15404

W.P.

BEACH EROSION IN SOUTH CAROLINA

Miles O. Hayes, Thomas F. Moslow
and
Dennis K. Hubbard

South Carolina Coastal Council

BEACH EROSION IN SOUTH CAROLINA

Miles O. Hayes[1], Thomas F. Moslow[1]
and
Dennis K. Hubbard[2]

Preparation of this document was financed in part through grant assistance from the U. S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Coastal Zone Management, Grant No. 04-7-158-44141, pursuant to Public Law 92-583.

[1] Coastal Research Division
Department of Geology
University of South Carolina
Columbia, S. C. 29208

[2] West Indies Laboratory
Farleigh Dickinson University
Christiansted, St. Croix
U.S. Virgin Islands, 00820

TABLE OF CONTENTS

SYNOPSIS

A characterization of beach erosion trends along South Carolina's shoreline has been based on beach profiles, beach processes and erosional-depositional history. Four coastal types have been identified: 1) arcuate strand, 2) cuspate delta, 3) beach-ridge barrier, and 4) transgressive barrier. The arcuate strand extends from the North Carolina border to Winyah Bay and is characterized by a stable, continuous beach, broken by few tidal inlets. This area has eroded to the extent that the modern beach presently rests against beach ridges dated at 100,000 years old. The cuspate delta, lying between Winyah Bay and Bulls Bay, contains a cuspate foreland, Cape Romain, which is characterized by an eroding headland, elongating spits on the flanks of the headland, and an overall erosional nature. Beach-ridge barrier islands, which comprise the bulk of the central and southern portions of the coast, are composed of vegetated beach ridges. Transgressive barrier island areas (Morris Island, Edingsville Beach and Bay Point), which are characterized by straight beaches, are rapidly retreating landward through a washover mechanism. Charts dating back to 1779 show evidence of beach ridges in some areas which have since eroded away.

These studies have lead to the following conclusions:

1) Erosion rates along the South Carolina coast are typically 10 inches (30 cm) to 3 feet (1 m) per year.

2) The area north of Winyah Bay is generally stable due to the nature of the underlying sediments.

3) The rest of the coast exhibits varying degrees of instability depending on the character of the backshore area and the size and occurrence of tidal inlets. Areas backed by well-developed beach ridges characteristically have lower short-term erosion rates than those where such features are absent.

4) Beach-ridge barriers longer than approximately 6 miles (9 km) are composed of unstable, bulbous updrift ends, stable or accretional central

portions, and progradational downdrift ends, which give the islands a drumstick-like shape. Beach-ridge barriers shorter than approximately 6 miles (9 km) show large and sporadic changes along their entire length in response to changes in neighboring tidal inlets.

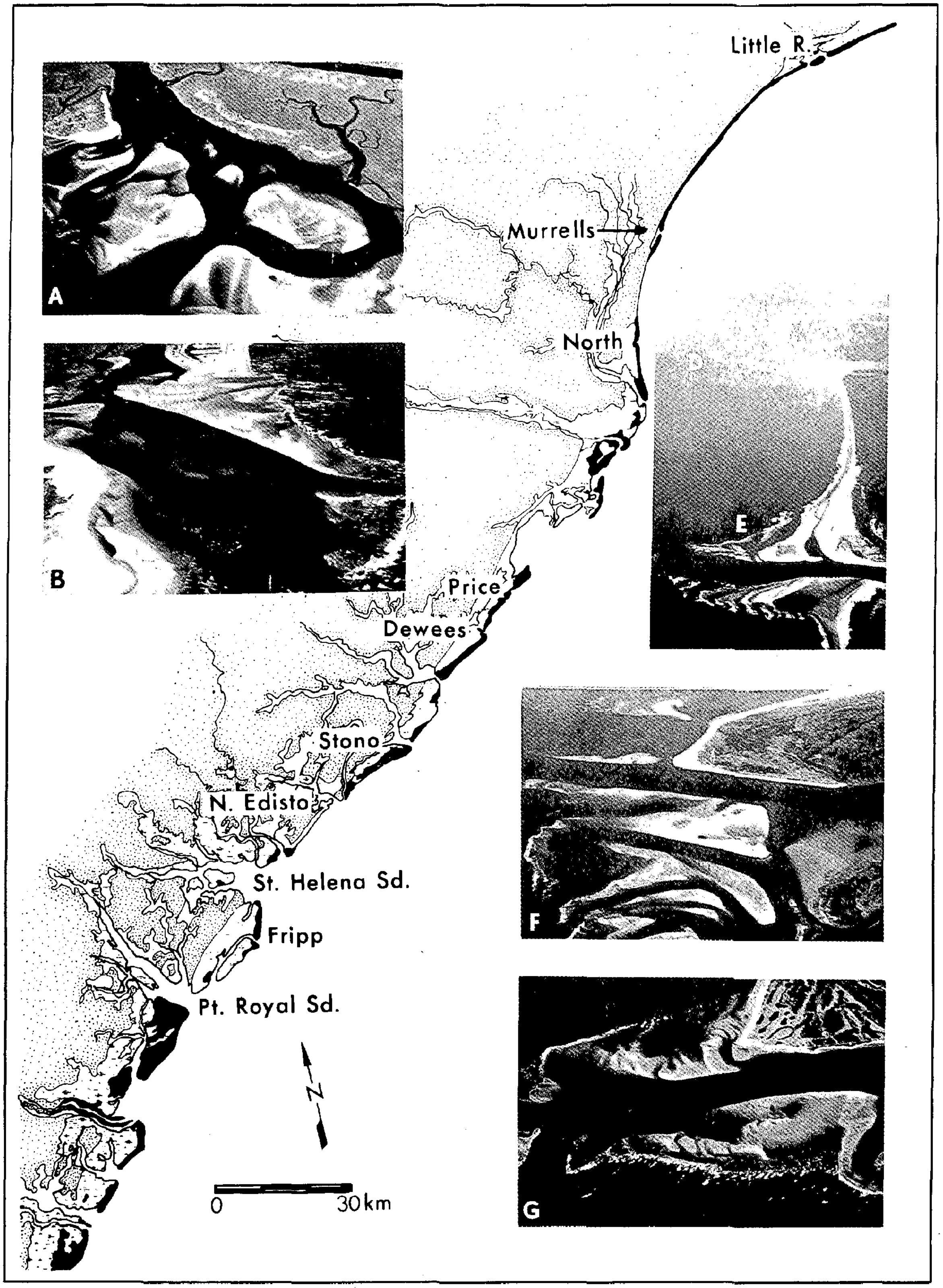


Figure 1. Location map of the South Carolina coastal zone. Those inlets shown in the insets are: A) Little River, B) Murrells, C) Dewees, D) Capers, E) Price, F) Stono, and G) Fripp. (from Hubbard and Barwis, 1977).

INTRODUCTION

Beaches and barrier islands of South Carolina comprise one of the state's most valuable natural resources (Fig. 1). The beaches are the greatest single attraction for the state's billion dollar tourism industry. In 1975 alone, more than six million vacationers stayed at lodging places and campgrounds in the coastal area, accounting for over 400 million dollars of the state's tourism revenue [35]. Therefore, it is of considerable economic interest to preserve and enhance the quality of the state's beaches. Unfortunately, many of the beach areas are threatened by severe erosion problems, some of which have been fostered by unwise construction and development techniques.

The primary goal of this report is to examine both the beach erosion trends and the dynamic processes responsible for them along the South Carolina coastline. Stable beach areas and areas of critical erosion are identified on the basis of studies of historical charts and maps, vertical aerial photographs and systematic measurements of shoreline changes carried out over a three-year period at over 70 field stations. Limits for set-back lines, which define areas suitable or unsuitable for development, are defined in a general way from the erosion-deposition graphs presented. The data are presented in a format that should be of use to state and federal agencies, developers, homeowners, and groups interested in the environment of the state. However, some caution should be exercised in using the graphs and tables as the sole means for making development decisions. In many locations, site-specific studies should be carried out by experts in coastal processes and engineering before final decisions are made regarding treatment of the erosion problem.

Climate

South Carolina's climate is mild, with an average temperature for the coastal region of 65°F, ranging from 50°F in December to 81°F in July.

The coastal plain, which makes up 40% of the state, receives an average of 46.5 inches of precipitation annually [26]. An average of 1.4 hurricanes and tropical storms affect South Carolina's coast annually, although none have occurred for many years[4].

On an annual scale, no predominant direction of wind approach is apparent along South Carolina's coast (Fig. 2). However, seasonal trends can be seen. During the spring and summer, winds from the south and southwest prevail; whereas, in the fall and winter, most winds come from northerly directions.[40] Shipboard wind and wave observations were used to derive wind and wave frequency distributions for the Charleston area (Fig. 3). Wave energy values (fluxes) show the same seasonal trends as the wind.

Waves

Wind-produced waves are the most dominant natural force affecting erosional-depositional trends along the coastal zone. The longer and stronger the wind blows (duration) and the greater the distance over which it blows (fetch), the larger and more powerful the waves will be. During storms, wave energy can carry beach sands seaward and damage or carry away man-made structures. During calm periods, waves move offshore sand onto the beaches, building them up.

Longshore Transport

The most important currents affecting shoreline changes are longshore currents. These are produced by waves that strike the coast at an oblique angle and run parallel to the shoreline. Longshore currents vary in velocity and direction with wave angle and wave energy. The combined forces of longshore currents and wave action result in the movement of large volumes of sand parallel to the coast. This is referred to as longshore transport.

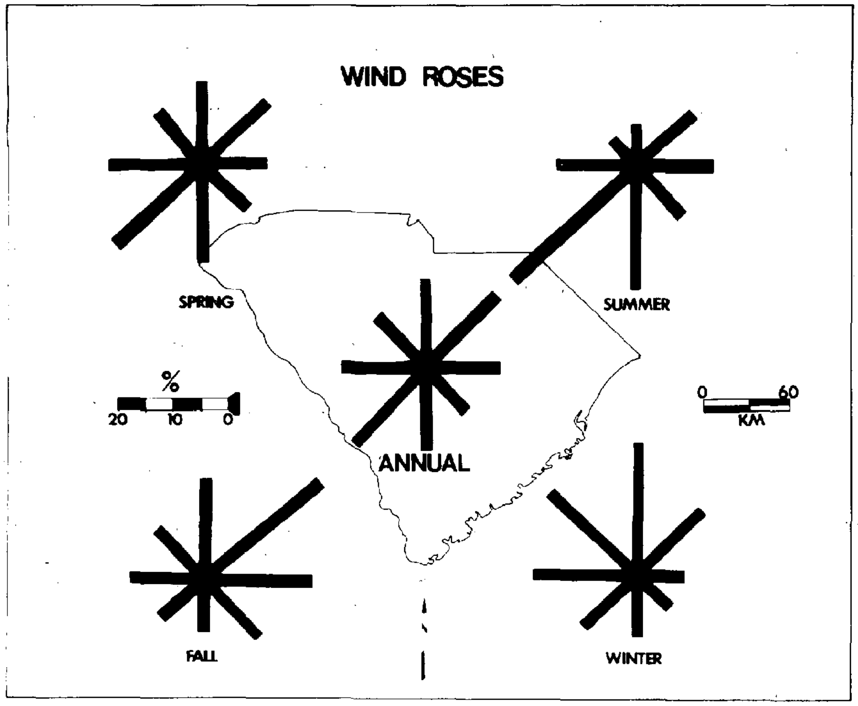


Figure 2. Seasonal and annual wind roses for the South Carolina coast. (from Brown, 1977).

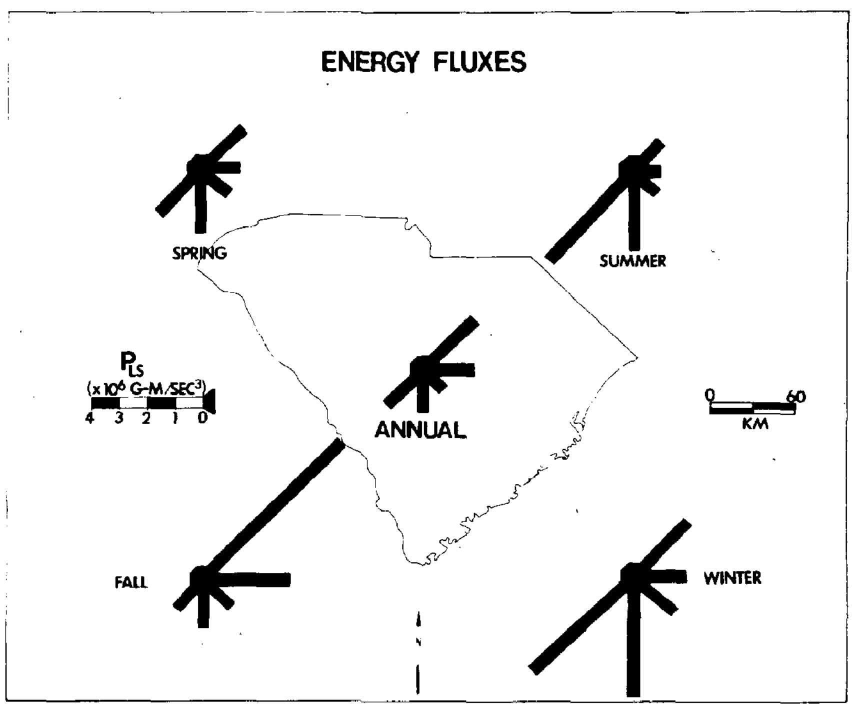


Figure 3. Seasonal and annual wave energy values for alongshore and onshore winds in the Charleston area. The length of any bar is a relative measure of the wave energy coming from that direction (from Brown, 1977).

Along the South Carolina coast, the dominant direction of longshore transport is to the south. The directions and rates of longshore transport for the central South Carolina coast are given in Figure 4.

When sediment is scarce, longshore transport will carry sand away from the beaches, causing erosion. However, this sand may eventually be deposited on beaches downdrift by natural processes or man-made structures, or it may also be carried seaward and deposited offshore.

Tides

The fluctuation of daily tides along the South Carolina coast can be a big factor in shoreline erosion. This is especially true when storms pile up tide levels, resulting in the flooding of low areas along the coast. Tide-produced currents are especially strong at harbor entrances or at inlets to lagoons or bays. Flood tides can sweep sediments from the longshore transport system into a bay or tidal marsh area. Ebb-tidal currents, which are more dominant along the South Carolina coast, can deposit sediments at the mouths of inlets or add material to the longshore transport of sediments. During hurricanes and storms, coastal areas which are normally safeguarded from wave attack may undergo severe wave erosion if the storm comes at high tide. [30]

South Carolina has a mixed wave and tidal energy coast with tidal influence increasing to the south. Mean tidal range shows a gradual increase from North Carolina to Georgia (Fig. 5). Mean tidal range at the North Carolina-South Carolina border is 5 ft. (150 cm) compared to 6.5 ft. (200 cm) along the southern coast. This change is largely controlled by nearshore bathymetry and the general shape of the coastline.

The increase in tidal range from north to south and the resulting increase in tidal prism has several effects on the South Carolina coastline: 1) Tidal inlets become more frequent and are larger to accommodate greater tidal flow; 2) Salt marshes are more extensive; and 3) The ebb-tidal deltas

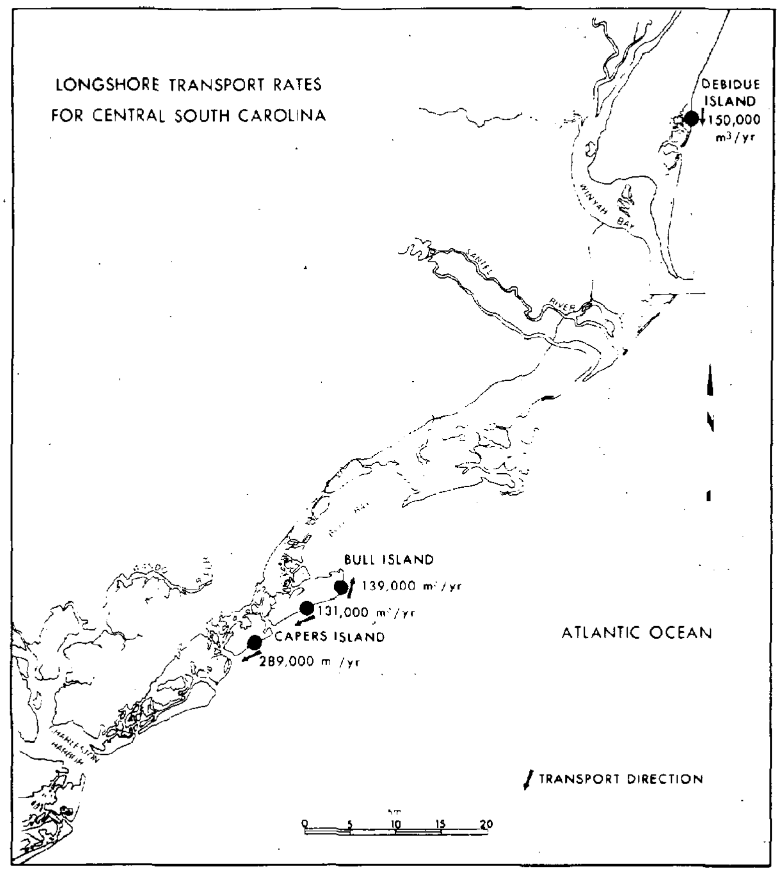


Figure 4. Location map and longshore transport rates for the central South Carolina coast. (from Kana and Knoth, 1977).

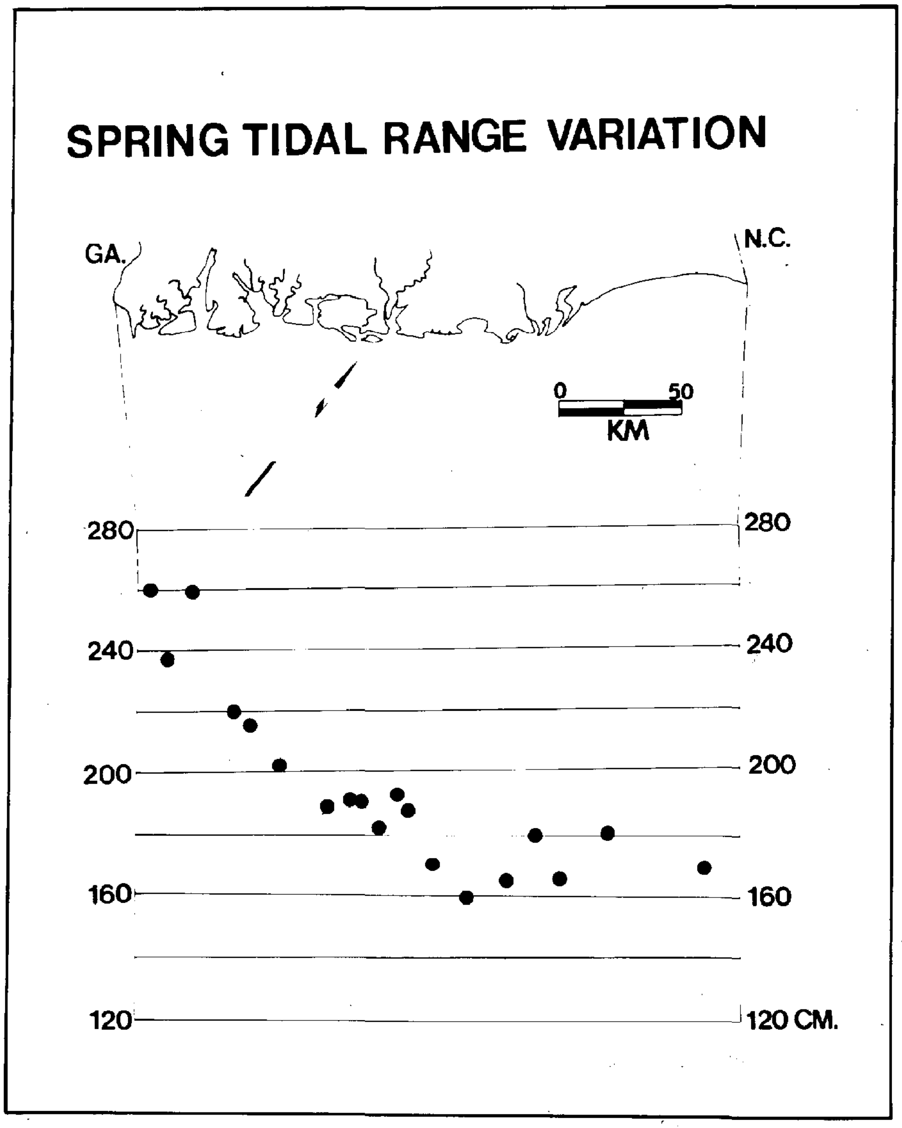


Figure 5. Spring tidal range variation along the shoreline of South Carolina. Note increase in southerly direction. (from Brown, 1977).

become much larger off the inlets and estuaries in the southern portions of the state [2].

GENERAL COASTAL MORPHOLOGY

The morphology of the South Carolina coast is a transition between that of North Carolina and Georgia. North Carolina's coast is predominantly made up of long, thin barrier islands broken up by a few tidal inlets. The morphology of the North Carolina coast is controlled mainly by wind-generated waves and currents. Georgia's coast is comprised of short, stubby barriers separated by many large tidal inlets, typical of tidal-current-controlled coasts [11]. The morphology of the South Carolina coast is dominated by a mixture of the wind-generated and tidal-generated forces.

