three westerly realignments, the least volume of construction dredging is required due to intersection with the original channel (Figure 32).

62. Alignment "D" involves the least amount of construction dredging, but it does not prevent or delay shoaling due to island migration. A

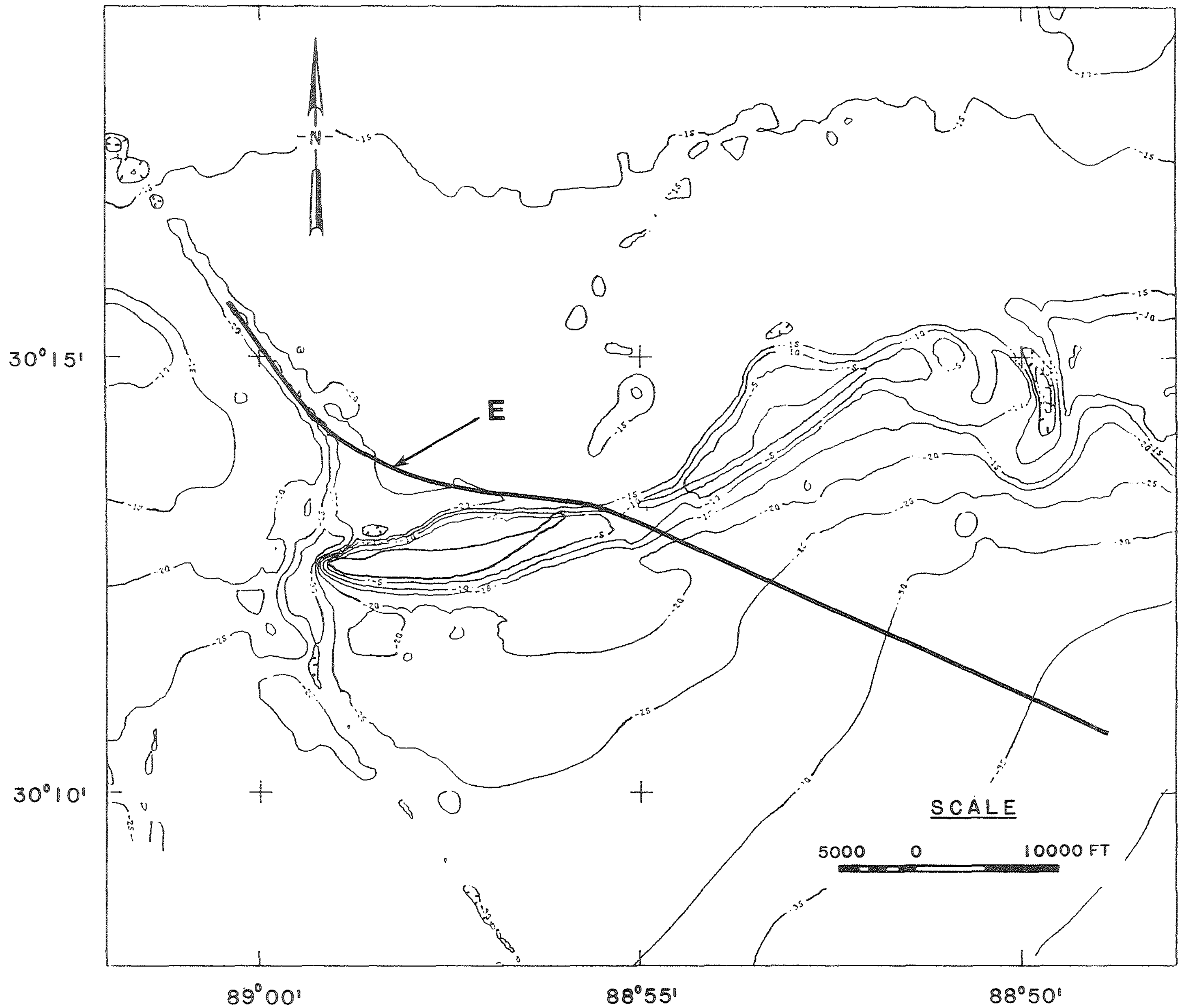

Figure 34. Channel alignment configuration "E"

Table 8

Construction Dredging Requirements for Five Channel Configurations

Channel Configuration	Area 1,000 sq yd	Construction Dredge Volume 1,000 cu yd
A	1,076	5,419
B	1,125	4,623
C	1,273	3,924
D	1,176	3,475
E	2,517	12,352

deposition basin would have to be constructed in association with alignment "D" to prevent or reduce shoaling interference with the use of the navigation channel (Figure 33). Other options which might reduce the shoaling rate include structures such as groins or jetties, a sand bypassing system, or a combination of techniques.