On the basis of geomorphology, the South Carolina coast is classified into the arcuate strand, cuspate delta and barrier island zones. The barrier island zone is further divided into islands that have beach ridges (beach-ridge barriers) and those that have no beach ridges (transgressive barriers) (Fig. 6). Each of these four divisions has its own characteristic sediment type, bathymetry and erosional-depositional history.

Arcuate Strand

The arcuate strand (Fig. 6) forms a gentle crescent between the North Carolina border and Winyah Bay, a distance of approximately 60 miles (100 km). Few tidal inlets breach the coast in the northern section, but the number of inlets increases south toward Winyah Bay. Inlet size also increases southward. This portion of the coast is normally backed by a well-developed dune system. Salt marshes are poorly developed or totally absent in the north and central portions of the strand, but become more prominent in the southern section. This section of coastline appears generally stable with the exception of the areas in the vicinity of tidal inlets.

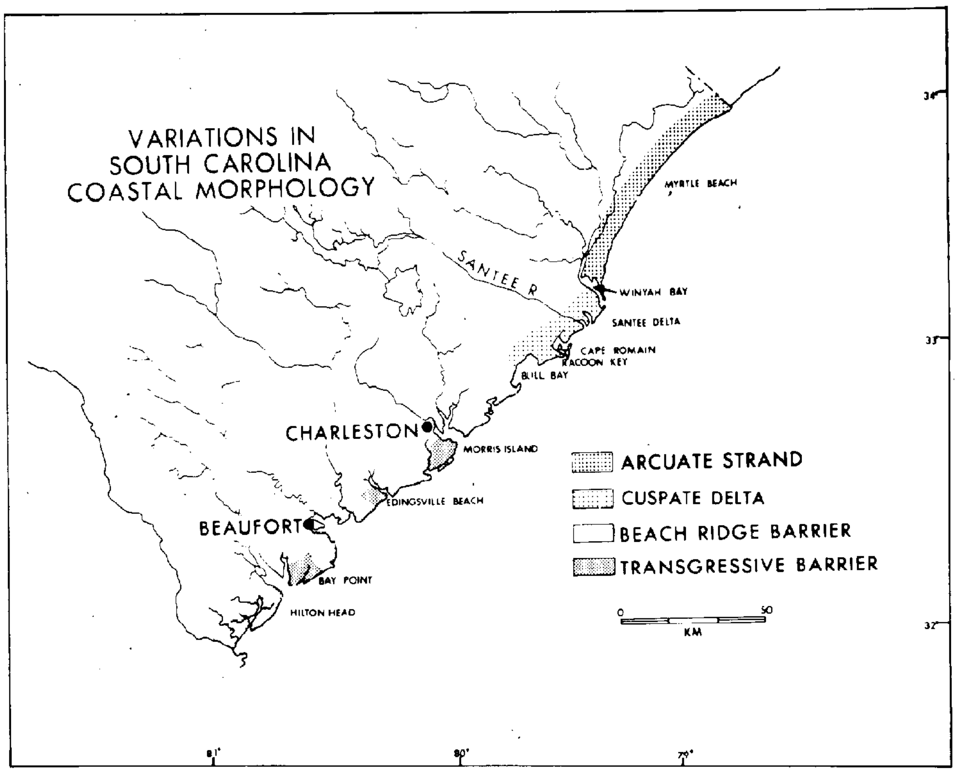


Figure 6. Map of the South Carolina coast showing the four major morphologic zones. (from Brown, 1977).

The shoreline owes its stability to the barrier sands of the Myrtle Beach Formation which formed before the Wisconsin glacial period, approximately 100, 000 years ago [21]. The present shoreline configuration generally parallels the orientation of these resistant relict beach ridges.

Cuspate Delta

The Santee River Delta, which extends 18.5 miles (30 km) along the South Carolina coast, is the largest deltaic complex on the east coast of the U. S. It is classified as a wave-dominated cuspate delta [33]. The shoreline components of the delta include: 1) a cuspate foreland, Cape Romain; 2) an eroding beach-barrier complex, Raccoon Key; and 3) distributary mouth sand bars and mud flats. The lower delta plain is presently covered by salt marsh. The sand which comprises the delta was originally supplied by the Santee River. Subsequent erosion by predominantly northeast storm waves has given the Cape its characteristic shape (Fig. 7). Erosion of the cape headland has caused its northern flank to change orientation dramatically during the past century, shifting from N-S in 1886 to its present NNE-SSW orientation. Since 1886, the northern arm of the cape has elongated approximately 1.1 mile (1.8 km), while the westward arm grew a length of 2.3 miles (3.7 km) [34]. The washover terraces and truncated beach ridges along the shoreline of the delta attest to its rapid retreat. Erosion of the Santee delta complex has been related to the decreased sediment supply after damming of the Santee River in 1942 [1]. Prior to the 1930's, the delta was in a stable or constructional phase. After that, the delta entered a destructive phase which presently continues. Sequential vertical aerial photographs reveal that, in some cases, over 615 ft. (215 m) of erosion has occurred since 1941 along Cape Romain [37]. Along Raccoon Key, to the south, erosion of up to 900 ft. (275 m) was noted at some localities. The proposed rediversion of the fresh water discharge back into the Santee River is expected to have little beneficial effect as most of the sand-sized material

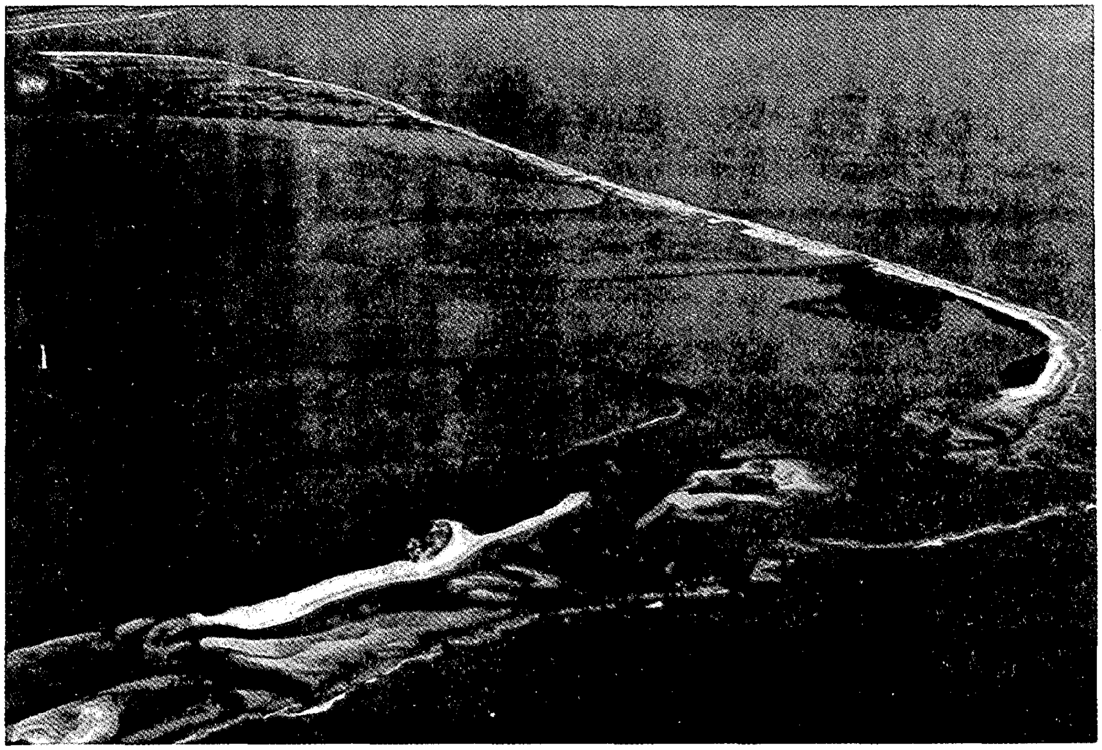


Figure 7. Oblique aerial view of Cape Romain (photo taken October 1974). (Brown, 1977)

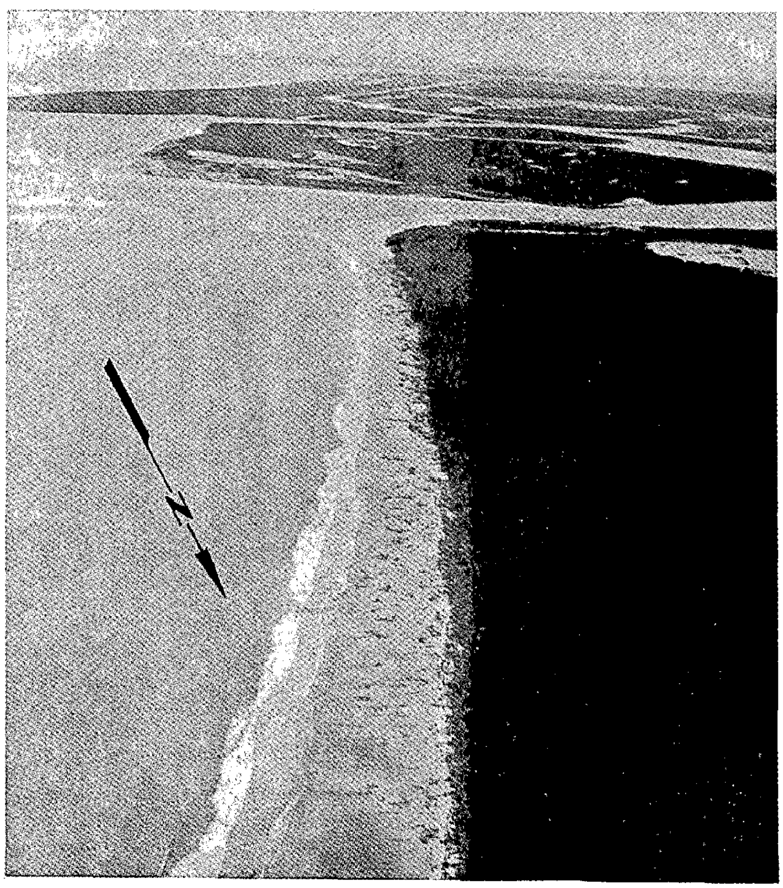


Figure 8. Oblique southerly aerial view of a series of beach-ridge barrier islands. Capers Island is in the foreground. Photo taken in February 1975 (from Brown, 1977).

will still be retained by upstream dams.

Barrier Islands

Between Bull Bay and the Georgia border, a distance of approximately 100 miles (160 km), a series of barrier islands front the coast. They average about 4.5 miles (7 km) in length and are separated from the shoreline by a zone of salt marsh which generally increases in width toward the south. Numerous tidal inlets separate the islands. These islands are of two types, beach-ridge barriers and transgressive (erosional) barriers.

Beach-ridge barriers comprise the majority of the central and southern portions of the South Carolina coast. These areas are characterized by extensive beach ridges, formed as the shoreline prograded. These ridges act as partial buffers to erosion; barriers with beach ridges generally show less variability than do those without ridges (Fig. 8). The morphology of these barriers is greatly affected by the adjacent tidal inlets. Wave refraction and storm protection afforded by the ebb-tidal delta can cause accretion on the adjacent beach, resulting in a bulbous updrift end of the island [12]. The larger barriers often exhibit a straight to crescentic central portion and a downdrift end which elongates and progrades through the formation of recurved spits. In areas where the barriers are shorter (Capers Island, Dewees Island) or the inlets much larger (Hilton Head Is.), this pattern becomes more complex. Migration of the inlets can further extend their influence.

Transgressive barrier shorelines are of lower relief and exhibit typically higher rates of erosion. They are characteristically straight and are a thin veneer of sand which retreats landward as a succession of washovers. Sequential charts and aerial photographs show that transgressive barriers can be the erosional end-product of beach-ridge barriers. Historic coastal charts of Morris Island and Edingsville Beach show that beach ridges existed in 1779. Lacking the local relief and storm protection provided by dunes and beach ridges, transgressive barriers are presently changing at an extremely rapid rate. Erosion rates of up to 50 ft. (15 m)/yr. have been documented at Morris Island [37]. Evidence of such rapid rates of erosion can be observed in the outcropping of marsh peat along some of the transgressive barrier beaches.

Nearshore Bathymetry

There is a significant change in bathymetry along South Carolina's coast. North of Winyah Bay, typical profiles are concave and very steep in the nearshore. South of Winyah Bay, the influx of fluvial sediments and the storage of sand in ebb-tidal delta complexes causes a decrease in nearshore slope, although the overall slope to a depth of 50 ft. (15 m) is very uniform along the entire coast (.5 ft./mi.). The area off Cape Romain has the most irregular bathymetry due to the presence of cape-associated shoals. Bathymetry in the barrier island portion of the coast is governed by proximity to tidal inlets. No appreciable difference is apparent in the bathymetry between beach-ridge and transgressive barriers.

Characteristics of South Carolina Beach Sand

When sand grain size and sorting parameters are plotted on a state-wide basis, three distinct groupings can be seen, corresponding to the arcuate strand, cuspate delta and barrier island zones. It is felt that the sediment types reflect three different sources of beach material. There is presently no direct source of fluvial sediments on the arcuate strand, although several rivers emptied into the ocean in this area during the relatively recent geologic past [21]. While some sediment is being transported alongshore into the area, most beach sands on the arcuate strand are apparently derived from ancient deposits lying directly behind the shore, as the area continues to erode. Sediment samples from the arcuate strand show a wide range of size and sorting values.

The cuspate delta area sediments are supplied by the Santee River, and since the cuspate delta lies near its fluvial source, sediment samples from the area are generally coarser than those found elsewhere on the coast. Due to proximity to their source, the sediments are "immature", showing a wide range of size and sorting values.

The barrier islands of the central and southern portions of the coast are farther removed from their fluvial sediment sources and are presently receiving very little sand. Sediments from this area have undergone a great deal of reworking and, hence, are much better sorted than sediments to the north. Due to lower wave energy in the area (and the constant reworking), the sediments are significantly finer than those to the north. These fine-grained sands pack very well, providing a hard pavement over which most motor vehicles can easily drive.

COASTAL PROCESSES AND BEACH EROSION

Beach Erosion - An Overview

The erosion or accretion of any coastline is ultimately controlled by the natural forces responsible for the movement of wind and water along the beach and in the nearshore zone. Under the action of nearshore currents, waves or winds, sediments are moved on, off and along the beaches. This mass transport of sand on the coast results in the net erosion or accretion of a particular segment of the coastline. [14]

The erosion occurring along South Carolina's beaches is not unique to this area. It has been estimated that there exists an average U.S. shoreline erosion rate, due to natural causes (wave energy, gradual sea-level rise, etc.), of between 1 ft. (30 cm) and 3 ft. (1 m) per year [5]. The National Shoreline Study, conducted by the U.S. Army Corps of Engineers, concluded that there are 20,000 miles (32,000 km) of eroding shoreline in the United States, nearly 3,000 (4,800 km) of which are classified as critically eroding areas (Table 1). These are areas where an erosion abatement program would be justified for "economic reasons". According to their figures, nearly 43% of the coastline of the U.S. is undergoing significant erosion. To consider the causes of erosion on South Carolina beaches, it is necessary to understand some of the basic causes of beach erosion in general. For purposes of communication, let us first consider some terminology. A typical beach is shown diagramatically in Figure 9. This diagram appeared in the U.S. Army, Corps of Engineers' Shore Protection Manual and was intended to represent a cross-section of "typical" U.S. beaches. Anyone who has visited the South Carolina coast, however, should be quick to realize that this does not look like many of the beaches in South Carolina.

However, Fig. 10 shows beach profiles that more adequately represent South Carolina beaches even though they were measured on the Massachusetts coast. In general, South Carolina beaches are wider and lower than many other beaches in the U.S. This is primarily related to the large tidal range and the fine grain size of the beach sands along the South Carolina coast. The upper profile in Fig. 10 is the more frequently occurring constructional type. The two lower ones display a more mature profile (10 September 1967) and the same station after a brief summer storm (22 June 1967). Figure 11 displays four beach profiles that are representative of the morphologic provinces along the South Carolina coast. Those profiles representing the more erosive portions of the coast, the transgressive barrier (D) and cuspate delta (B) have steep beach faces, probably because of the coarseness of the beach sediment. Profile C is a beach-ridge barrier (Fig. 11) and resembles the constructional beach profile at the top of Figure 10, reflecting the barrier's depositional nature. The representative profile of the arcuate strand (Fig. 11A) is concave upward, which is typical of an erosional type beach profile.

Table 1 Shoreline Characteristics

	Shoreline			Shore Change		Shoreline	
Region	Total (miles)	Exposed (miles)	Sheltered (miles)	Eroding (miles)	Non-Eroding (miles)	With Beach (miles)	Without Beach (miles)
North Atlantic	8,620	4,730	3,890	7,460	1,160	2,320	6,300
South Atlantic-Gulf	14,620	2,470	12,150,	2,820	11,800	3,600	11,020
Lower Mississippi	1,940	810	1,130	1,580	360	830	1,110
Texas Gulf	2,500	370	2,130	360	2,140	380	2,120
Great Lakes	3,680	3,020	660	1,260	2,420	2,110	1,570
California	1,810	1,320	490	1,550	260	680	1,130
North Pacific	2,840	650	2,190	260	2,580	2,050	790
Hawaii	930	900	30	110	820	180	750
Total	36,940	14,270	22,670	15,400	21,540	12,150	24,790
Alaska	47,300	20,250	27,050	5,100	42,200	Unknown	Unknown
Total National	84,240	34,520	49,720	20,500	63,740	12,150	24,790

From: Report on National Shoreline Study, Department of the Army, Corps of Engineers, August 1971.

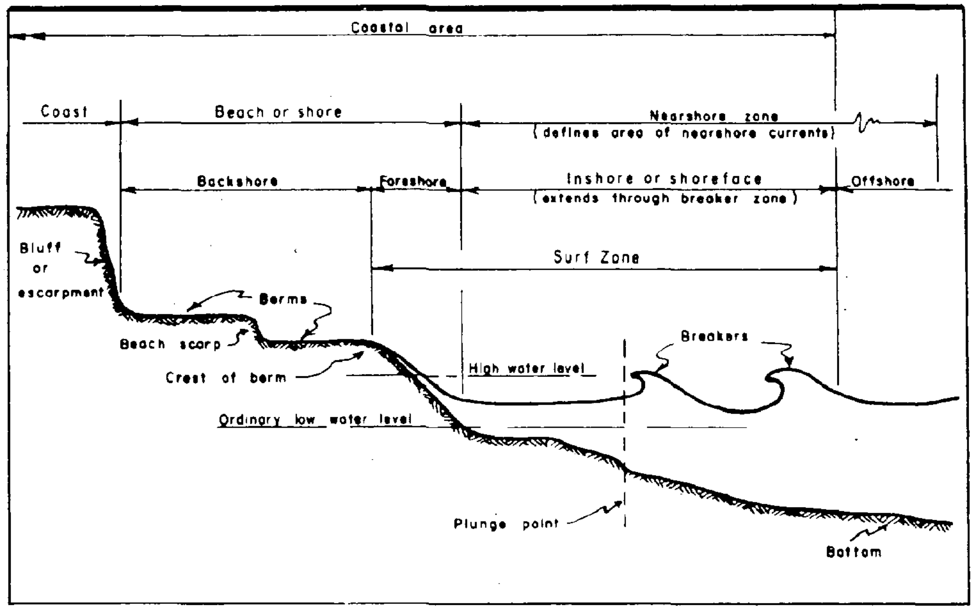


Figure 9. Idealized beach profile displaying the features which may be found in a "typical" beach cross-section (Shore Protection Manual; Fig. 1-1).

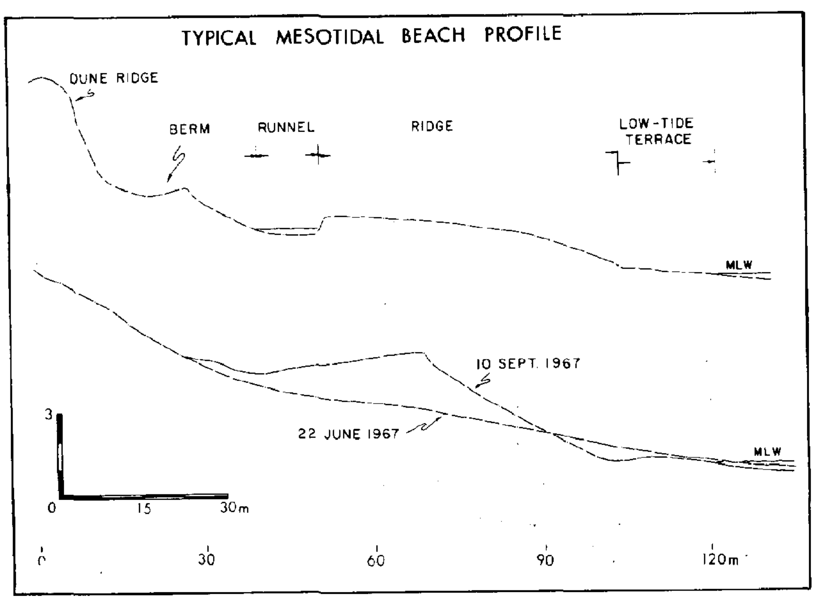


Figure 10. Typical mesotidal (2-4 m tidal range) beach profiles (MLW = mean low water). The upper profile is the more frequently occurring constructional type.

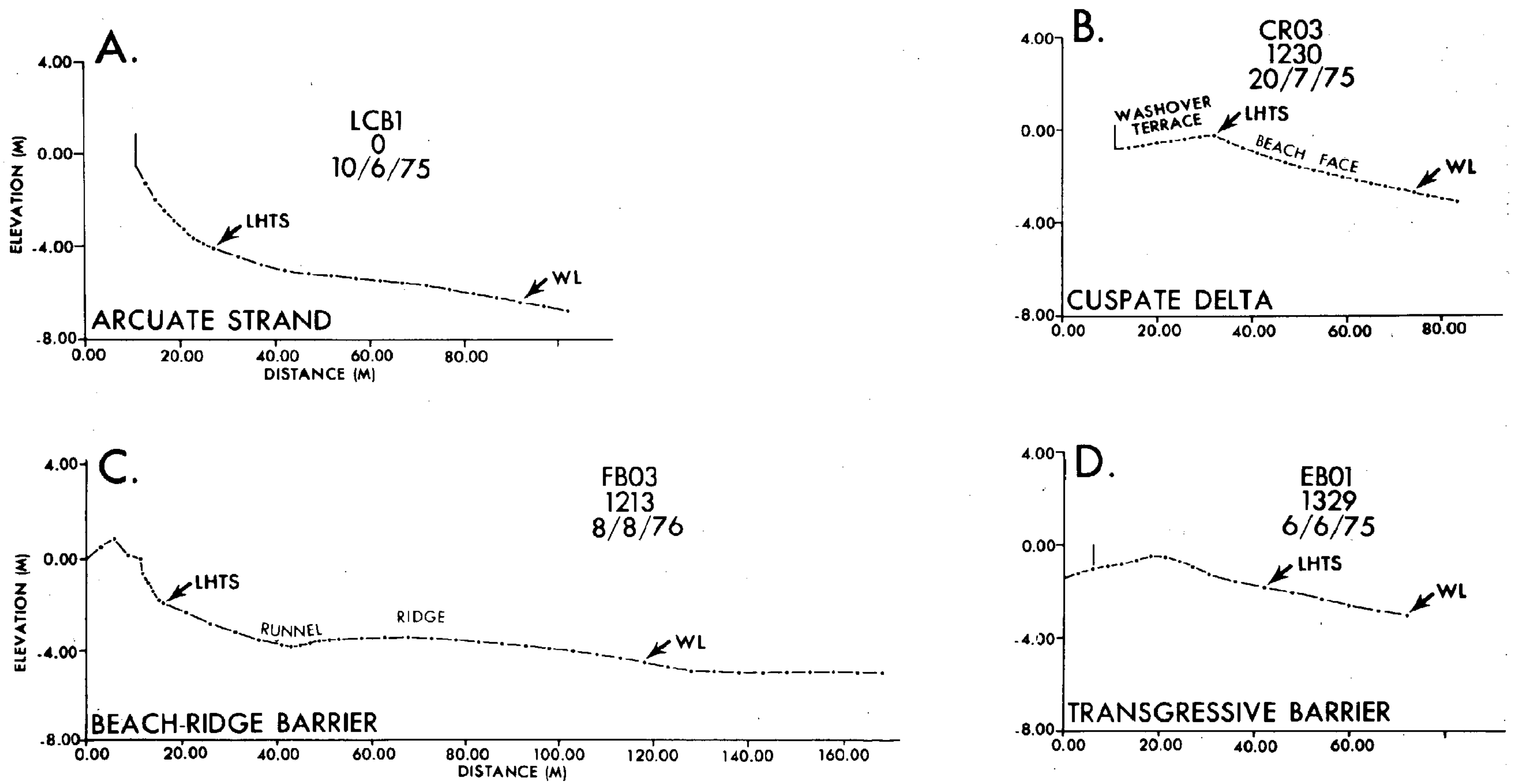


Figure 11. Beach profiles for representative stations from the four morphological provinces of the South Carolina coast. (WL = water line at the time the profile was taken; LHTS = last high tide swash).

Causes of Beach Erosion

Wave attack. - In South Carolina, as elsewhere in the U. S., the primary cause of beach erosion is wave attack. This is obvious to anyone who has stood on or near the beach during a passing storm. What is often not so obvious is the effect of smaller waves. During a minor storm in 1977 at Debidue Island, up to 10 ft. (3 m) of shoreline eroded away in only a six-hour period. The maximum recorded wave height associated with this storm was only 4 ft. (120 cm)[22]. It should be realized that a catastrophe is not necessary to produce the rates of erosion cited in the following pages; however, storm waves, no doubt, play an important role in changing our shoreline (Fig. 12).

Research into what type of waves cause coastal changes has found that, in general, short, steep waves tend to erode the beach while longer, lower profile waves cause sand to be added to the beach. Four types of waves shown in Figs. 13-16 occur on the S. C. coast. These are:

A) Spilling (Fig. 13): Bubbles and turbulent water spill down front face of wave. The upper portion of the front of the wave may become vertical before breaking. Breaking is generally over quite a distance.

B) Plunging (Fig. 14): Crest curls over an air pocket; breaking is usually with a crash followed by a smooth splash-up.

C) Collapsing (Fig. 15): Breaking occurs over lower half of wave. There is no associated air pocket and usually no splash-up. Bubbles and foam are present.

D) Surging (Fig. 16): Wave peaks up, but bottom rushes forward from under wave, and wave slides up from beach face with little or no bubble production.

Wave type plays a major role in determining the severity of erosion. Plunging waves tend to suspend large amounts of sand in the water and, therefore, are the most erosive type of wave along the beach.[23]

The seasonal variations in wind and wave conditions along the S. C. coast were noted in the diagrams displayed in Figures 2 and 3. The dominant winds

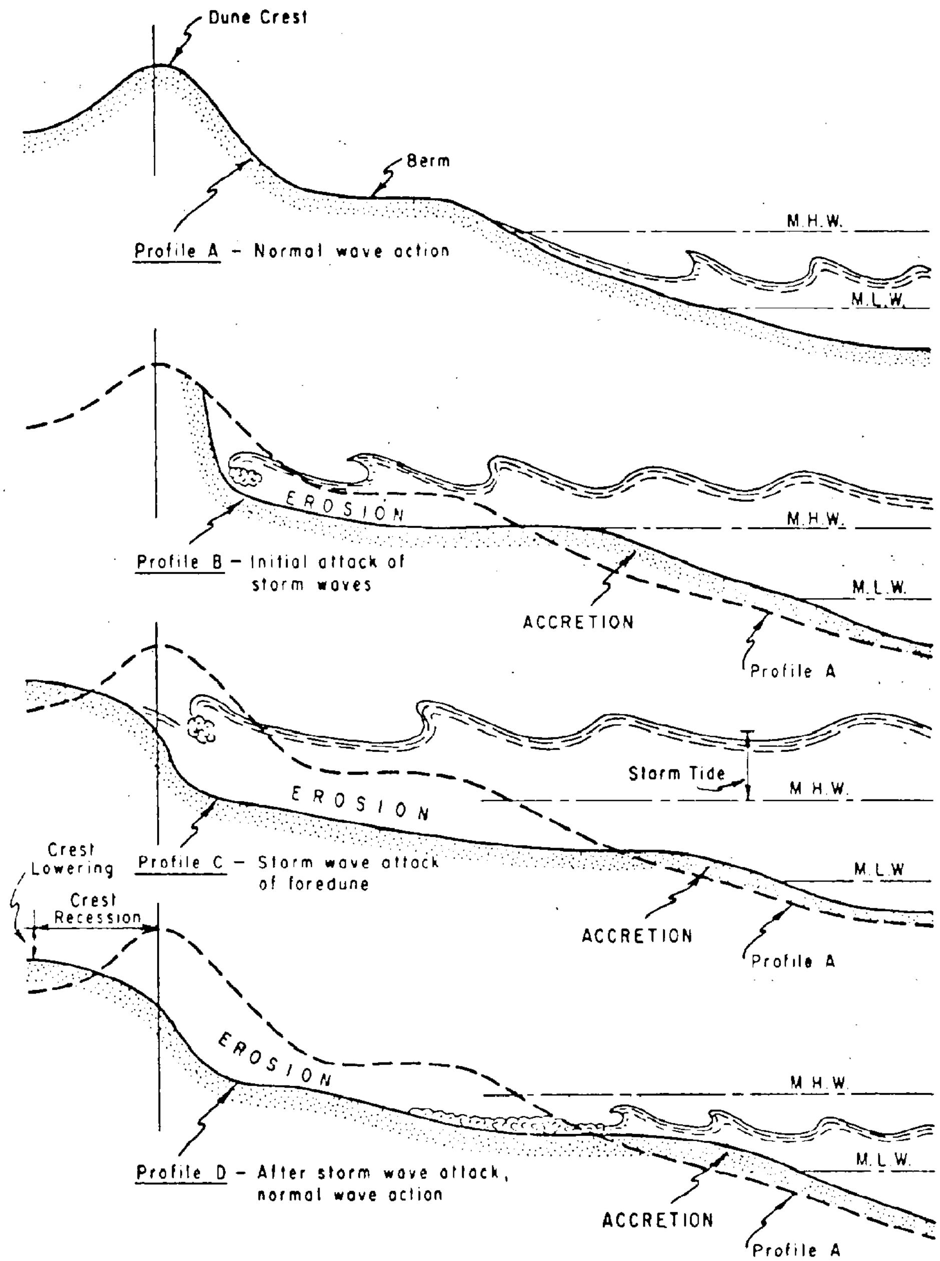


Figure 12. Schematic diagram of storm wave attack on coastal beaches (Shore Protection Manual, Fig. 1-7).

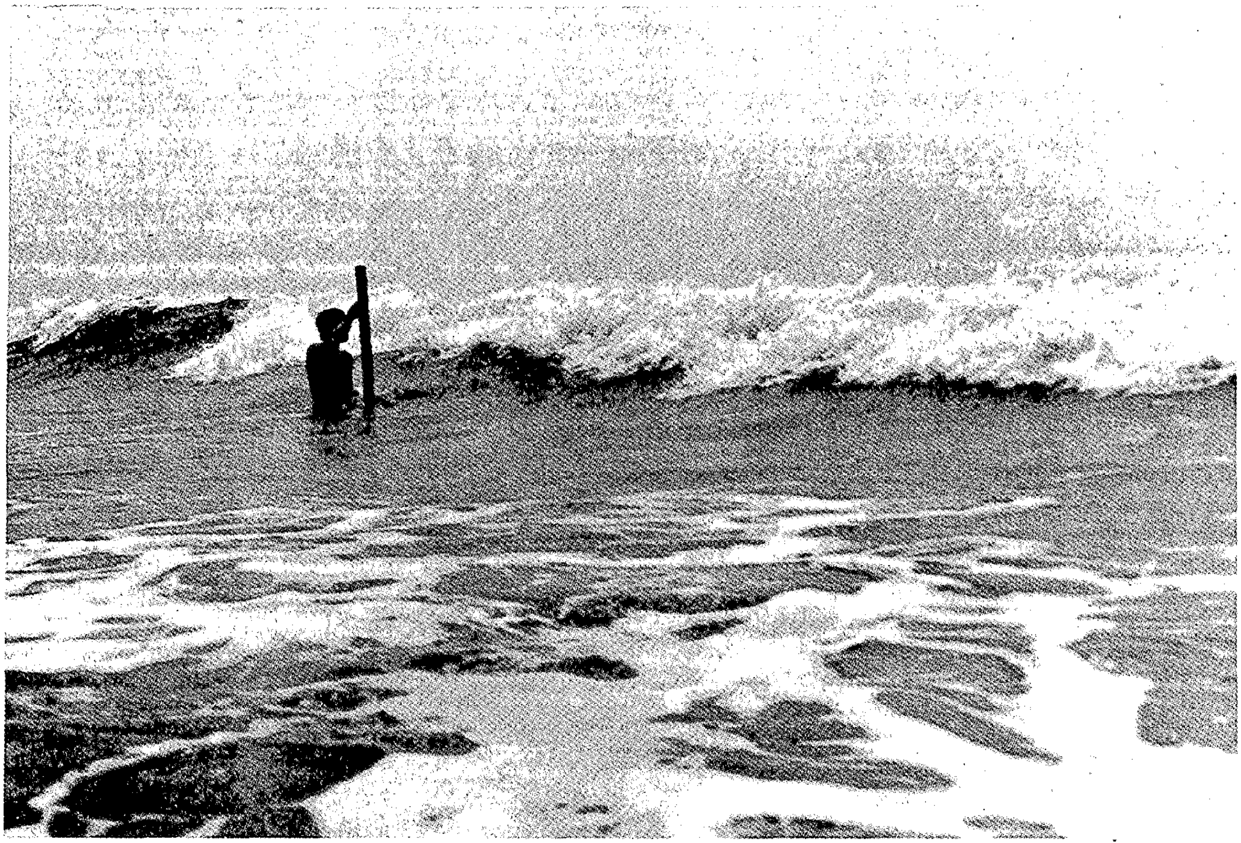


Figure 13. Spilling breaking wave.

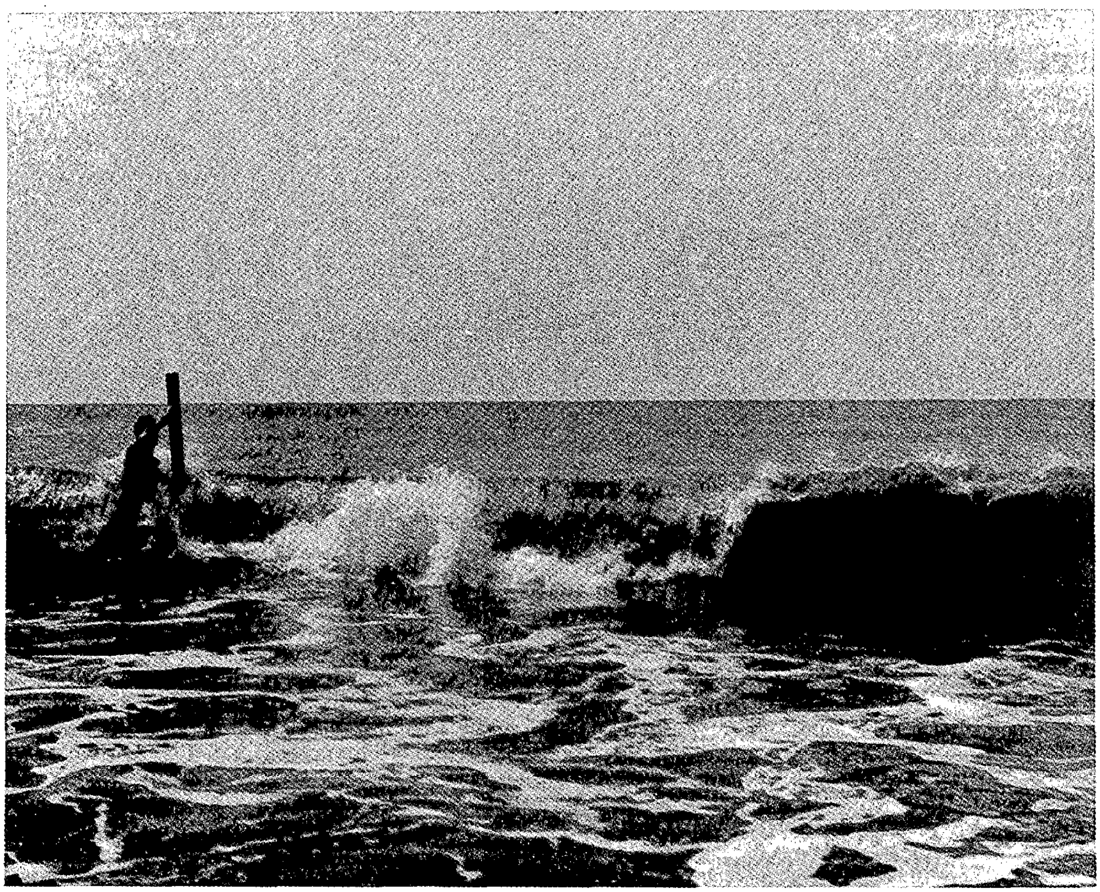


Figure 14. Plunging breaking wave.

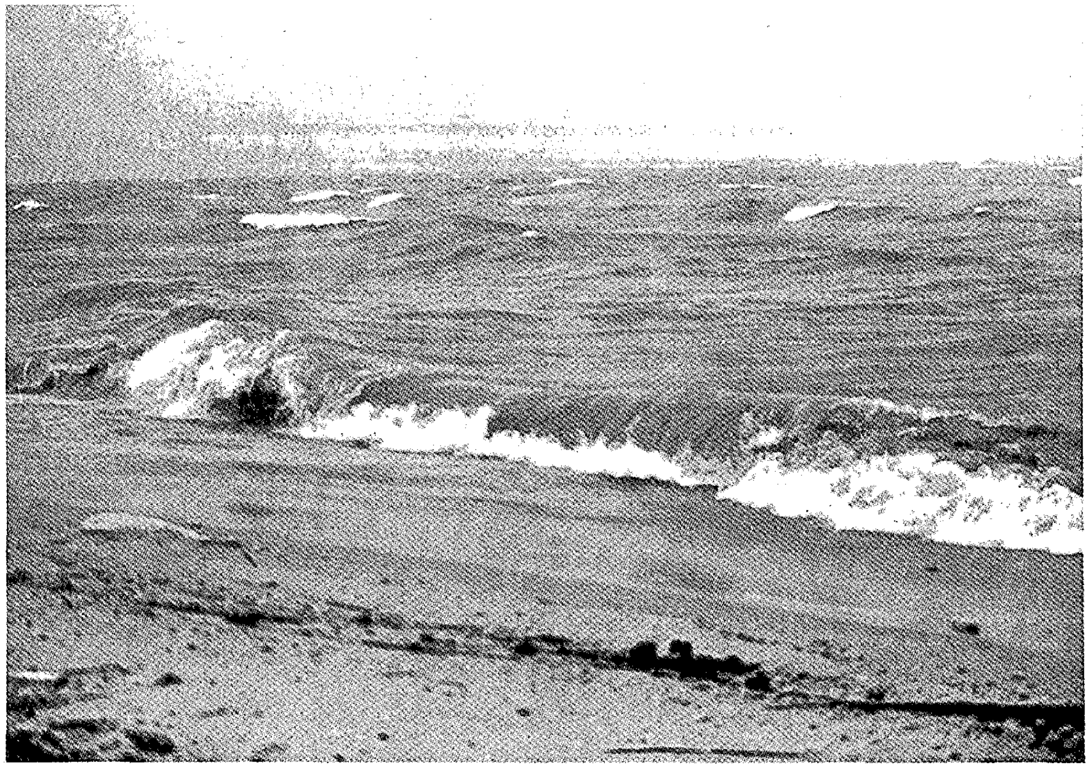


Figure 15. Collapsing breaking wave.

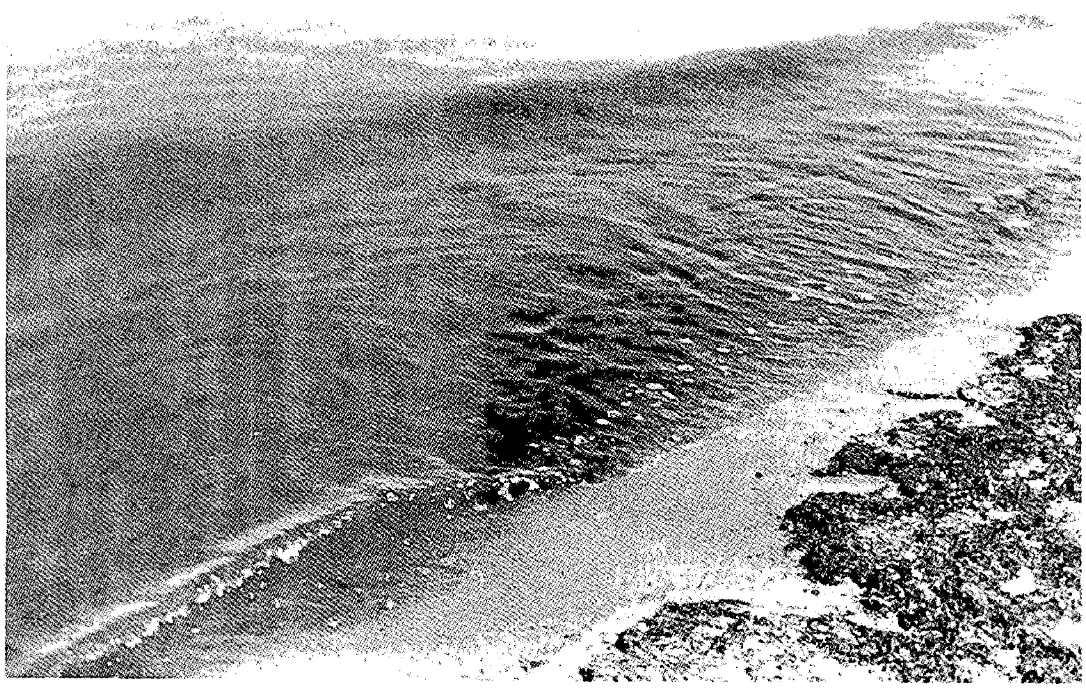


Figure 16. Surging breaking wave.