63. Construction of the fifth channel alignment, "E," would involve dredging over 12 million cubic yards of material, due to extensive channel construction across shallow, native bottom areas (Figure 34) (Table 6). This configuration would require construction dredging greater than twice the amount estimated for configuration "A."

Deposition Basin Analysis

64. Although channel alignment "D" (Figure 33) would require the least amount of construction dredging (Table 8), a deposition basin would probably be required to trap littoral material transported from Ship Island. Four deposition basin configurations have been analyzed, ranging from 236 to 102 acres in area (Figure 33). Estimated dredging volumes for construction of these deposition basins are contained in Table 9.

65. Three basin depths (-25, -20, and -15 ft) were analyzed for each configuration, with additional volumetric calculations for configuration #4 at depths of -30 and -35 ft. Side slopes of 1:6 are included with each estimated dredge volume. Side slopes were increased from 1:4 to 1:6 to account for greater anticipated slope instability associated with unconsolidated sand at the edge of the island. The actual boundaries of the basin configurations

Table 9

Deposition Basin Construction Dredging Requirements

Basin	Area acres	Dredge Volumes, 1,000 cu yd*				
		35 ft	30 ft	25 ft	20 ft	15 ft
1	236			5,200	3,665	2,403
2	210			4,428	3,115	2,043
3	149			2,932	2,078	1,349
4	102	3,885	2,877	1,766	1,193	722

* Dredge volumes are to indicated depths.

would extend several dozen yards beyond the boundaries illustrated in Figure 33 due to side slope construction. All four deposition basin configurations are adjacent to channel alignment "D" and would involve dredging upland areas.

66. Basin configuration #1 (Figure 29a) extends across Ship Island approximately connecting the -15 ft contours on the gulf and sound sides. The eastern boundary of basin #1 is approximately 2,000 ft east of channel alignment "D" (Figure 33). Basin configurations #2 and #3 approximately connect -20 and -25 ft contours, respectively, resulting in smaller basin areas (Figure 33b,c). Basin configuration #4 is parallel and functionally similar to a widening of channel alignment "D" (Figure 33d) in the vicinity of the west island tip.

67. The amount of estimated construction dredging shows a close correlation to the basin sizes and depths, except where deeper depths are proposed. At greater depths, the percent of basin below the average bottom depth greatly increases, resulting in a sharp increase in dredging requirements. Basin configuration #4 shows a slightly better ratio of effective volume (the total volume within the confines of the basin) to required construction dredging volume than other configurations. The more favorable ratio of effective volume to required contruction volume of basin #4 is due to a greater initial average water depth than the other configurations. As with the channel alignment analysis, these deposition basin configurations are not engineering designs but examples of possible plans for comparative purposes. Actual dredging volumes would depend on specific design criteria and acquisition of up-to-date bathymetric and topographic data.

Cost and Benefit Factors

68. Economic, engineering, and environmental factors should be considered when comparing the costs and benefits of each channel alignment. Some qualitative analysis of the navigational characteristics of each alignment was also performed. However, environmental analysis was not within the scope of this study.

Economic

69. For the purpose of this study, estimated dredging volumes associated with each alignment configuration are principally used to compare alignments economically. Total dredging volumes associated with each alignment include initial construction dredging volumes plus estimated annual maintenance requirements. Alignment "D" is the most economical in terms of initial construction dredging volume requirements. However, because "D" is adjacent to Ship Island, a provision for significant annual maintenance dredging of littoral material (140,000 cu yd/year) must be included through construction of a deposition basin. This additional construction dredging volume would make the total amount of construction dredging required for alignment "D" greater than for "A," "B," and "C."