(highest velocities) from the north and east during fall and winter (Fig. 2) are reflected in the direction of the deep water wave energy (Fig. 3). Strong storm winds from the northeast are generated by northward passing extratropical storms and are considered to be the most important wave generators on the South Carolina coast. Up to 24 ft. (7.3 m) of foredune erosion was documented on Debidue Island in a two-week period following an extratropical cyclone in February 1973 [9]. In spring and summer, an increasing frequency of winds are observed from the south and southwest. These winds are generated by an anti-cyclonic circulation pattern associated with a high pressure zone settling over Bermuda.

Storm surge. - Storm surge is a rise above normal water level on the open ocean along the coast due to the action of wind stress on the water surface. During a hurricane, storm surge is accentuated as a result of reduction in the atmospheric pressure. Storm surge is the primary agent of geologic change in storms, particularly hurricanes. The generation of storm surges gives hurricanes the ability to pile up great quantities of water against the coastline [10]. The storm surge is determined by the effect of wind velocities in the hurricanes, by the speed of its forward movement, and also by the offshore bathymetry [32].

Storm surges can produce extremely high tides along the South Carolina coast, flooding areas along the coastline that lie above mean high tide. Strong winds producing high waves in conjunction with a storm surge tide can cause severe beach erosion along the coast. Table 2 provide some storm surge tide levels for Charleston, South Carolina.

Hurricanes. - Two general categories of storms strike the coastal region of South Carolina. These are: tropical storms or hurricanes, and extratropical storms, commonly referred to as northeasters. Although hurricanes are by far

Table 2. Storm surge tidal elevations affecting Charleston, S. C. (1893-1964) (From Myers, 1975).

Storm Date	Maximum Storm Tide (Ft)
28 Aug. 1893	8.9
11 Aug. 1940	8.0
27/28 Aug. 1911	7.9
27/28 Sept. 1894	7.0
29 Sept. 1959 (Gracie)	6.0
15 Oct. 1947	6.0
14 July 1916	5.9
20 Oct. 1944	5.8
18 Sept. 1928	5.6
17 Aug. 1955 (Diane)	5.2
11 Sept. 1960 (Donna)	5.0
18/19 Sept. 1955 (Ione)	4.4
11 Aug. 1955 (Connie)	4.3
15 Oct. 1954 (Hazel)	4.2
29/30 Aug. 1954 (Carol)	4.2
30 Aug. 1952 (Able)	4.0
27 Sept. 1958 (Helene)	3.9
25 Oct. 1963 (Ginny)	6.9

the more severe storms, their lower rates of occurrence make them less significant than northeasters in terms of continual shoreline change. The probability of a hurricane-force tropical storm striking the South Carolina coast is about 0.04, or one in every 25 years (Table 3). The effects of northeasters along the South Carolina coast as a cause of beach erosion is discussed in the previous section on wave attack.

Hurricanes are storms of tropical origin with a cyclonic wind circulation (counterclockwise in the Northern Hemisphere) of 74 mph (64 kts) or higher. Hurricanes occur in the North Atlantic with a frequency of approximately 7.5 per year and occur most often during the months of August, September and October[6]. The name "hurricane" is derived, via Spanish, from a West Indian word for the storms[27]. Over the years, hurricanes have produced many disasters along the South Carolina coast. The loss of life and damage to property by these storms is primarily the result of the hurricane storm tide (discussed earlier as "storm surge") and, on the immediate coast, high waves. The hurricane winds are also a danger. The more destructive hurricanes of the past

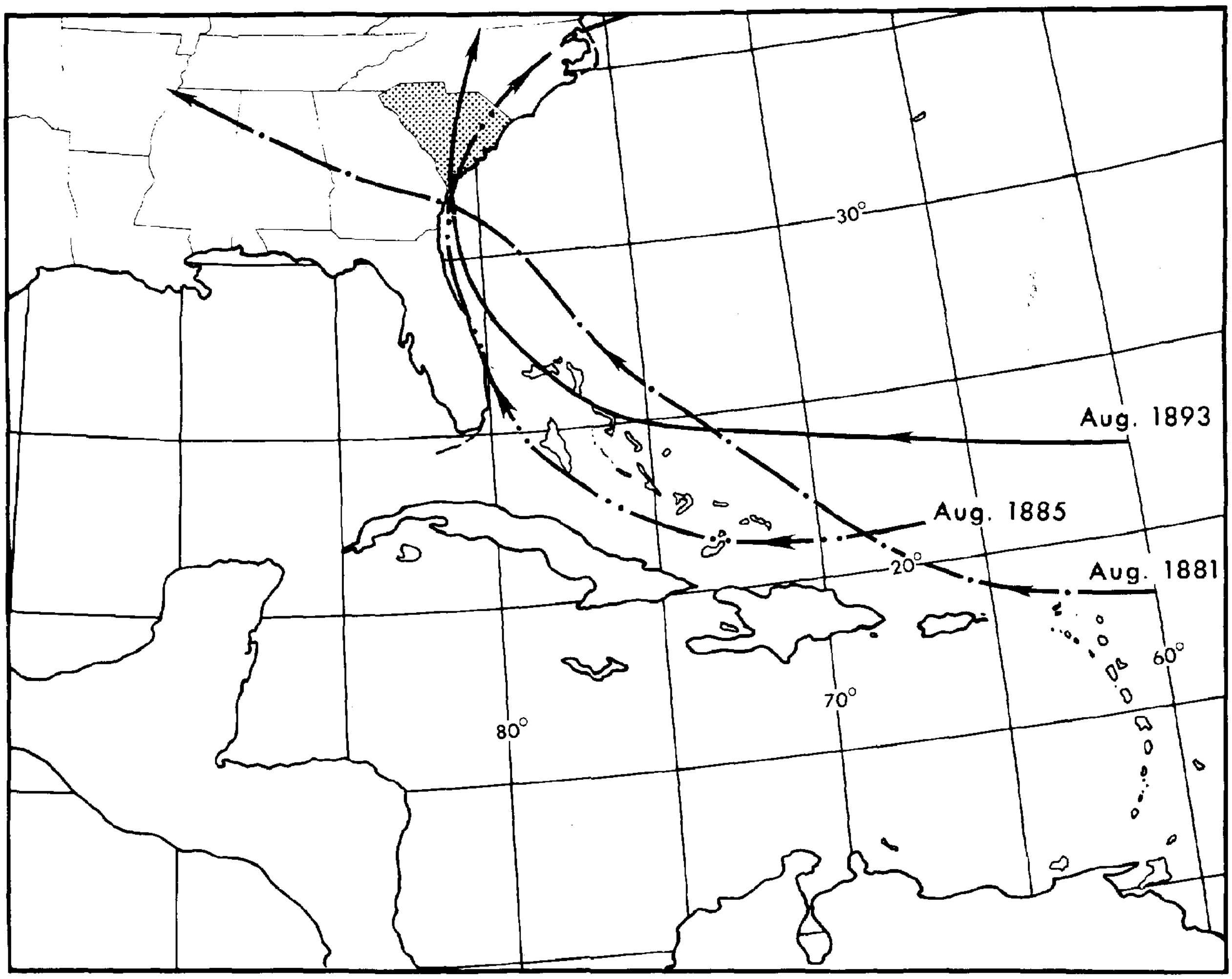


Figure 17. Tracks of the major late 19th century hurricanes affecting the South Carolina coast (from Myers, 1975).

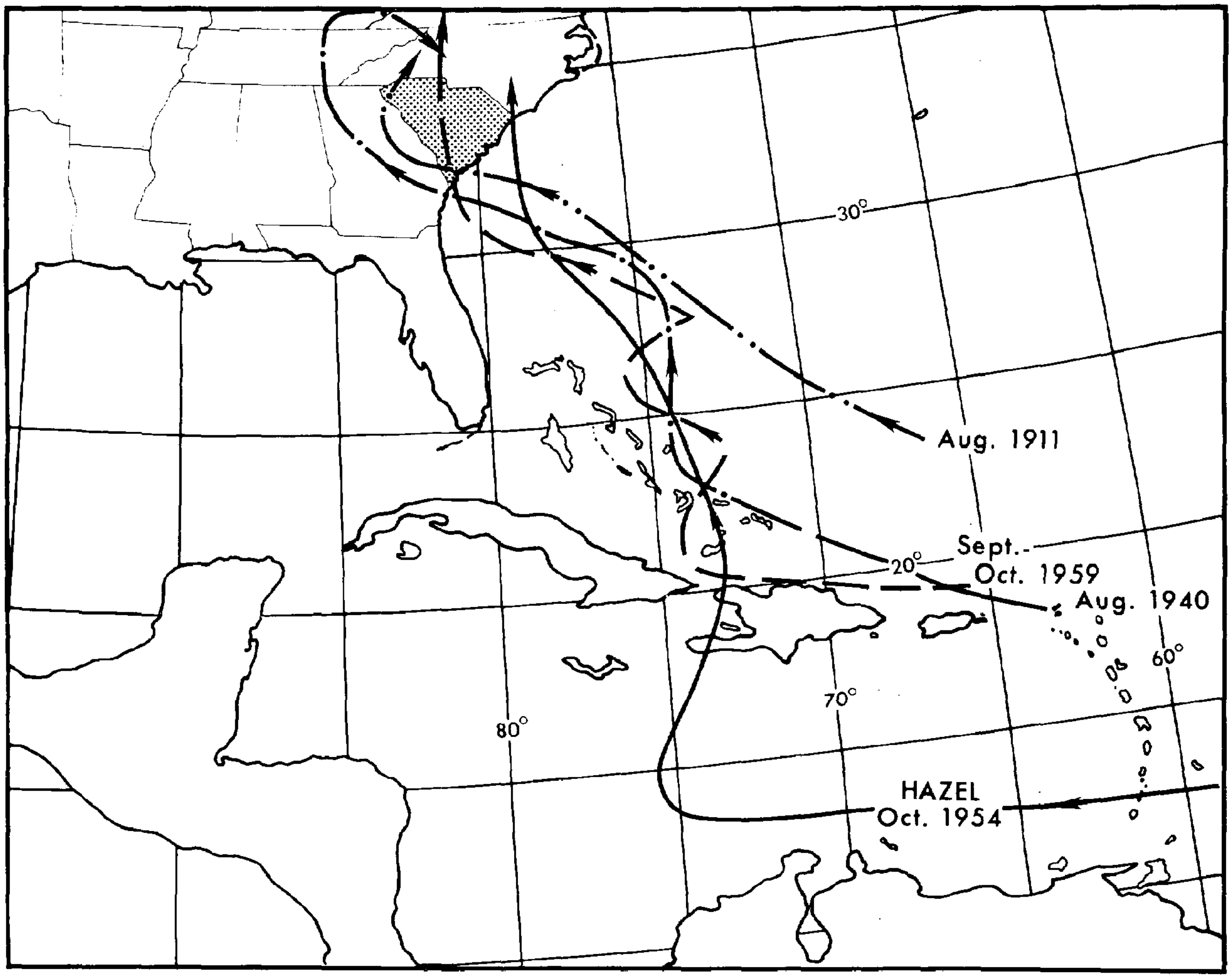


Figure 18. Tracks of the damaging hurricanes of the 20th century affecting the South Carolina coast (from Myers, 1975).

vividly illustrate the potential danger of life and property along the South Carolina coast. The storm tracks of those hurricanes which had a damaging effect on the South Carolina coastline are displayed in Fig. 17 (for the late 19th century) and Fig. 18 (20th century).

One of the most severe hurricanes to strike the South Carolina coast was hurricane Hazel in 1954. The storm track of this hurricane is shown in Figure 18. A description of its destructive path along the South Carolina shoreline is given below.

"Hurricane Hazel entered the coast just north of Myrtle Beach, S. C., and was one of the most destructive hurricanes, in terms of property damage. Hurricane winds hit the Atlantic Coast between Georgetown, S. C., and Cape Lookout, N. C., and storm tides devastated the immediate ocean front of this stretch coast. Every fishing pier from Myrtle Beach to Cedar Creek, N. C., a distance of 170 mi., was destroyed. High tides of 16.6 MSL were observed at Holden Beach Bridge and Calabash, N. C. The lowest recorded barometric pressure of 938 mb was reported at Little River Inlet on the South Carolina-North Carolina border. At Cherry Grove Beach, a 17-ft MSL tide destroyed all front-row houses and washed some second-row houses from their foundations. At Tilghman Beach, Ocean Drive, Crescent Beach, Atlantic Beach, and Windy Hill, S. C., practically all front-row houses were destroyed or damaged, with waves breaking at housetop heights along some of the beach front. At Myrtle Beach, high-water marks at "Edgewater Apartments" near 16th Avenue South indicated a tide height of 15.5 ft MSL. The highest wind gust at Myrtle Beach AFB was 106 mph. It is estimated that wind and water combined badly damaged or destroyed about 80 percent of the beach front property in the Myrtle Beach area. At Surfside and Garden City, S. C., hundreds of houses were destroyed by tides in excess of 13 ft MSL. On Pawleys Island, S. C., 75 percent of the houses on the beach were badly damaged, and 10 ft waves covered the northern and southern ends of the island, as well as low-lying areas in the middle. At Georgetown, sections of the streets were inundated. Folly Island, Sullivans Island and Isle of Palms suffered light property damage and slight beach erosion. No serious damage was done at Charleston. Total property damage was estimated at $34 million in North Carolina, $27 million in South Carolina. Advance warnings enabled people to evacuate the threatened areas, and only one person was killed in South Carolina as a result of this storm. After devastating the coast, hurricane Hazel moved across North Carolina with diminishing winds, passing through Virginia and heading northward toward Lake Ontario and Canada" (Corps of Engineers, 1957) (From Myers, 1975).

Sea level rise. - One of the most important yet least obvious geologic agents of shoreline erosion is the slowly rising level of the sea. While rapid erosion may take place during storms as beaches suffer from wave attack, a longer term shoreline erosion resulting in barrier island retreat is the result of a relative rise in sea level (Fig. 19). Sea level has been steadily

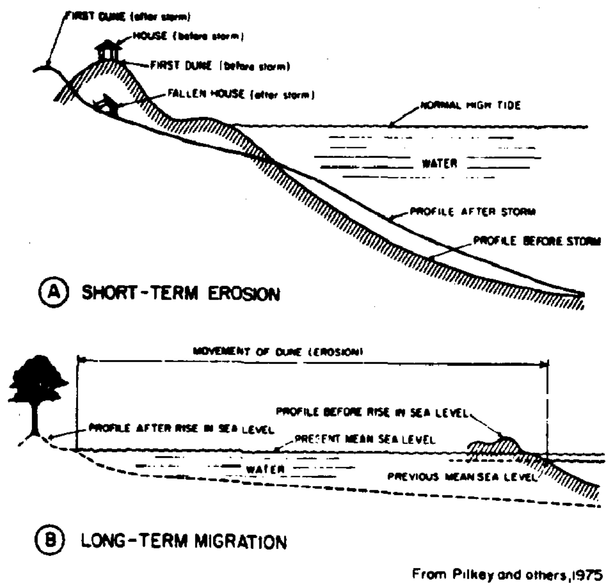


Figure 19. Beach and dune changes resulting from storms and the relative rise of sea level (from Pilkey *et al.*, 1975)

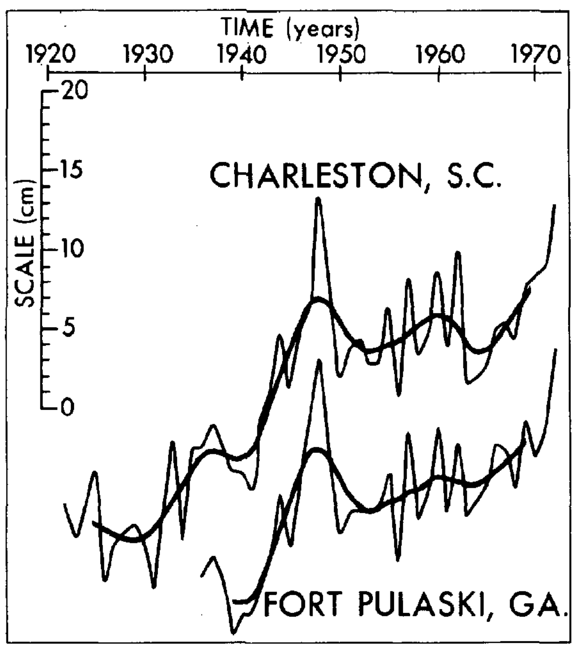


Figure 20. Changes in sea level with respect to the adjacent land at Charleston, S. C. and Fort Pulaski, Ga. (from Hicks and Crosby, 1974).

rising since the end of the last glacial epoch, approximately 14,000 to 18,000 years before present (years BP). Between 14,000 and 7,000 years BP, the sea rapidly rose, and the shoreline retreated some 50 miles from the edge of the continental shelf [28]. From 7,000 to approximately 3,000 BP, sea level along the east coast of the U.S. rose at a rate of about one foot per century [25]. The sea level curve for the Delmarva Peninsula shows a relative rate of sea level rise of approximately half a foot per century for the past 3,000 years.

Although sea level has been continuing to rise, it is doing so at an ever decreasing rate. However, between 1964 and 1971, sea level rose 4 inches (10 cm) along many portions of the east coast (Fig. 20)[16]. The recent and relatively rapid rate in sea level rise of roughly half a foot per decade is probably only a short term fluctuation, but striking nonetheless.

EROSION-DEPOSITION TRENDS

The causes of beach erosion have been outlined above. A final consideration is how does the beach build after an erosive event. After a storm, the beach is wide and flat and often backed by a scarp (Fig. 21). The sand that was removed from the beach is deposited offshore as a bar. Soon after the storm (usually 2 days to 6 weeks), small ridges of sand migrate onto the beach and gradually build a low berm (Fig. 22). This feature is further built by waves rushing up the beachface and over the berm top where sand is deposited. Finally, wind-blown sediments are trapped by straw and debris deposited above high water level and form low, incipient dunes. If left alone, these will develop a mature dune ridge. In essence, the dunes become a type of natural levee against wave attack providing a line of protection from storms and serve as a reservoir of beach sand.

Figure 21. Typical post-storm (1 day) beach profile displaying a wide, flat beach backed by a scarp.

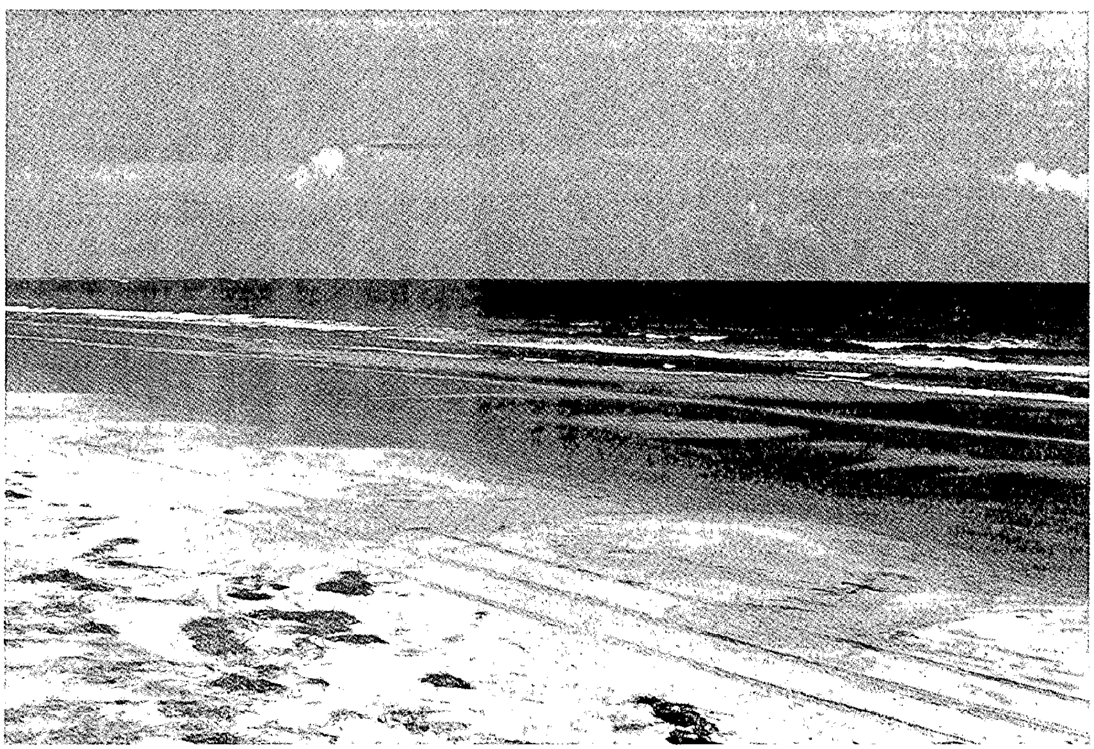


Figure 22. Profile at the beach two to six days after a storm which shows the development of a low berm. Photo taken at Kiawah Island, S. C.