Engineering

70. Information regarding coastal processes and geomorphic history of the Ship Island area should also be considered when comparing the assets and liabilities of each channel alignment configuration. The migration of Ship Island is the principal process to consider. Alignments "A," "B," and "C" will not be affected by this process for an estimated 50 years, due to their positions 1,900 ft west of Ship Island. Alignment "D" would use a deposition basin to deal with the problem immediately, with periodic maintenance dredging as the basin fills. Alignment "E" would avoid the problem through realignment to the east but would probably experience similar problems in the vicinity of Camille Cut.

71. Additional shoaling problems could result from location of alignments "A," "B," and "C" away from the main tidal channel, although the 1,900-ft westward shift would not put these alignments entirely out of the realm of stronger tidal currents associated with Ship Island Pass. Ship channel relocation to the west may also capture some of the tidal flow, resulting in natural scouring of the channel bottom. Greater problems could

result from inability to predict the behavior of a deposition basin constructed in association with alignment "D," especially if considered without a control structure.

72. Sediment storage capacities and trapping efficiencies of the basin configurations are difficult to estimate. Certainly a basin would not fill uniformly across the entire basin area. Significant quantities of sediment could bypass a basin and still deposit in the navigation channel. The only effective way to predict the future performance of any basin configuration and associated structure would involve a monitoring program during the first few years after construction. Even with such a program, side-slope adjustments and short-term events such as storms could limit use of survey data for predicting long-term deposition basin behavior. The passage of a major hurricane could have significant effect upon a deposition basin. The volumetric change which occurred at the end of ship island between 1968 and 1970 revealed that 238,000 cu yd of material was removed, presumably during Hurricane Camille. Although this storm removed sediment from the channel area, a different set of storm characteristics could result in comparable amounts of material being deposited within the channel or an associated deposition basin.

73. Shoaling effects due to slope failure at channel bends may be a factor to consider. Changes in flow patterns in the vicinity of bends may also cause increased shoaling. Alignment "C" would have the greatest potential for increased shoaling, due to its inclusion of several sharp bends. Alignment "E" would also have a high possibility for this problem due to its many bends. Alignments "B" and "D" contain about the same degree of bends and are therefore approximately equal in this comparison. Alignment "A" has the least number and angle of bends and would probably experience the least amount of shoaling due to flow interruption and slope failure.

Other factors

74. Navigability is another factor which should be addressed prior to selecting a channel alignment. Although a detailed analysis of navigability was beyond the scope of this study, the relative navigability of the five channel configurations could be assessed. In general, navigability decreases as the number of channel bends and channel curvature increases. Alignment "A" is the straightest channel and would presumably be the most navigable, followed by "D," "B," "E," and "C."

75. Ease of design and construction may also help select an appropriate

alignment. The simplest channel configuration would also be the easiest to construct, if other factors are equal. Alignment "D" would probably be fairly simple to design and construct due to its position within the present alignment. However, the deposition basin is a critical factor, which causes the overall design and construction associated with "D" to be the most complicated of the five. Design and construction of alignment "E" would be relatively more complicated because it is a completely new alignment requiring extensive dredging.

76. Table 10 summarizes comparative economic and engineering characteristics of each channel alignment. Economic characterization is based on construction and maintenance dredging volumes required for each alignment configuration. Other qualitative characteristics of the alignments are ranked in relation to each other.

Table 10

Economic and Engineering Characteristics of Five Proposed Ship Channel Alignments

Alignment	Dredging, 1,000 cu yd: Total Construction	Dredging, 1,000 cu yd: Annual Maintenance (Littoral Material)	Siltation	Navigability	Complexity of Design and Construction
A	5,400	0*	Moderate	High	Low
B	4,600	0*	Moderate	Moderate	Low
C	3,900	0*	Moderate	Low	Moderate
D	3,500	140	Low-Moderate	Moderate	High
E	12,400	>140**	High	Moderate	High

* Realignment west of Ship Island will delay littoral shoaling for approximately 50 years; however, some littoral shoaling could still occur in alignments "A"-"D" in the vicinity of Ship Island Pass outer bar.