The cycle of erosion and deposition on beaches differs markedly from place to place and is dependent on such variables as:

1) direction of prevailing winds

2) sand grain size

3) nature of storm activity

4) wave climate

5) nature of offshore topography

A series of beach profiles displaying trends of erosion and deposition over a 2-year period for each of the four morphologic provinces of the South Carolina coast is shown in Fig. 23. The migrating beach ridges in the profiles from Hilton Head Island represent a form of sediment accumulation in the coastal zone, while the steep beachface and extended washover terraces of Cape Romain are erosive beach features. A very important reservoir of sand along the South Carolina coast is the large ebb-tidal deltas associated with the seaward projection of tidal inlets. These shoals contain large volumes of sediment and are an important source of sand for the accretion of beaches along portions of the South Carolina coast (Fig. 24).

Certain generalizations are possible regarding the overall trends of erosion and deposition along the South Carolina coastline. Depositional trends are most likely to occur at the downdrift ends of barrier islands. Although drift reversals do occur, over most of South Carolina the trend of longshore sediment transport is to the south. Deposition occurs as sediment in recurved spits is welded to the shoreline as spits successively migrate southward. At Cape Romain, recurved spits have prograded in two opposite directions because of the unusual shoreline orientations at the Cape (Fig. 7).

Erosional areas are related to several factors. At Cape Romain, Raccoon Key, Morris Island and Edingsville Beach, extensive erosion is taking

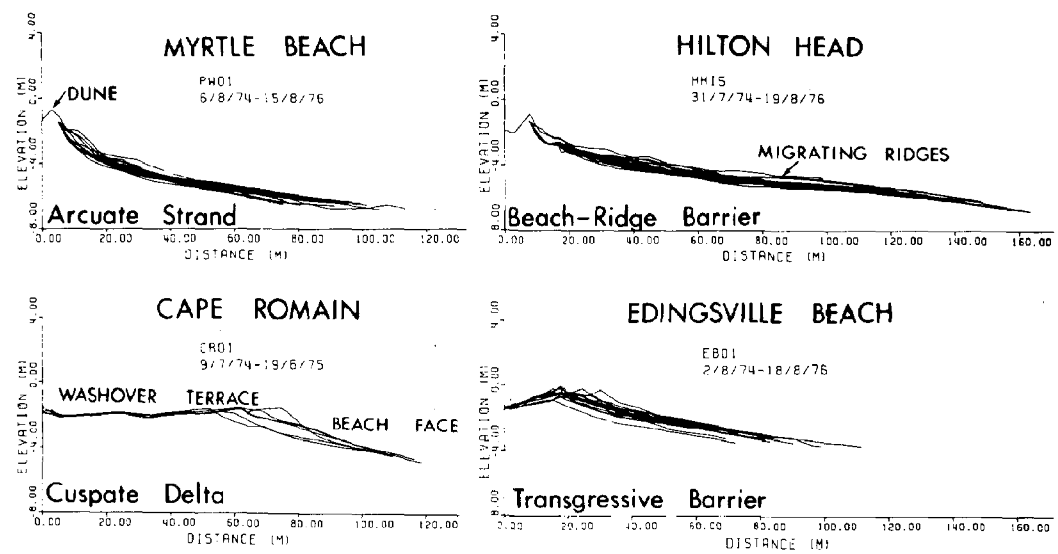


Figure 23. A series of beach profiles (sweep zone) displaying trends of erosion and deposition over a two-year period for each of the morphologic provinces of the South Carolina coast.

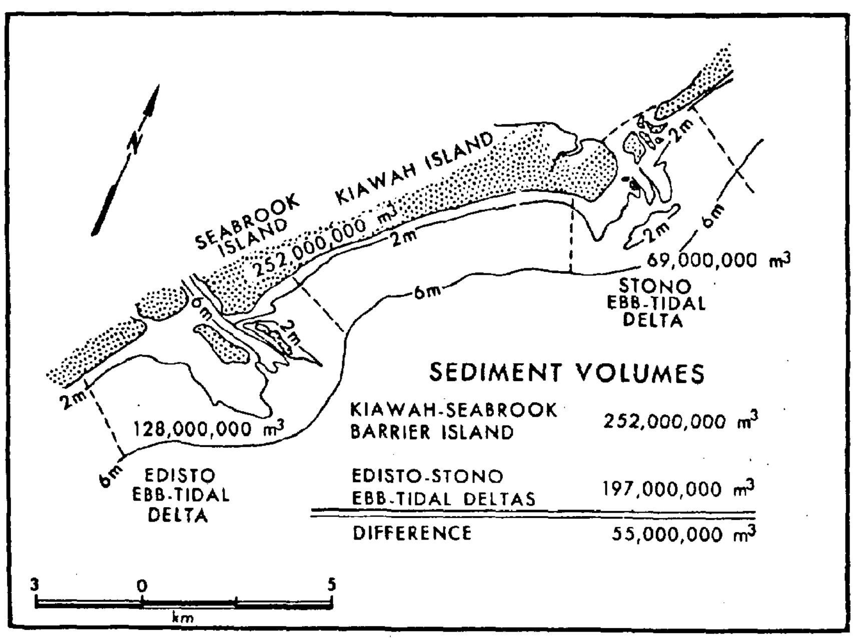


Figure 24. Volumes of sand contained in Kiawah and Seabrook Islands and the ebb-tidal deltas of the two adjacent inlets, Stono and North Edisto (from Hayes et al., 1976)

place along marsh shorelines. Erosion at the Santee Delta, Cape Romain, and on Morris Island can be related to the reduction of sediment supply resulting from artificial controls due to modifications by man. In other areas, the erosion is related to the fact that the beaches are exposed to severe wave attack from large stretches of open water. This is true for northern Bull Island, Cape Romain, and the southern tip of Edisto Beach.

Without exception, highly unstable areas are related to the presence of tidal inlets. Lateral migration of inlets, wave refraction around inlet-associated shoals and changes in inlet morphology all cause rapid and large-scale erosional-depositional fluctuations in areas associated with inlets (Fig. 25). In places, such as at Bull Island, these effects can modify the beaches up to two miles away from the inlet.

Stable shorelines occur along the central portions of the larger islands. These beaches are far away from tidal inlets. Also, some stable areas are the result of large monetary expenditures to construct groins and seawalls to hold the sand in place and prevent movement of the shoreline position (Fig. 26).

Recently, a computer program has been developed that can predict wave refraction patterns and the resulting distribution of wave energy along the South Carolina coast (Fig. 27). These results have proven useful for determining zones of potential erosion or deposition along the coastline. Some of the more interesting findings include:

1) The Myrtle Beach area, or the South Carolina "Grand Strand", appears relatively protected against damage by a northeast storm. However, the most violent storms known to hit the state, the hurricanes, may actually focus wave energy on this highly developed shoreline section.

2) In a manner similar to Myrtle Beach, the southwestern part of the Isle of Palms appears relatively protected against northeast storms but very exposed to hurricane waves arriving from the south or southeast.

Figure 25. Morris Island light. The lighthouse was located on the beach at the south end of Morris Island in 1939. Over 1600 feet of erosion has occurred since that date. This erosion is in part related to the construction of jetties at Charleston Harbor to the north, as well as its proximity to a tidal inlet. Photo taken January 7, 1975.

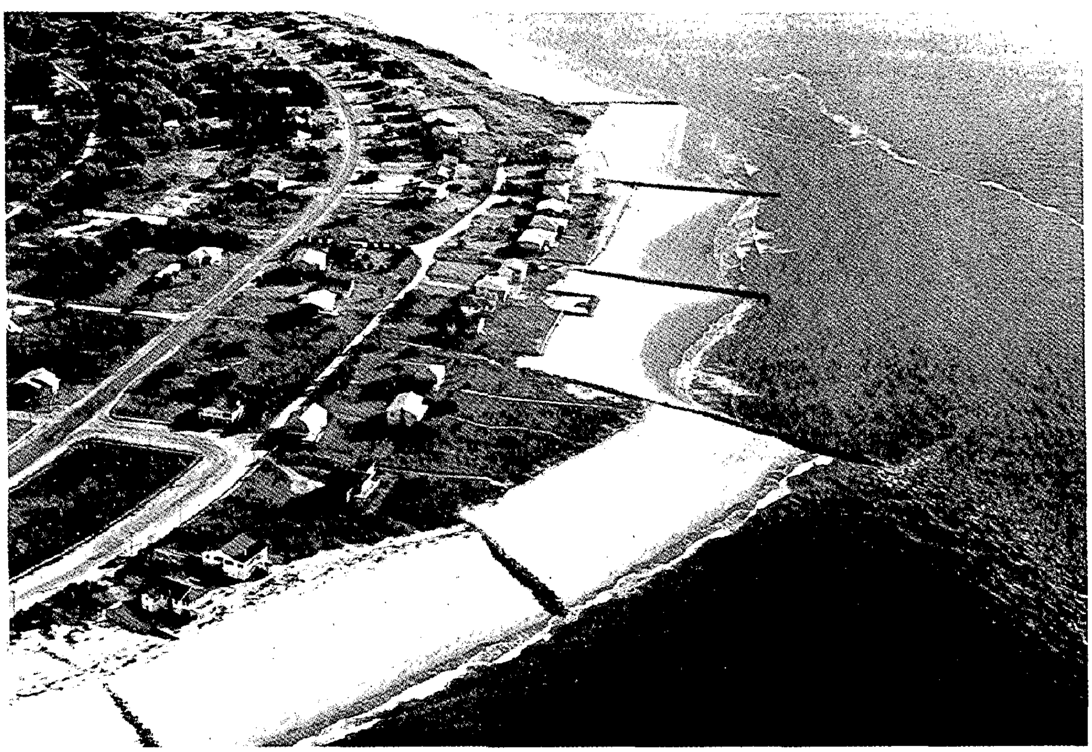


Figure 26. Oblique aerial photograph of a series of groins constructed along Edisto Island beach. Note the accumulation of sand along the updrift (eastern) margin of each groin.

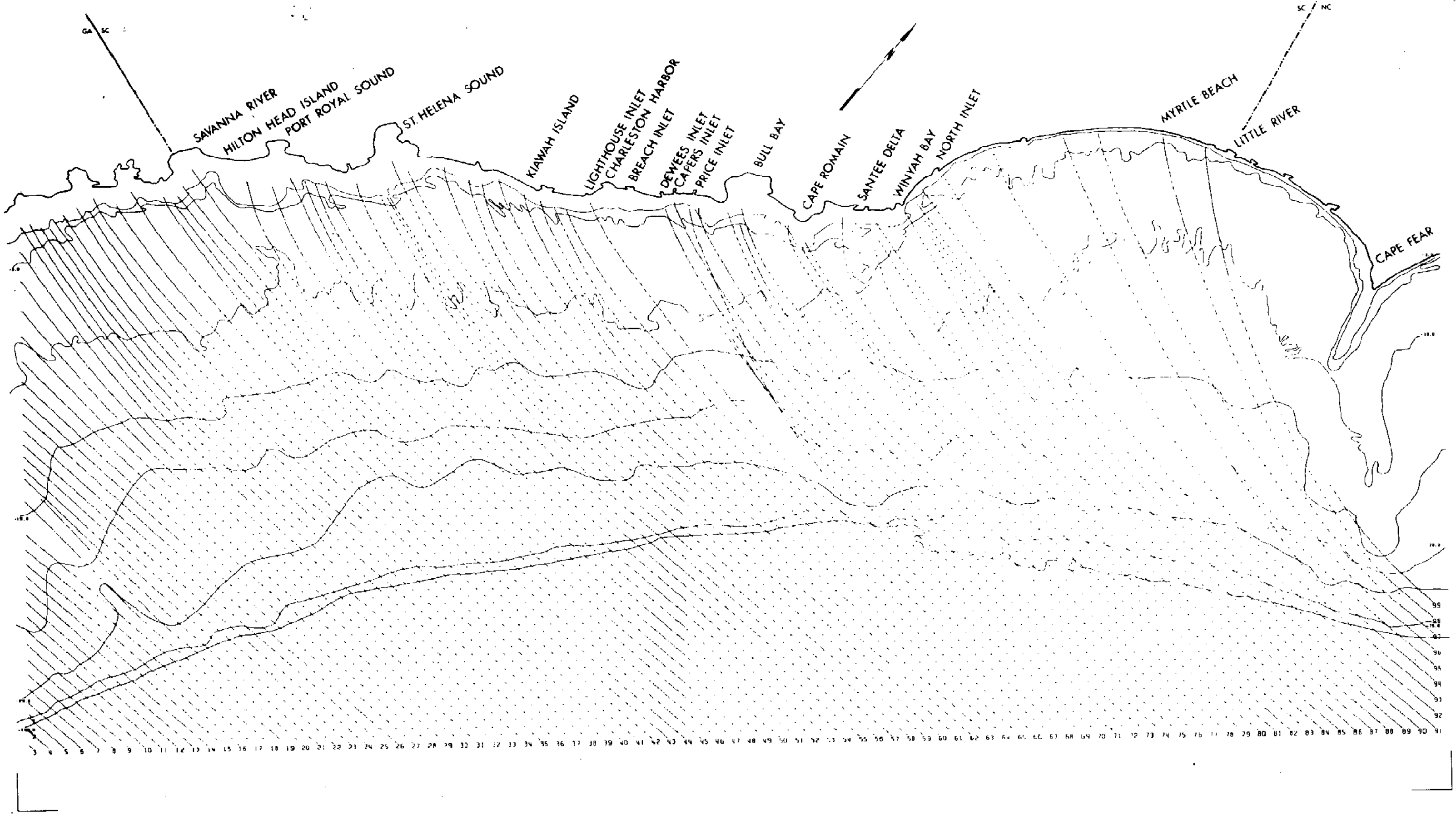


Figure 27. Computerized wave refraction diagram for waves of 10 sec. period out of the east. This diagram shows the effects of northeasters on the South Carolina coastline. Each line intersecting the coast represents the approach of a series of wind-produced waves (from Fico, 1977).

3) The large downdrift offset of Dewees Inlet appears to be related to a sudden reduction in southward-directed longshore drift at the Isle of Palms compared to Dewees Island and the other barriers further to the north [8].

SHORT TERM CHANGES

This next section examines the short-term erosion-deposition trends for the four major morphological provinces along the South Carolina coastline. This section is preceded by a discussion of how and what kind of data was collected for this study.

What is a beach profile?

A beach profile is a topographic survey run normal to the trend of the beach. Profile locations were selected after careful aerial and ground reconnaissance of the entire coast of South Carolina. At each site, two permanent reference stakes were set well landward of the spring high tide position on a line normal to the beach. The top of either stake served as a permanent origin for all beach profiles run at that location. The surveying technique is modified slightly from the method illustrated in Figure 28 [7].

Data Presentation

Since 1973, personnel from the Coastal Research Division have run well over 1000 beach profiles along the South Carolina coast. The large volume of data generated from these studies would be, at best, unmanageable if treated by hand. Therefore, a program was created to reduce and store these data in the University computer facility. These profiles can be recalled singly or as a group and plotted in one of three formats.

In later sections of this report, information on moderate to long-term changes in beach configuration will be discussed. Although these types of information are extremely useful for the coastal zone planner, it is necessary to consider the shorter term (monthly or seasonal) variations that can be superimposed on these longer trends. It is only at this scale that we

Figure 28. Photograph illustrating the survey technique of Emery (1961) used to determine beach profiles.

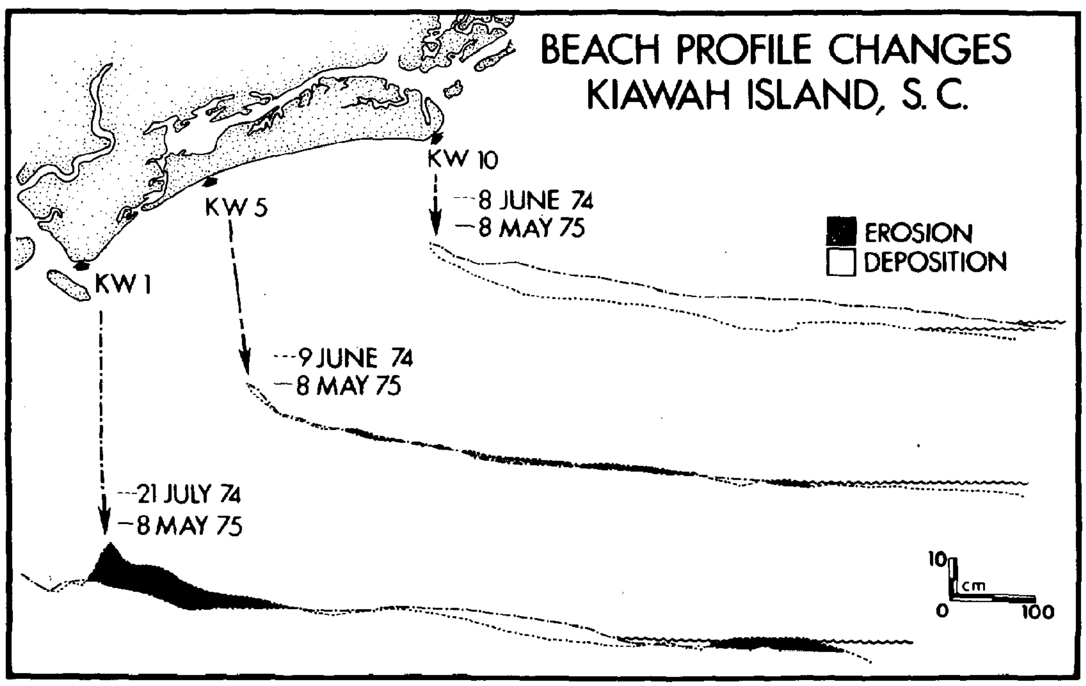


Figure 29. Beach profile changes at 3 stations, KW-1, KW-5, and KW-10 between June-July 1974 and May 1975. Station KW-1, located near the Guest House on Seabrook Island showed the most erosion of any station (over 100 m of landward retreat of the high tide line). Station KW-10, which is located on the lee side of a large offshore sand shoal, showed the largest amount of accretion (over 100 m of seaward progradation of the high-tide line). Station KW-5, located in the middle of Kiawah, showed little change (from Hayes, 1977).

can fully understand the relationship between coastal processes and beach changes. For that reason, the South Carolina Beach Profile Network was established.

This network consists of approximately 70 beach profiles. Thirty-five of these profiles were run at one month intervals for two years to establish the pattern of short-term changes associated with each location. They are presently run at 3-month intervals to document seasonal erosion-deposition patterns along the South Carolina coast. In addition, 35 profiles have been surveyed at varying intervals as part of other Coastal Research Division projects.

First, individual profiles can be plotted separately. Each plot shows the beach configuration for the days on which beach profiles were run. In addition, any two profiles at one station can be overplotted to show changes in the beach between surveys. The amount of change is calculated and is displayed as the area between the two profiles (Fig. 29). This information can be used to determine the response of different beaches to a variety of events (storms, long periods of fair weather, etc.). Finally, all of the surveys from any one location can be overplotted to define a <u>sweep zone</u> (Fig. 23). By superimposing all the data from one profile in this fashion, we can readily see the maximum and minimum elevation of any point along the beach profile and determine the variability (or lack of it) that has occurred during that period of record.

To facilitate discussion and conserve space, the profiles will be considered in groups rather than individually. Complete data listings for individual profiles can be obtained by writing to:

Coastal Research Division
Geology Department
University of South Carolina
Columbia, S. C. 29208

The areas discussed are 1) the grand strand, 2) the North Inlet area, 3) Cape Romain, 4) Capers and Bull Islands, 5) Sullivans Island, 6) Isle of Palms,

7) Folly Beach, 8) Kiawah Island, 9) Edisto Beach, 10) Hunting Island, 11) Fripp Island, and 12) Hilton Head Island, for short term changes.

Grand Strand

The grand strand (Fig. 30) is 50 miles (80 km) of straight to gently-curving shoreline. The beaches of this area are characteristically wide and flat. Beach profiles in this area reflect general shoreline stability, which is in agreement with longer-term information. Most of the moderate variability seen in this area is roughly seasonal, and net changes through the study period were small.

The nature of the backshore area varies from profile to profile. At station CGB-1, a well-developed dune system of over 10 feet high sits in front of the first row of houses as protection against sudden erosion (Fig. 31). Likewise, at station LCB-1, substantial foredune ridges occur locally. These dunes are well vegetated, primarily by sea oats (*Uniola peniculata*). At the beginning of the study period, a 6 ft. (2 m) dune ridge was present at station NMB-2. This ridge was subsequently removed, presumably for development purposes, and the profile is presently backed by a high-rise condominium (Fig. 32).

Debidue and North Islands

At the southern end of the grand strand is the Belle W. Baruch Plantation. Contained within the tract are two Holocene barriers, Debidue and North Islands, separated by North Inlet (Fig. 33). In the vicinity of the inlet, the barriers are wide. Further from the inlet (to the north and south), the islands thin to approximately 1000 ft. (300 m). On North Island, a low and continuous dune ridge partitions the marsh from a wide supratidal flat. In contrast, actively eroding foredune scarps (4-6 ft. high) and washover deposits dominate on Debidue. Both beaches are wide and relatively flat, while seasonal variations are minimal.

Both Debidue and North Islands are characterized by instability. Exposure of *Spartina alterniflora* peat occurs on the lower foreshore at both beaches.