** The littoral shoaling problem would be higher due to higher wave energy at the entrance to Camille Cut.

PART VII: DREDGED MATERIAL DISPOSAL

77. Regardless of the final engineering designs, or chosen channel alignment, proposed improvements to the Gulfport Harbor Ship Channel will require the disposal of several million cubic yards of dredged material. Part VI of this report discussed potential disposal areas in relation to the coastal processes and geomorphic history of the study area discussed in Parts III and IV. This discussion is only a preliminary analysis of potential provisions for dredged material disposal in the Ship Island area based on general coastal processes analysis. Prior to actual disposal, a complete dredged material management and analysis study would be required. A study of this magnitude would include current and wave field analysis, environmental assessment, and engineering/geotechnical investigations.

78. Dredging conducted in the immediate vicinity of Ship Island will probably involve significant quantities of sand-sized material, compatible with the beaches of Ship Island. Beneficial use of this dredged material could be made by placement on local beaches (Figure 35a). Erosion of the sound shoreline in the vicinity of Old Fort Massachusetts has been rectified in the past by placement of maintenance dredging material from the ship channel adjacent to Ship Island. Bypassing of sand-sized material to shallow-water areas west of Ship Island is also a disposal alternative (Figure 35b). Material placed in shallow water could be reworked by wave activity possibly resulting in subaerial emergence and formation of an island. Similar emergence often occurs along shoals downdrift of tidal inlets where natural bypassing occurs. These areas are favored nesting grounds for many seabird species.

79. The majority of dredged material associated with the improvement project will probably be clay, silt, or very fine sand from both new work areas and maintenance dredging. Since this material will be too fine for beach disposal, the coastal process information gathered in this study may be used to help determine potential disposal areas for the material. Detailed dredged material management and analysis would be required prior to designation of disposal sites. The regional wave refraction analysis of the present study revealed that the typically low-period wave climate of the northern Gulf of Mexico produces minimal wave refraction effects. These low-period waves have limited ability to entrain deeper water bottom sediments. Silt- and