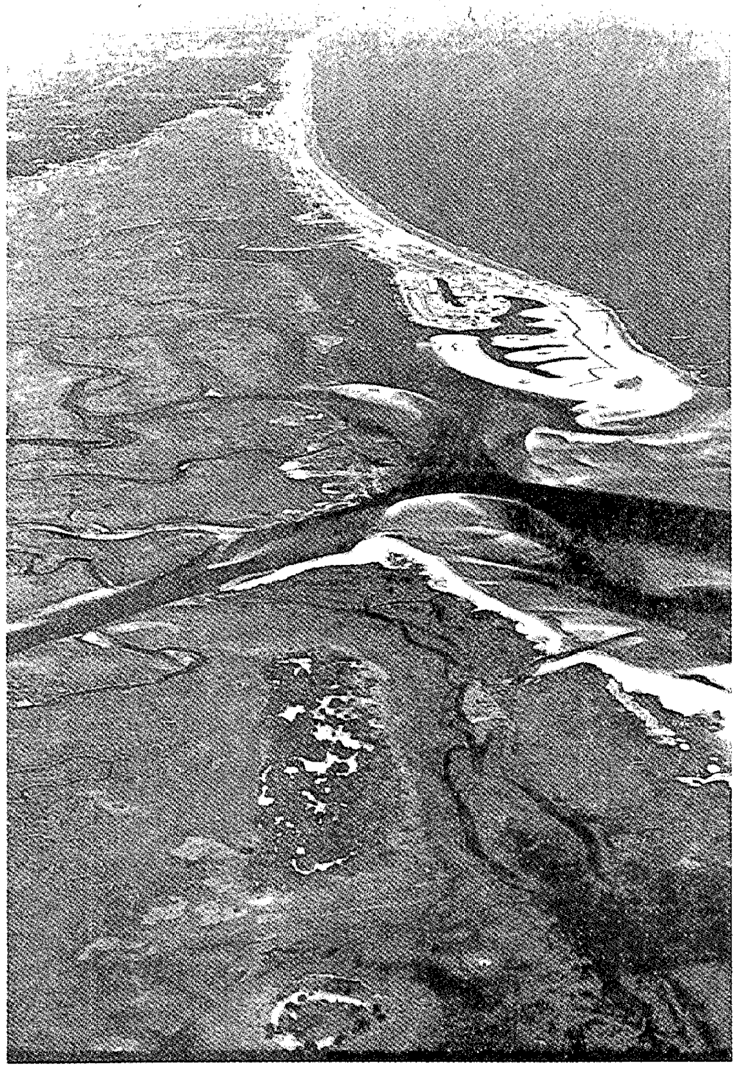


Figure 30. Oblique aerial view of the arcuate strand looking north from Murrells Inlet.(from Brown, 1977).

Figure 31. Well-developed dune system in front of the first row of houses at station CGB-1, Garden City beach. These dunes provide protection from storm-produced wave attack.

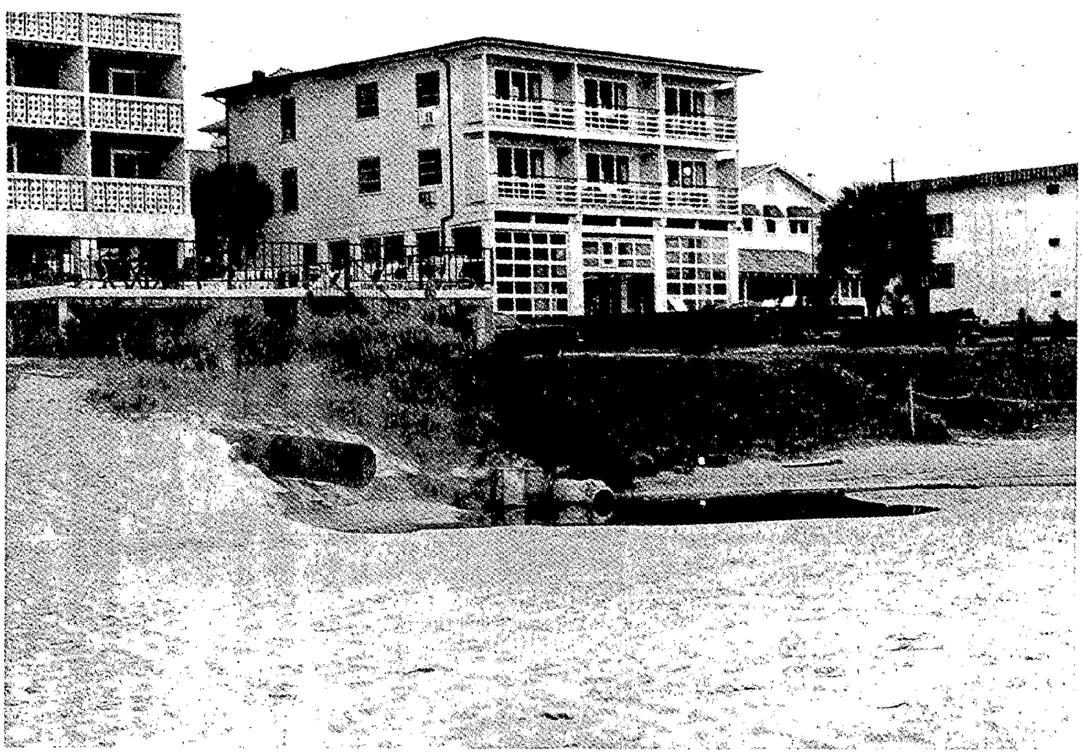


Figure 32. Location of profile station NMB-2 at North Myrtle Beach. The high-rise condominium presently backs the profile.

Figure 33. Oblique aerial view of North Inlet that separates Debidue (to the north) and North Islands.

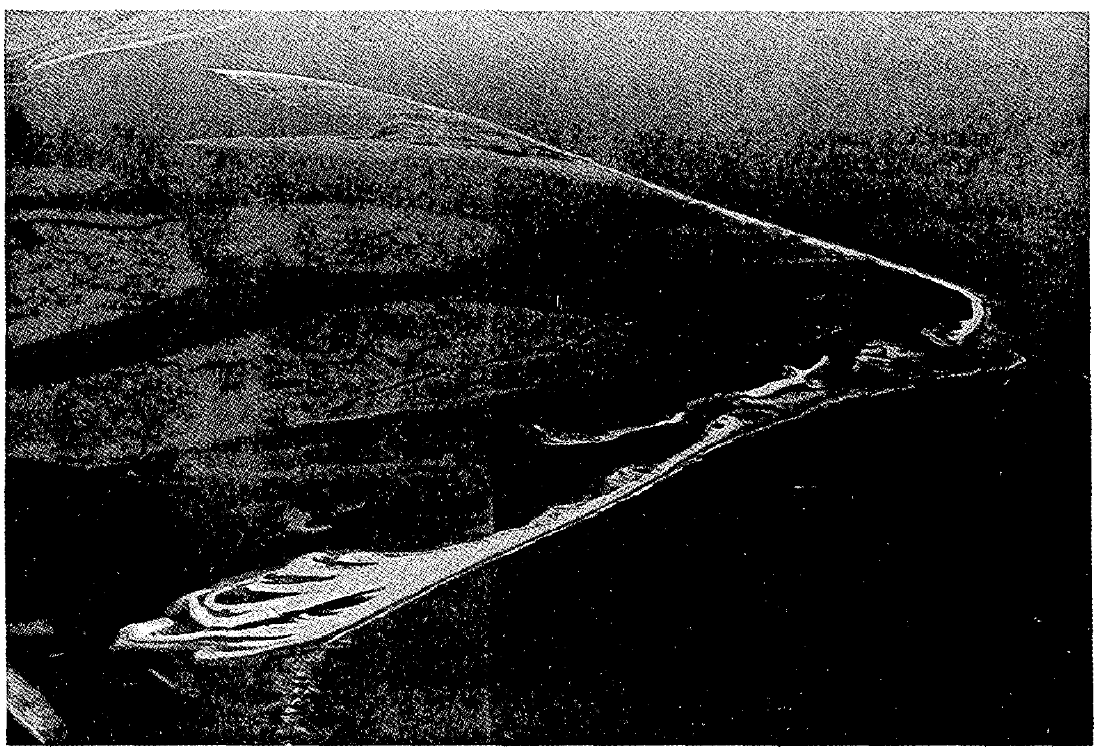


Figure 34. Aerial photograph of Cape Romain. Sediment eroded from the cape moves away in two directions forming recurved spits to the north and west.

Historic charts show southward inlet migration by recurved spit accumulation and shoreline retreat in the vicinity of the inlet. Seasonal profile data shows that Debidue Island is more stable than North Island.

Cape Romain

Cape Romain is a large cuspate foreland. This area is quite unstable and presently migrates landward at a rapid rate. Sediment eroded from the vicinity of the Cape moves away in two directions forming recurved spits to the north and to the west (Fig. 34). Beach profiles in this area reflect a general shoreline instability. The Cape is dominated by beach erosion and washover deposition. A steep beachface and extensive washover terraces are typical for much of the central portion of Cape Romain.

Capers-Bull Islands

Overall, these beaches are generall quite wide (235 ft. at Bull; 240 ft. at Capers) and relatively flat; however, the beaches adjacent to Price Inlet (Fig. 37) are even wider and are the sites of frequent ridge-and-runnel systems. These profiles have been generally stable and are backed by small incipient dunes covered by sea oats (Uniola peniculata) or sparse maritime forest.

Further from the inlet, the profiles exhibit much more variability. Station BUL-1, on central Bull Island, has been erosional throughout the study period. At station CI-02, on Capers Island, although net changes have been small, drastic changes in beach position and configuration can occur, evidenced by the high scarp and the in-place palmetto trees on the beach (Fig. 36).

Isle of Palms

Beaches at the Isle of Palms generally increase in width from 150 ft. at the northern end to 325 ft. at the southern end. With little exception, the entire length of beach is backed by dunes. At profile IP-01, on the northern end of the island, the dunes are small (approximately 2.5 ft.) and sparsely

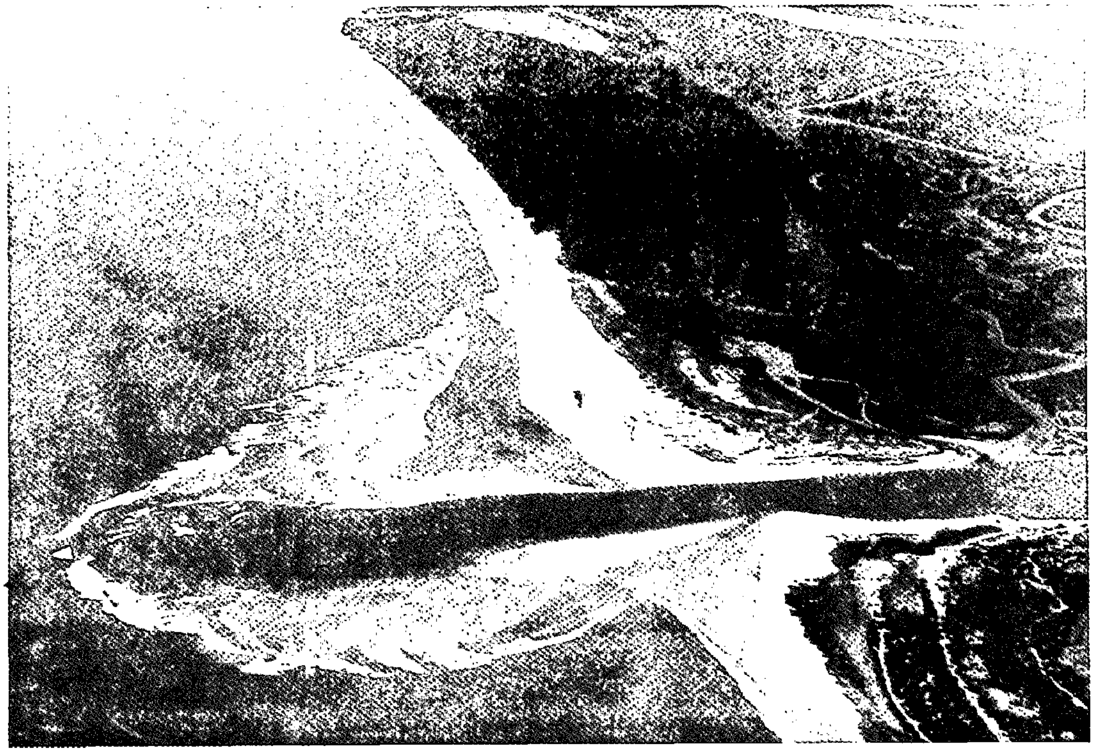


Figure 35. Aerial photograph of Price Inlet and the adjacent beaches of Bull and Capers (view is to the south).

Figure 36. Ground view of profile station CI-02 on Capers Island. Drastic changes in beach configuration are evidenced by the occurrence of a high scarp and in place palmetto trees.

vegetated. A small scarp often occurs due to wave attack. At IP-02, the dunes are still small, but they are wider and better vegetated with sea oats (<u>Uniola</u>). Further south, at profile stations IP-03 and IP-04, dune height increases to 5 ft. (1.5 m).

Effects of development can be seen at all profile locations. IP-01 sits in a grain field and is backed by front row houses. At IP-03 and IP-04, the second row of dunes was leveled for development purposes (Fig. 37).

The beaches along Isle of Palms have generally been stable. With the exception of station IP-04, little change in the position of the beach was noted through the study period.

Sullivans Island

All beach profiles on Sullivan's Island are extremely wide, averaging over 500 ft. (152 m). Ridge-and-runnel systems are common at stations SI-00 and SI-01. Dune height varies between 2.5 and 6.5 ft. Dunes are vegetated by sea oats (<u>Uniola</u>) and at SI-02, by wax myrtle.

Folly Beach

Beaches in this area are characteristically wide (260 ft.) and flat. In general, dune height increases in a southerly direction. At station FB-01, the beach is backed by overwash and small incipient dunes. At FB-02, dunes vary between 3 and 6 ft. in height and are vegetated by sea oats (<u>Uniola</u>). Houses are built in or on the edge of the dune field. The largest dunes on the island occur at FB-03. Heights up to 15 ft. (4.5 m) were measured. Development is confined to a small road through the back of the dune field.

The erosional-depositional trends along Folly Beach are highly variable. Slight net erosion was measured at FB-01 through the study period. At FB-02, slight accretion occurred. Exact determination of erosion-deposition rates at station FB-03 are impossible. In almost every instance, the permanent profile stakes were either removed or eroded away between surveys.

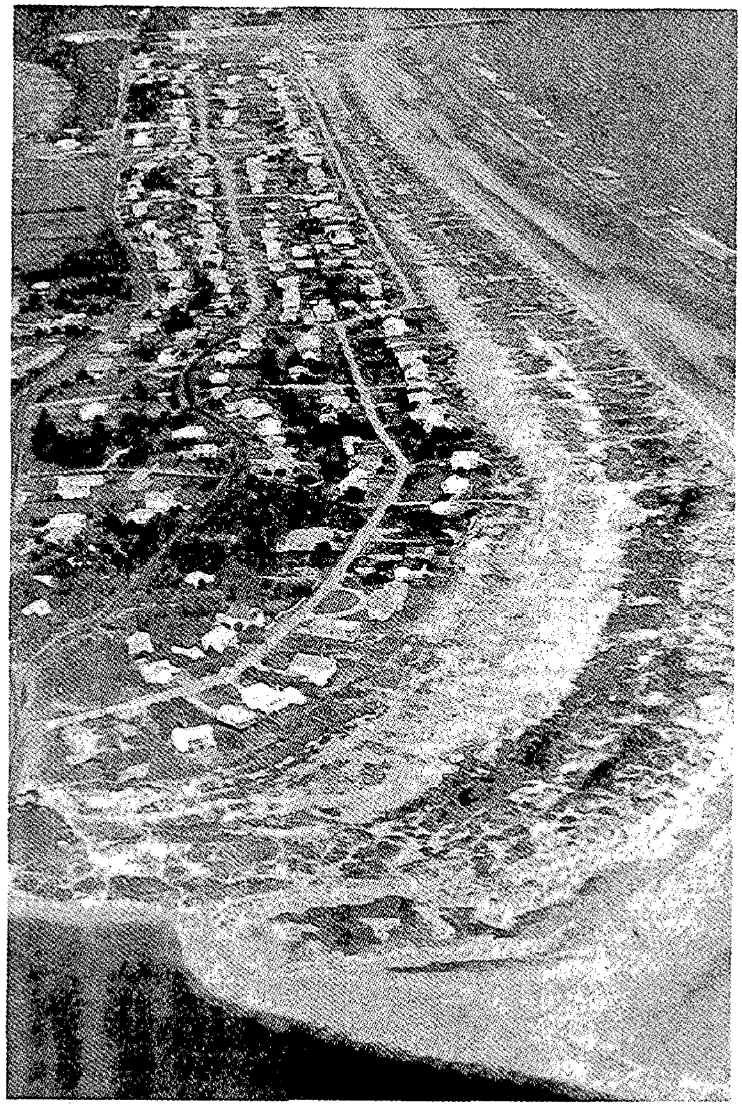


Figure 37. South end of Isle of Palms. Southerly migration of Breach Inlet has allowed the deposition of a recurved spit at the south end of the Isle of Palms. Note houses built on older recurves. Large open area is where a developer has flattened the sand dunes in the location of profile stations IP-03 and IP-04. View looks north.

Kiawah Island

Kiawah Island is composed of a series of prograding beach ridges that have been highly modified on either end by migration of adjacent tidal inlets. In the central portion of the island, the beach is wide (80 - 300 ft.) and flat. The dune area in this part of Kiawah is also relatively wide, averaging between 250 - 300 ft. (75 - 90 m). There is usually a well-defined foredune ridge that rises 5 - 10 ft. (1.5-3 m) above the swash line of high spring tides. In most of this area, there is also an intermediate high dune ridge as well as a high dune ridge at the back portion of the grass vegetation. The vegetation in the dunes is dominated by Uniola (sea oats), Iva imbricata (sea elder) and Croton A three-dimensional block diagram of a segment of this zone is given in Figure 38. Further to the east is an area characterized by progradation. The beach in this area is wide, averaging about 425 - 460 ft. (130 - 140 m) and is characterized by consistently larger depositional features than those found in the mid-barrier straight beach. Well-developed ridge-and-runnel systems are common in this area. The backshore is highly complex and extremely wide, reaching a maximum width of approximately 4.3 miles (2.7 km). The beach ridges are quite high in places, commonly attaining heights of 10-15 ft (3-4 m). They are often separated by expanses of salt marsh averaging approximately 650 ft (200 m) in width. Many tidal creeks are located between the beach ridges, and, in some places, the meanders of the creeks cut into the ridges. Generally, the beach ridges are covered with climax forests dominated by live oaks and palmettos, but there are a few that have pine forests of unknown origin.

Near the eastern end of Kiawah Island, the beach is frequently overwashed during high spring tides and storms. The intertidal beach in this area is relatively complex, ranging in width from approximately 60 ft. to over 200 ft. In places, the beach is steep and undergoes some dramatic seasonal changes, with ridge-and-runnel systems and well-developed low-tide terraces having been observed during the summer months. The opening and closing of the two small tidal inlets that occur in the area bring about changes in the profile, such as the development of small tidal deltas at the mouths of the creeks. The most conspicuous features of the intertidal zone are the large outcrops of peat and intertidal muds. These deposits commonly contain abundant razor clams and oysters in life position, all of which are less than 50 years old. There is no recent dune area along this stretch of the beach. The washover terraces and fans are building into a salt marsh dominated by Spartina alterniflora (smooth cordgrass) and Spartina patens (salt-meadow cordgrass). The supratidal sand areas contain abundant Salsola kali (Russian thistle) and other dune vegetation. The washover terraces average 65 - 98 ft. (20 - 30 m) in width and have flat to slightly landward dipping surfaces that are littered with shell and heavy mineral accumulations. There are a few isolated wind-shadow dunes which attain a height of 2-4 ft. (.6-1.2 m). This section of the beach contains an unusually large percentage of heavy minerals, presumably a result of their concentration by waves as part of the erosional process. A unique aspect of this area is the fact that the beach zone can be intensely eroded by runoff of rain water. During heavy rains, water will accumulate behind the washover terraces and the low foredune ridges. As this water eventually breaks through these natural dams and spills down the beach front, large erosional rills and channels are developed.

The west end of the island is a recurved spit complex associated with Kiawah Inlet. This spit is 1.7 miles (2.1 km) in length and has a maximum width of 2000 ft. (Fig. 39). The growth of the spit present today was initiated around 1949. In terms of its morphology, the spit is made up of essentially two zones: a) recurved, vegetated dunes, and b) the intertidal beach zone. The intertidal beach zone is wide and flat, averaging about 300-600 ft. in width. The beach profile normally contains two low-amplitude

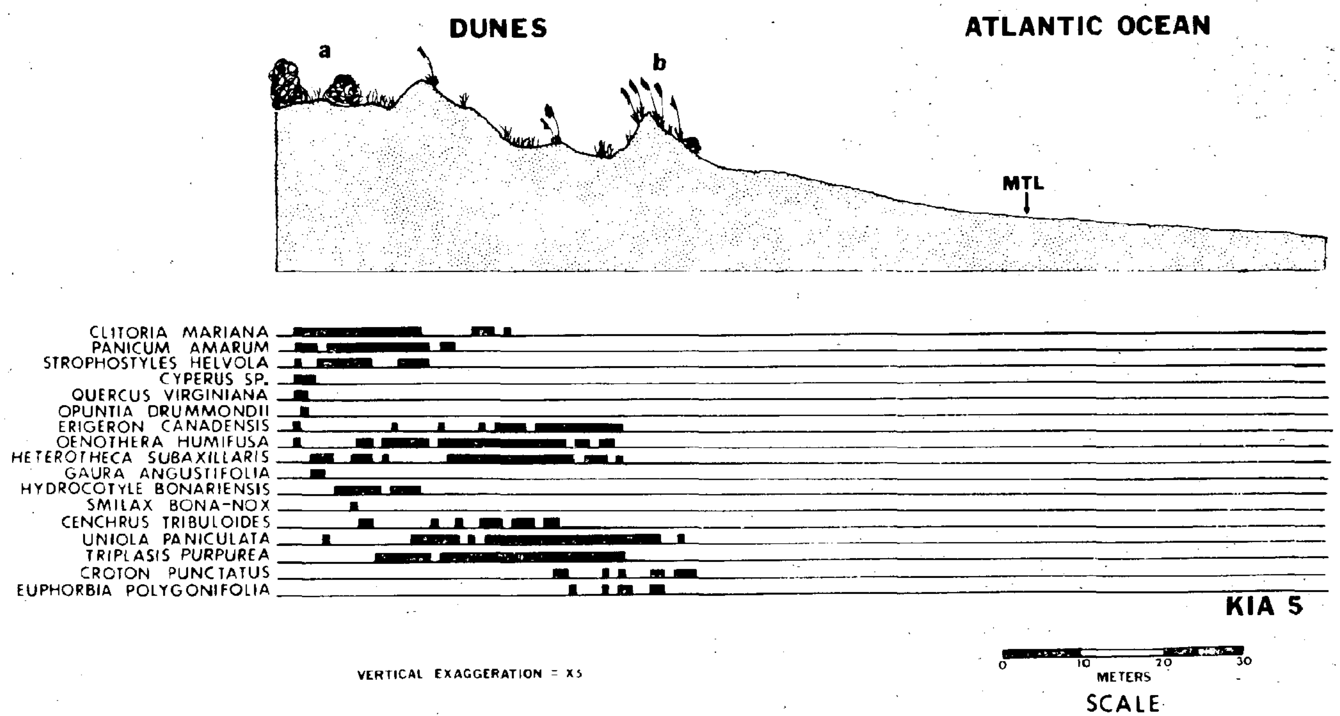


Figure 38. Three-dimensional block diagram of a segment of the beach and dune ridge environment of Kiawah Island. The transect extends from mean tide level (MTS) across the foredune ridge (b) to the rear dunes (a). The diagram shows the vegetation zonation for this section of Kiawah Island (from Hosier, 1975).

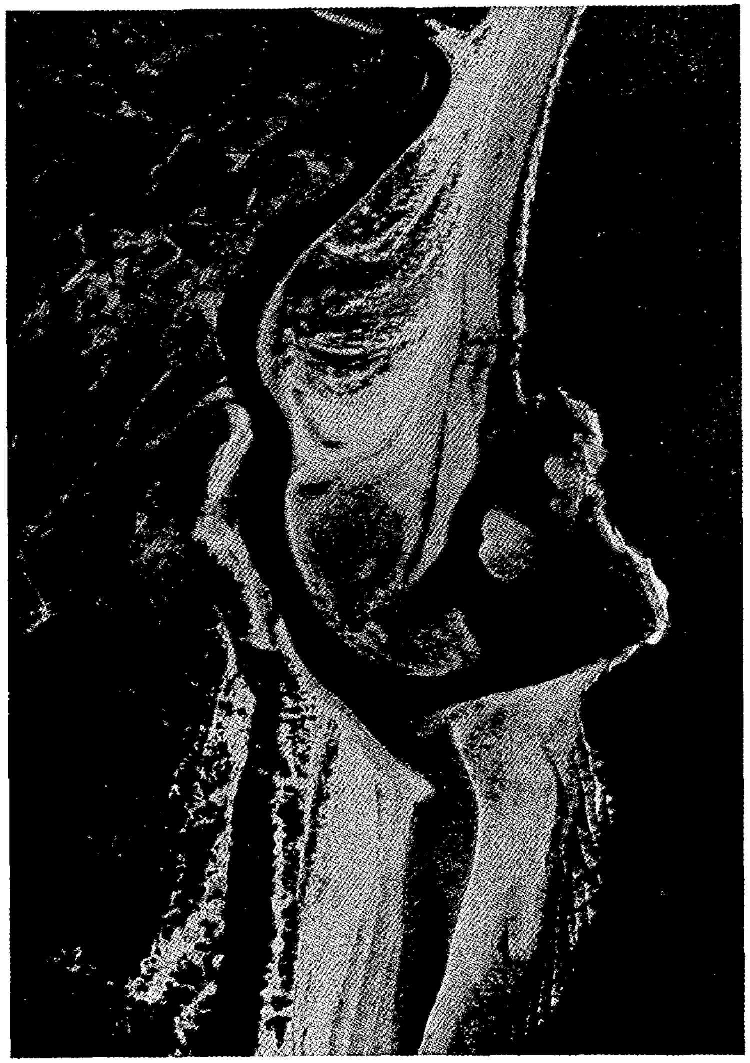


Figure 39. West end of Kiawah Island. The lateral migration of Kiawah River has resulted in deposition of this classic recurved spit. View looks to the north toward Kiawah Island.

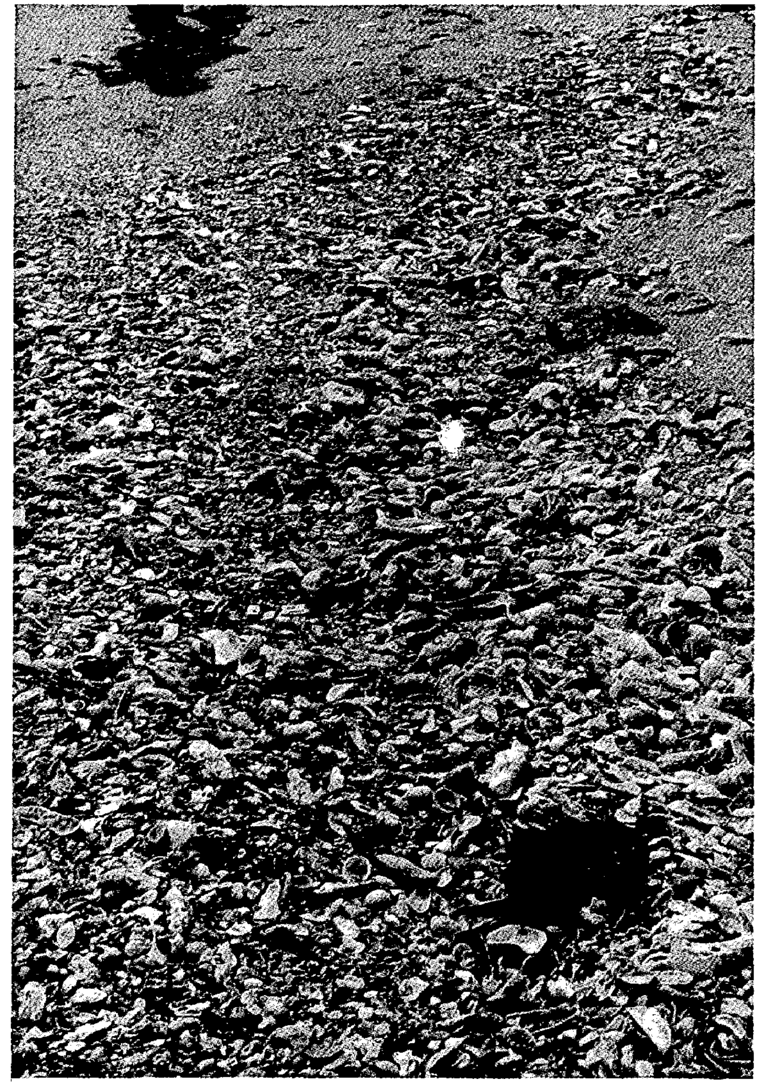


Figure 40. Ground view of profile station EB-01 at Edisto Beach showing the local occurrence of shell beach ridges and large shell overwash deposits.

ridges on the seaward half of the profile. On several occasions, the inner ridge welds to form a very low-amplitude berm. The dune ridges are distinctly linear and curve in toward the Kiawah River. The ridges are continuous for several hundreds of feet and attain a maximum height of approximately 10 ft. (3 m) above the swash line of high spring tides. It is evident that the neck of the spit has been overwashed by storm surges during the past decade. Therefore, the highest dunes are found in the widest portion of the recurve. The dunes are vegetated primarily by grasses, with Uniola, Ivy, and Croton being the most common forms. Spartina patens (salt-meadow cordgrass) and Spartina alterniflora (smooth cordgrass) occupy the swales between the ridges on the landward side of the spit.

Edisto Beach

Edisto Beach is generally narrow (100 - 125 ft.) and steep. It is largely a transgressive or erosional type of barrier. Exposures of marsh peat on the beachface at Edisto Island are not uncommon. The high contribution of shell material in the sediment has resulted in a large grain size. Often, this coarser material is concentrated in shell cusps on the beachface.

The character of the area backing the beach is highly variable. At EB-01, shell beach ridges occur locally (Fig. 40). Large shell overwash fans are transgressing over active salt marsh. At station EB-02, the beach is backed by a remnant maritime forest at the northern end of the public camping area. EB-03 is characterized by low dunes (3-5 ft.) backed by front row houses.

Beach profile data indicate that erosion of these beaches is largely related to storm activity. Station EB-01 showed net erosion throughout the study period, most likely related to the low elevation of the beach in this area. Station EB-02, however, showed overall stability, and EB-03 demonstrated net accretion. Therefore, the exposed marsh peat and other indications of a rapidly eroding profile are short-lived features. It should be stressed, however, that although these areas show an overall stability or accretion, they have been highly variable at times.

Hunting Island

Hunting Island is a state-owned park facility. Beaches in this area are quite wide (about 300 ft.) and of intermediate steepness. The beaches are backed by low dunes and, in the central portion of the island, maritime forest. The highest variability measured in the area occurred at station HI-02 where erosion of up to 8 ft. (2.5 m) between monthly surveys was measured in 1976. Evidence of these rapid changes are the tree remains exposed in the present beachface (Fig. 41).

Hunting Island has been the site of two beach nourishment projects. The source for the first, in 1964, was a large borrow pit in the central portion of the island. Sand for the more recent nourishment was obtained from the shoals at the mouth of Fripp Inlet (Fig. 42).

Hilton Head Island

Hilton Head Island, South Carolina's development "jewel" is the site of some of the most luxurious summer and year-round homes on the east coast. Island beaches are characteristically wide (300 ft.) and of moderate steepness. The beaches are generally backed by some sort of dune ridge or dune system. At HHI-2 (Fig. 43), a low, planted ridge covered by *Uniola* (sea oats) occurs. At HHI-3, a 6 ft. (2 m) ridge was created artifically from coarse *dredge material*. The back portion of the ridge is covered by low grasses, but the face of the dune is bare and exposed to wave attack. Further north at HHI-04 (Fig. 44), a wide (3 ft.), high dune ridge is covered with a healthy growth of *Uniola*. Other flora are scattered on the seaward edge of the dunes.

Generally, the beachfront on Hilton Head shows remarkable stability or accretion. One notable exception occurs at station HHI-3 where slow, steady erosion was measured throughout the study period. This area is not suffering

Figure 41. Tree remains exposed on the present beachface in the locality of station HI-02 at Hunting Island.

Figure 42. Aerial view of Fripp Inlet showing the source of sand for the more recent nourishment project on Hunting Island. The sand was obtained from the shoals on the seaward side of Fripp Inlet, referred to as the ebb-tidal delta.

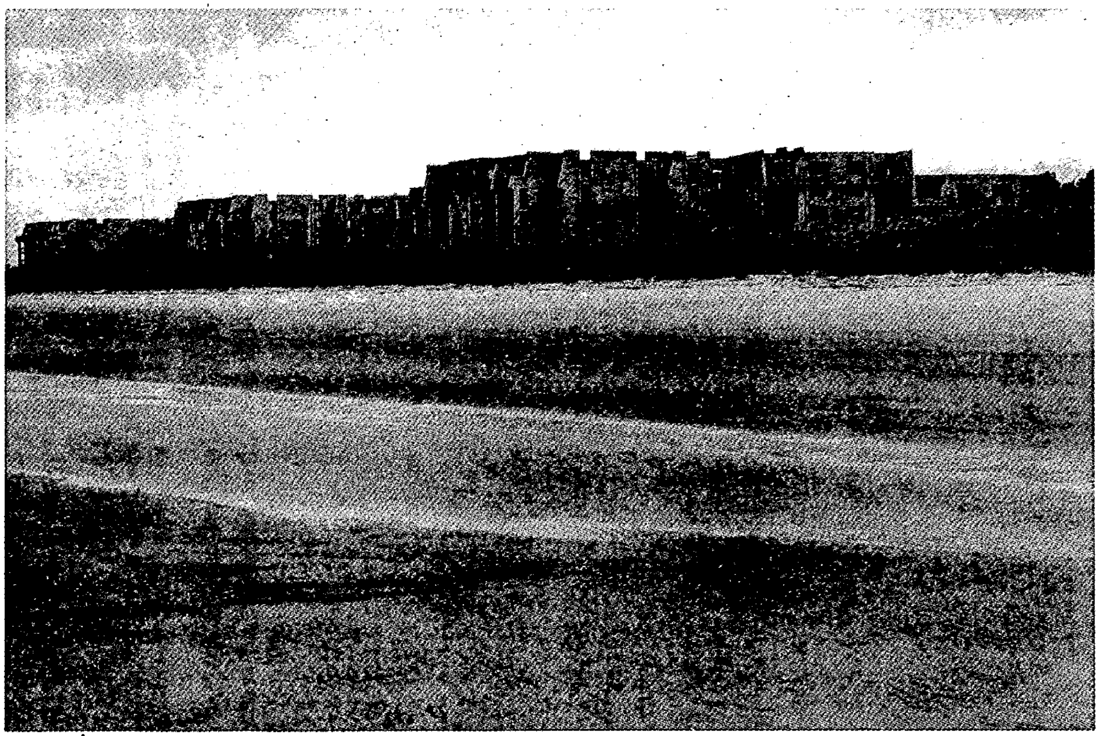


Figure 43. Ground view of profile station HHI-2 at Hilton Head Island. The beach in this location is backed by a low planted ridge covered by Uniola (sea oats).

Figure 44. Ground view of profile station HHI-04 at Hilton Head Island. Here, there is a naturally occurring dune ridge about 3 ft. (1 m) high also covered by a growth of Uniola.

from erosion due to extreme waves or tidal currents. Instead, it is felt that this sudden change in erosional character of the beach is related to the artificial shaping and molding of the beach. This practice is referred to as beach "manicuring" and often creates more problems than it may immediately solve.

LONG-TERM CHANGES

Up to now, this report has concentrated on the short-term variability and erosion-deposition trends along the South Carolina coast. This information is valuable in providing insights of the day-to-day changes on beaches and barrier islands, as well as defining areas of general stability or instability. However, it is most important to homeowners and coastal planners to examine the longer-term variations in these areas. An important consideration in any beach management program is the establishment of a reasonable set-back line, seaward of which no construction is allowed. Critical to the determination of such a line is the knowledge of the changes that can be expected along any given section of beach through time. The individual erosion-deposition curves presented in this section detail the variability that exists at given locations over the past 25 to 50 years. Erosion-deposition data in this report could be used in conjunction with existing environmental data (wave height, storm surge expectance, etc.) to establish zones where development should be prohibited.

Study Procedure

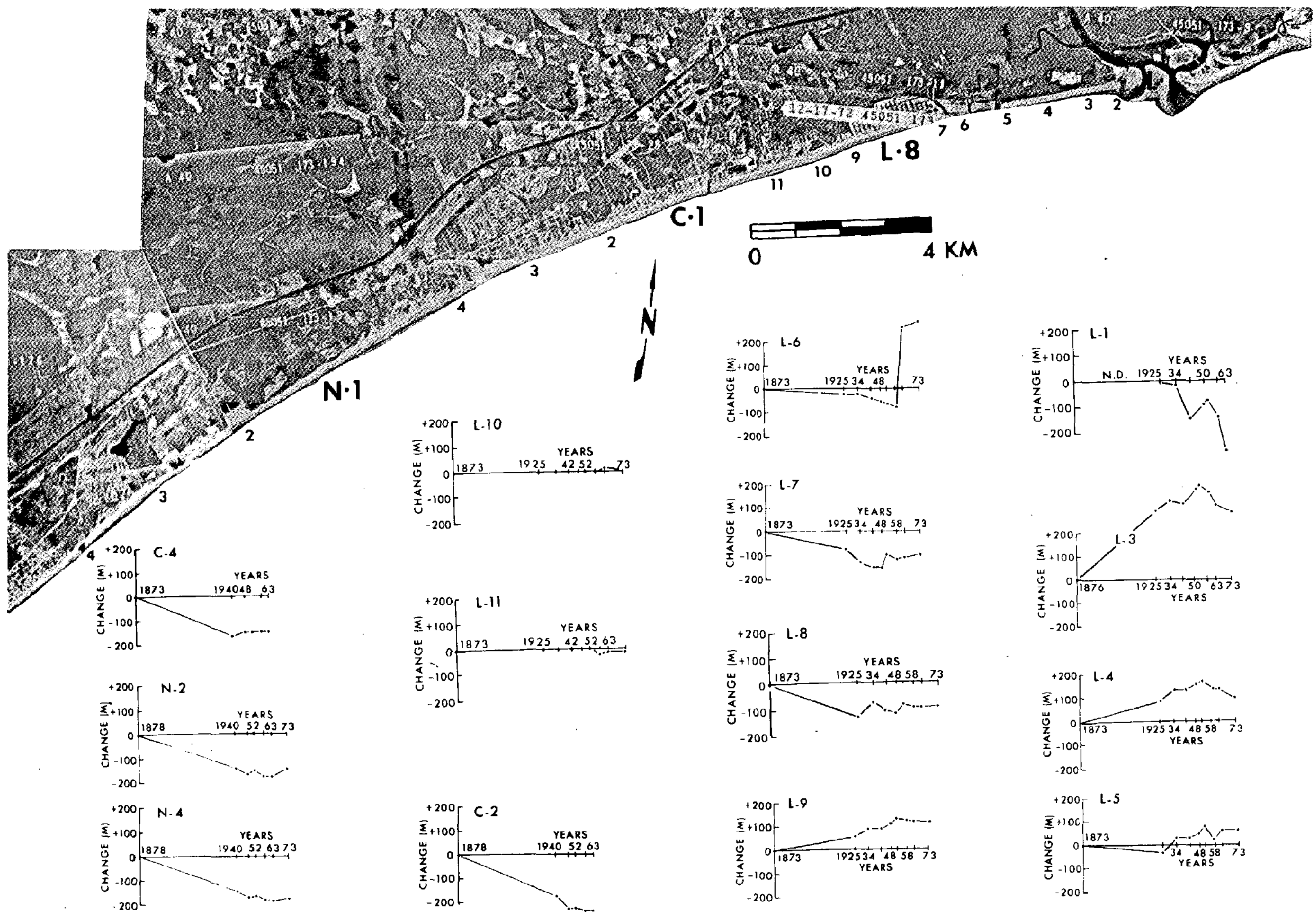
Information appearing in the following section comes from two sources: coastal charts and sequential vertical aerial photographs. Vertical aerial photographs were obtained from the U.S. Agricultural Stabilization and Conservation Service, the United States Geological Survey and the National Archives. Charts were obtained from the National Ocean Survey, the Waterways Experiment Station in Vicksburg, Mississippi and the Coastal Engineering Research Center in Washington, D. C.

Information on shoreline changes prior to the years of photographic record were obtained from NOS hydrographic survey sheets dating to 1859 and high water shoreline change maps prepared by the U.S. Army Coastal Engineering Research Center, Washington, D.C. Shoreline positions along each survey line were input to the IBM 370 to be included with the existing photographic information. This work was done as two separate studies, one of Charleston County and the other for Horry, Georgetown and Beaufort Counties (see refs. 20 , 36 and 37).

Data Presentation

As previously discussed, an examination of short-term variability along the coast can provide for a rapid estimate of shoreline behavior at any location. However, this type of information might be misleading in certain instances. Rapid changes which average out over a longer period of time can result in a stable trend. A large amount of erosion observed as a short-term variation could subsequently be balanced by a gain of sediment along the beach. For that reason, another level of information, individual erosion-deposition graphs have been included. In areas where changes are somewhat similar for large stretches of coastline, only representative curves are shown on the figures. In areas that exhibit higher coastline variability (especially near tidal inlets), all the data are presented. Erosion-deposition figures for all measured stations have been prepared and can be acquired from the Coastal Research Division, Department of Geology, University of South Carolina, Columbia, S. C. The graphs that appear in this report (Figs. 45-61) are included only to illustrate concepts and to provide a means for rapidly determining general trends along various areas of the coast.