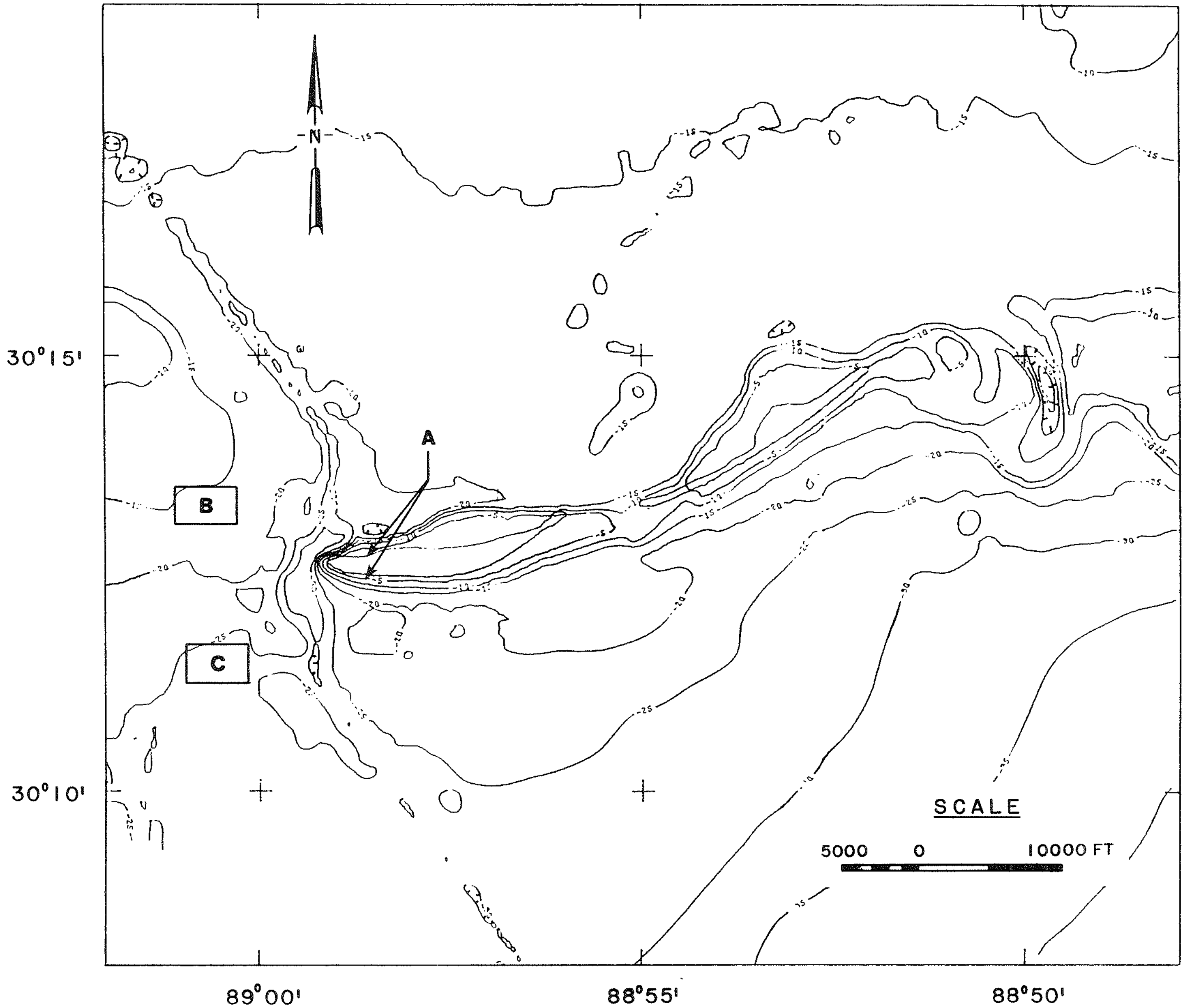

Figure 35. Locations of potential dredged material disposal sites

clay-sized dredged material would probably be fairly stable at bottom depths greater than 25 ft in this area. An embayment in the -25 ft contour west of the Ship Island outer bar (Figure 35c) may be a suitable disposal site for finer material. The location within an embayment and position northwest of a shallower water area may provide protection from southeasterly waves, the largest waves expected to approach this area.

80. The shallow-water area west of Ship Island (Figure 35b) previously discussed as a potential disposal area for sand-sized material (Figure 35b) may also serve as a potential site for finer grained material. Initial placement of the finer material could be followed by placement of sandy material, burying the silt- and clay-sized material. Over a period of time, compaction and dewatering of the finer material may occur beneath the sand. A sandy cover may be less susceptible to suspension by waves and currents.

PART VIII: SUMMARY AND CONCLUSIONS

81. Ship Island is a barrier island adjacent to Mississippi Sound, along the northern Gulf of Mexico coast of Mississippi. Severe erosion of East Ship Island is supplying sediment to a westerly littoral transport system along the gulf shoreline. This sand is transported to the west tip of West Ship Island where deposition occurs into Ship Island Pass, resulting in westward migration of the island tip, estimated at 38 ft/year. As the island tip migrates, deposition along the east side of Ship Island Pass deflects currents, causing erosion of the western channel bank and westward migration of the pass. This deposition and erosion process has been occurring since the mid-1800's and probably for several thousand years, accompanied by westward migration of the entire island. A combination of sea-level rise and limited sand availability is causing the extreme erosion of Ship Island, resulting in island area losses of 4.5 acres/year since 1848. Initial alignment of the Gulfport Harbor ship channel in 1899 was about 2,900 ft west of the west island tip at that time. However, island migration caught up with the ship channel alignment about 1950. At that time, channel shoaling due to island migration became a problem. Maintenance dredging could not keep up with the shoaling, and the ship channel gradually realigned around the migrating island tip. This study was conducted to document the coastal processes and geomorphic history of the Ship Island area. This information would then be used to assess economic and engineering aspects of several proposed ship channel alignments. Five channel alignments were evaluated.

82. Three proposed channel alignments pass 1,900 ft to the west of the present channel alignment, the projected distance of migration of Ship Island over the next 50 years. These alignments would effectively delay the littoral shoaling problem for 50 years. The fourth alignment is located along the original ship channel alignment. A deposition basin would have to be constructed with this alignment in order to deal with the littoral shoaling problem. A fifth alignment was studied to determine if relocation of the ship channel farther east would be feasible. This alignment would pass through the inlet formed by Hurricane Camille in 1969.

83. Although other factors are important in choosing one of these alignments for incorporation into the overall harbor improvement plans, the amount of dredging associated with each channel alignment will probably be the

deciding factor. The alignment passing through Camille Cut would require an excessive amount of construction dredging. The potential for increased littoral shoaling is high due to wave focusing in the inlet entrance area and westward migration of East Ship Island. Several sharp turns in one of the three westerly alignments would result in poor navigability, although the total dredging volume required would be relatively small. Continuing with the present channel alignment around the advancing western island tip is not considered an option due to navigation problems caused by the increased channel sinuosity.

84. The selection process is narrowed to two basic choices: (a) reconstruct the original alignment along with a deposition basin, or (b) relocate the ship channel farther west, delaying the shoaling problems for 50 years. Alignment even farther west would delay the littoral shoaling problems longer; however, higher construction dredging volumes would be required due to channel location in shallower water. The two westerly alignments analyzed in this study are similar, with the inclusion of an extra bend in one to reduce dredging amounts by intersection with the original alignment at a shorter distance.

85. When the dredging volume necessary for construction of a deposition basin is added to the dredging volume estimated to construct the original channel alignment, the total is similar to the western alignment volumes. However, the deposition basin constructed with the original alignment alternative would shoal with littoral material at an annual rate of approximately 140,000 cu yd/year. The amount of total shoaling that would occur in the western alignments is unknown, but it would be characterized by finer grained, suspended material and would probably be more uniformly distributed along the length of the channel. All proposed channel alignments would be subject to siltation, although siltation would be less in the vicinity of Ship Island Pass due to increased tidal currents.

86. Analysis of the geomorphic history and coastal processes at Ship Island has been effective in determining economic and engineering aspects of several proposed ship channel alignments. Some preliminary observations regarding potential dredged material disposal sites were also made based upon this information. The methods of analysis used in this study may be effectively applied for analysis of navigation plans/projects in other coastal areas.

REFERENCES

Dedrick, K. G. 1983. "Use of Early Hydrographic Surveys in Studies of California Estuaries," Coastal Zone '83, American Society of Civil Engineers, New York, pp 2294-2316.

Ebersole, B. A., Cialone, M. A., and Prater, M. D. 1985. "Regional Coastal Processes Numerical Modeling System," Technical Report CERC-85-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Eleuterius, C. K., and Beaugez, S. L. 1979. "Mississippi Sound, A Hydrographic and Climatic Atlas," Miss./Ala. Sea Grant Consortium, pub. no. MASGP-76-024, Ocean Springs, MS.

Hayes, M. O. 1978. "Impact of Hurricanes on Sedimentation in Estuaries, Bays, and Lagoons," Estuarine Interactions, M. L. Wiley, ed., Academic Press, New York, pp 323-45.

Jensen, R. E. 1983. "Mississippi Sound Wave-Hindcast Study," Technical Report HL-83-8, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Otvos, E. G. 1982. "Coastal Geology of Mississippi, Alabama, and Adjacent Louisiana Areas," Field Trip Guidebook, New Orleans Geological Society, New Orleans, LA.

Shore Protection Manual. 1984. 4th ed., 2 vols, US Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, US Government Printing Office, Washington, DC.

US Army Corps of Engineers. 1973. "Regional Report, South Atlantic-Gulf Region, Puerto Rico and the Virgin Islands," National Shoreline Study, Vol III, US 93rd Congress, 1st session, House Document 93-121.

__________. 1983. "Hydraulic Design of Deep-Draft Navigation Projects," Engineer Manual EM 1110-2-1613, Washington, DC.

US Army Engineer District, Mobile. 1954. "Beach Erosion Control Report, Cooperative Study of Perdido Pass, Alabama," Mobile, AL.

US Army Engineer District, Mobile. 1984. "Mississippi Sound and Adjacent Areas: Dredged Material Disposal Study, Feasibility Report," Vols I, II, and III, Mobile, AL.

Waller, T. H., and Malbrough, L. P. 1976. "Temporal Changes in the Offshore Islands of Mississippi," Water Resources Institute, Mississippi State University, Mississippi State, MS.