Figure 45. Erosion-deposition graphs for stations L-1 (Little River) to N-4 (Myrtle Beach). These graphs show the individual changes that were measured from successive aerial photographs and coastal charts. A positively sloping line indicates net accretion; a negatively sloping line shows net erosion. An adequate understanding of the variability along this section of coastline can be achieved only through careful inspection of these individual graphs. For example, the relatively high short-term variability seen at stations C-2 and N-3 is the result of erosion occurring between 1940 and 1948 and 1952 and 1958. The high variability seen at Little River Inlet (stations L-1 through L-5) on the other hand, is the result of repeated large-scale changes in shoreline position. This is related to the constant shifting of the inlet and the resulting modifications in wave processes and sediment transport patterns along adjacent beaches. The variability seen at stations L-6 and L-7 attest to the effect that even small inlets (Hog Inlet) can have on adjacent beaches.



12-17-72 45051 173
L·8
C·1
N·1
0
4 KM
N
L-1
L-3
L-4
L-5
L-6
L-7
L-8
L-9
L-10
L-11
C-2
C-4
N-2
N-4
CHANGE (M)
YEARS
N.D.

Figure 46. Erosion-deposition curves for stations M-1 (Myrtle Beach) to G-4 (Garden City Beach). The most noticeable characteristic of these curves is the nearly linear change at each station. Stations M-4 and M-6 show steady, gradual erosion throughout the entire period of record. Changes at stations M-2, G-1 and G-3 are consistently small. Intermediate stations behave similarly.

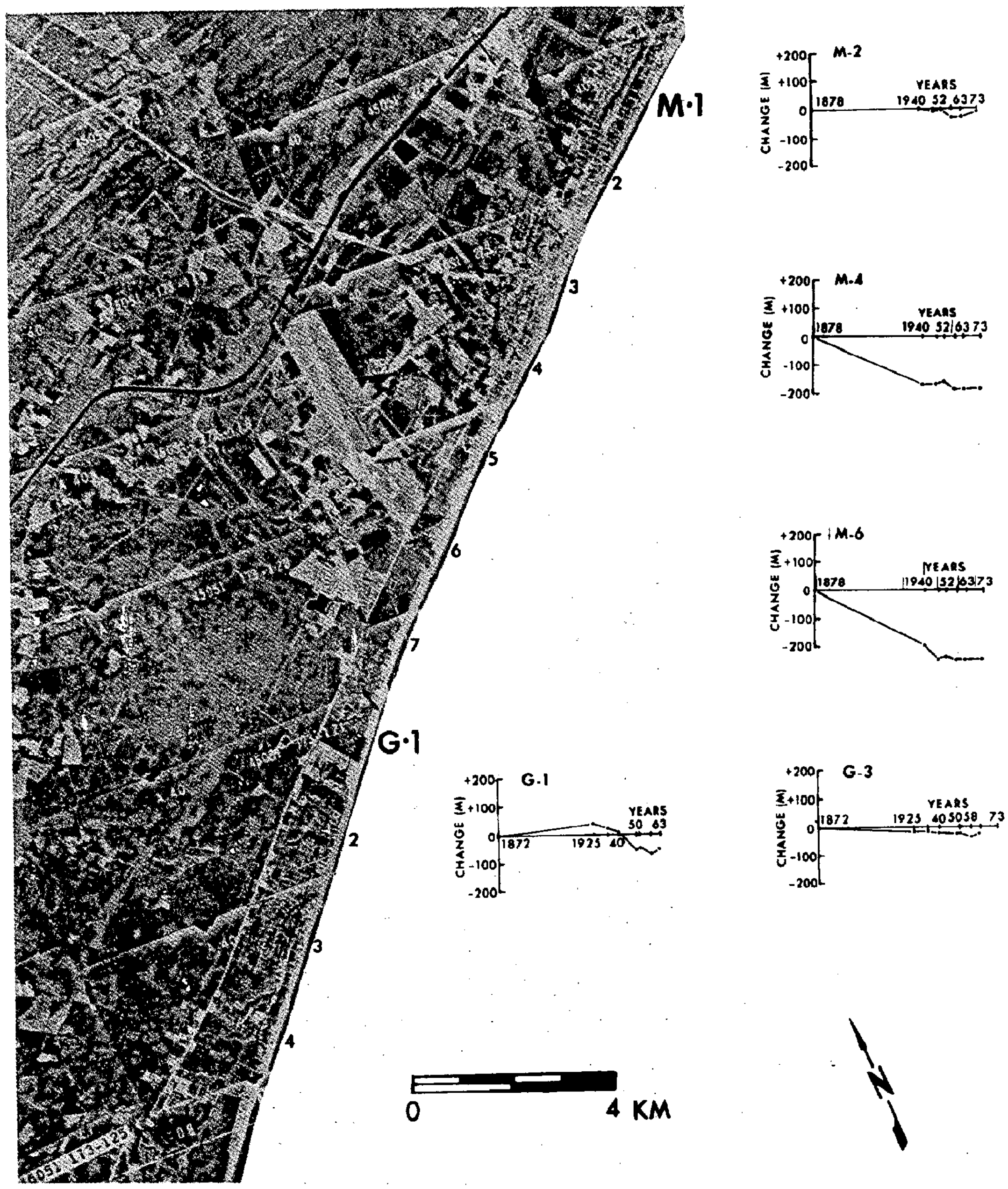

M·1
2
3
4
5
6
7
G·1
2
3
4
M-2
+200
+100
0
-100
-200
CHANGE (M)
YEARS
1878
1940 52 6373
M-4
+200
+100
0
-100
-200
CHANGE (M)
YEARS
1878
1940 52 63 73
M-6
+200
+100
0
-100
-200
CHANGE (M)
YEARS
1878
1940 52 63 73
G-1
+200
+100
0
-100
-200
CHANGE (M)
YEARS
1872
1925 40
50 63
G-3
+200
+100
0
-100
-200
CHANGE (M)
YEARS
1872
1925 40 50 58 73
0
4 KM
N

Figure 47. Erosion-deposition curves for stations G-5 (Garden City Beach) to P-5 (near Pawley's Inlet). The curves show drastic changes in shoreline position in the vicinity of Murrells Inlet. The amount of erosion observed at stations south of Murrells Inlet is nearly equal to the deposition portion of those curves from stations north of the inlet, indicating a shift of sediment rather than a total loss of sand from the system. These trends in the vicinity of Murrells Inlet imply that the effect of migrating tidal inlets is much more important as a short-term event. This is certainly an encouraging thought to those trying to relate tidal inlet processes to changes on adjacent beaches.

Station X-1 and X-3 show only slight change over the short term. This is due to the fact that these figures are based only on erosion measured during the most recent 25 years of record. This example illustrates, how, when using this type of information, the reader must consider all the input he has into the problem, including the erosion-deposition curves and common sense. The location of these stations on a spit flanking an extremely active inlet should indicate to the prospective planner that these areas could be subject to sudden and extreme erosion.

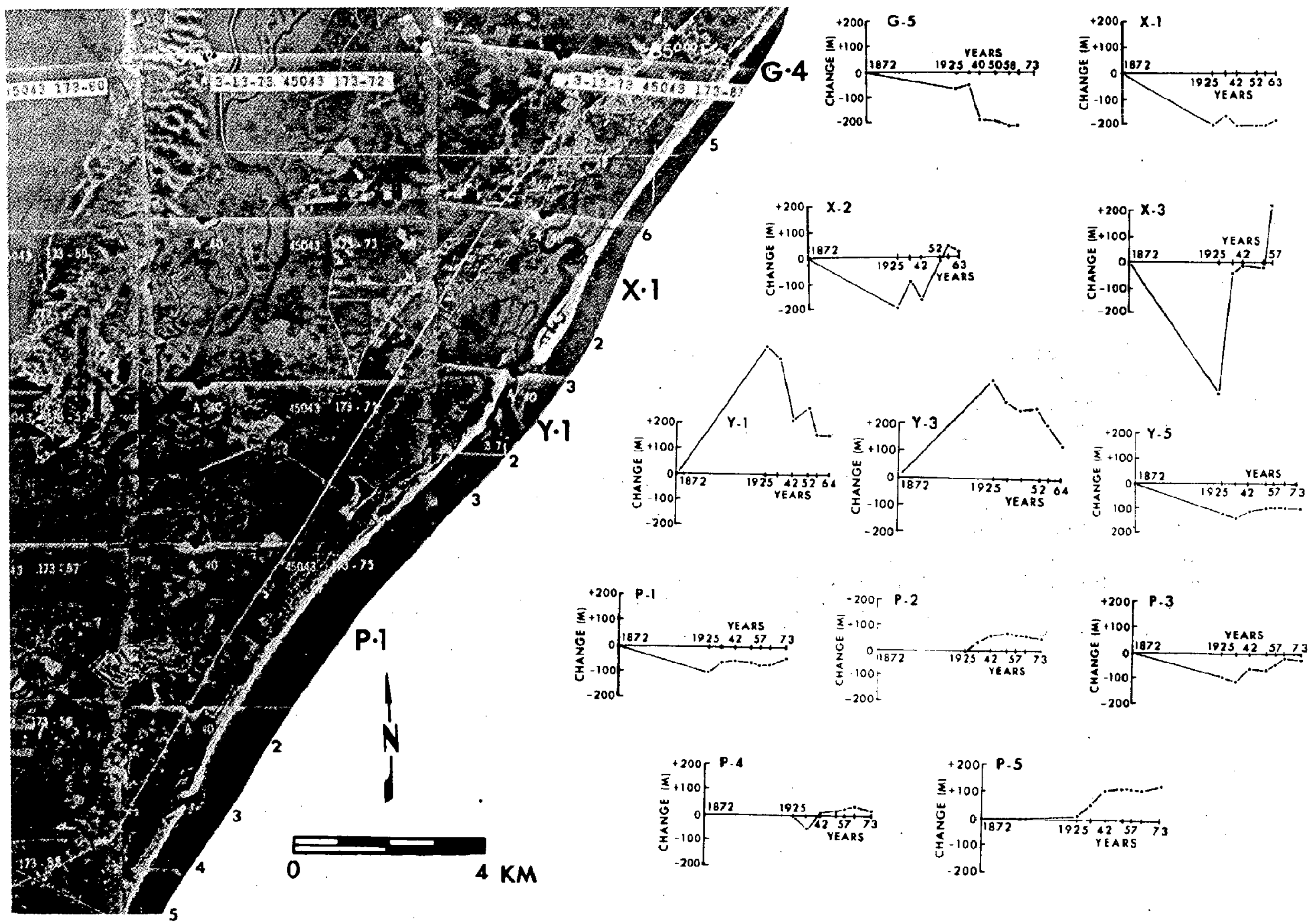

G·4
X·1
Y·1
P·1
N
0
4 KM
G-5
X-1
X-2
X-3
Y-1
Y-3
Y-5
P-1
P-2
P-3
P-4
P-5
CHANGE (M)
YEARS

Figure 48. Erosion-deposition curves for stations D-1 (Debidue Island) to W-6 (Santee Islands). Note the rapid shoreline changes occurring in the vicinity of North Inlet (stations D-3 to I-3). The 3000 feet of shoreline advance at station D-5 between 1934 and 1942 is a result of the southward migration of the Debidue recurved spit past that location and does not represent 3000 feet of steady shoreline advance along that transsect. Note also the rapid and steady shoreline retreat shown at station I-4. This erosion is related to the occurrence of washover fans in the area.

Graphs W-1 through W-6 show shoreline retreat between 1952 and 1973. Inspection of earlier coastal charts showed a different trend. The spit extending northward into Winyah Bay was formed between 1908 and 1928. March deposition occurred subsequent to spit development. Recent erosion is most likely related to damming of the Santee in 1939.

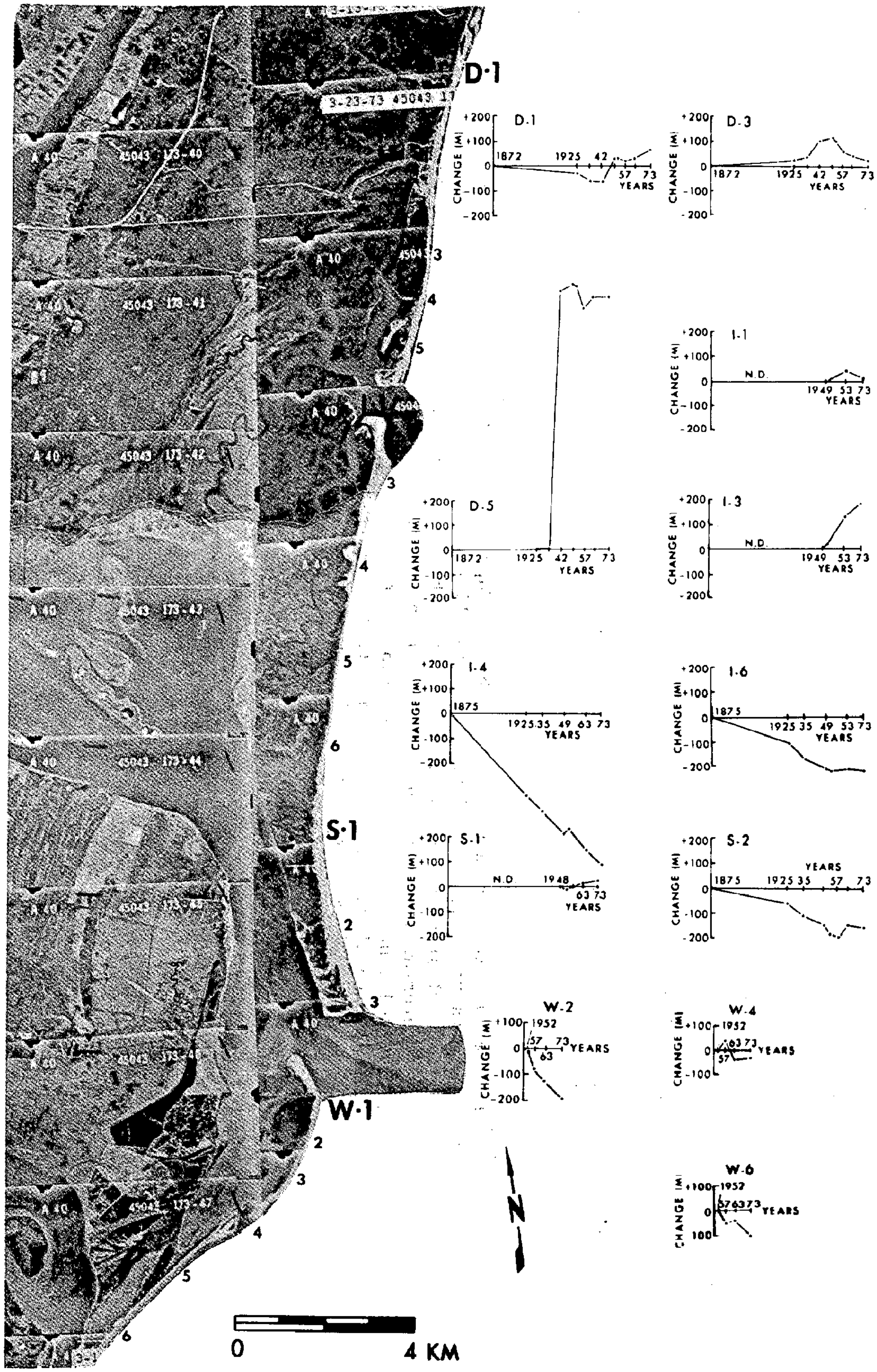

D·1
3-23-73 45043
A 40
45043 173-40
45043 173-41
45043 173-42
45043 173-43
45043 173-44
D·1
CHANGE (M)
1872
1925
42
57 73
YEARS
D·3
1872
1925 42 57 73
YEARS
I·1
N.D.
1949 53 73
YEARS
D·5
1872 1925 42 57 73
YEARS
I·3
N.D.
1949 53 73
YEARS
I·4
1875
1925 35 49 63 73
YEARS
I·6
1875
1925 35 49 53 73
YEARS
S·1
N.D.
1948
63 73
YEARS
S·2
YEARS
1875 1925 35 57 73
W·2
1952
57 73 YEARS
63
W·4
1952
63 73 YEARS
57
W·6
1952
57 63 73 YEARS
W·1
N
0
4 KM

Figure 49. Erosion-deposition graphs for Cape Romain and Raccoon Key. Graph numbers refer to the reference points illustrated on the map above the graphs. Erosional areas are shaded. Cape Romain has undergone steady erosion during the interval of study. However, at location 5, over 2000 feet of accretion have occurred since 1941 and 450 feet (135 m) of accretion have occurred at location 1. The remainder of the reference localities are erosional. The recurved spit at location 13 was not present during the interval 1941-1963. This spit, which is over 4000 feet (120 m) long, accumulated between 1941 and 1968 and grew at an average rate of about 145 feet (45 m) per year.

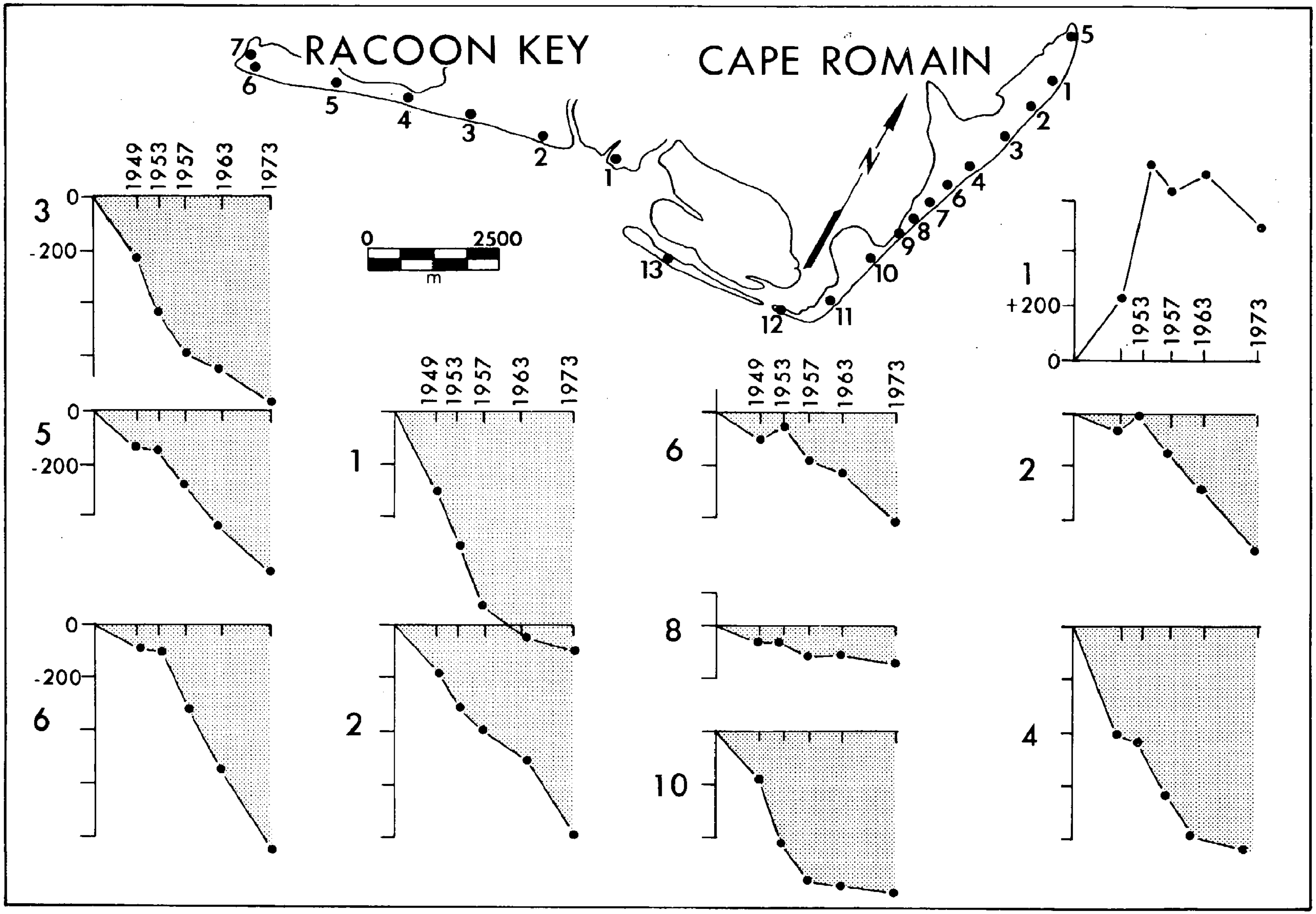

RACOON KEY
CAPE ROMAIN
0
2500
m
N
1949
1953
1957
1963
1973
-200
+200
0

Figure 50. Erosion-deposition graphs for Bull Island. Graph numbers refer to the reference points illustrated on the map above the graphs. Erosional areas are shaded. Note the extensive erosion at the north end of Bull Island, which is open from all sides to wave attack. Over 350 feet (105 m) of long-term erosion is illustrated in graphs 1-4. The south-central portion of the island is characterized by alternate erosion and deposition (graphs 5-9). As much as 1000 feet of deposition occurred between 1958 and 1963 at location 8.

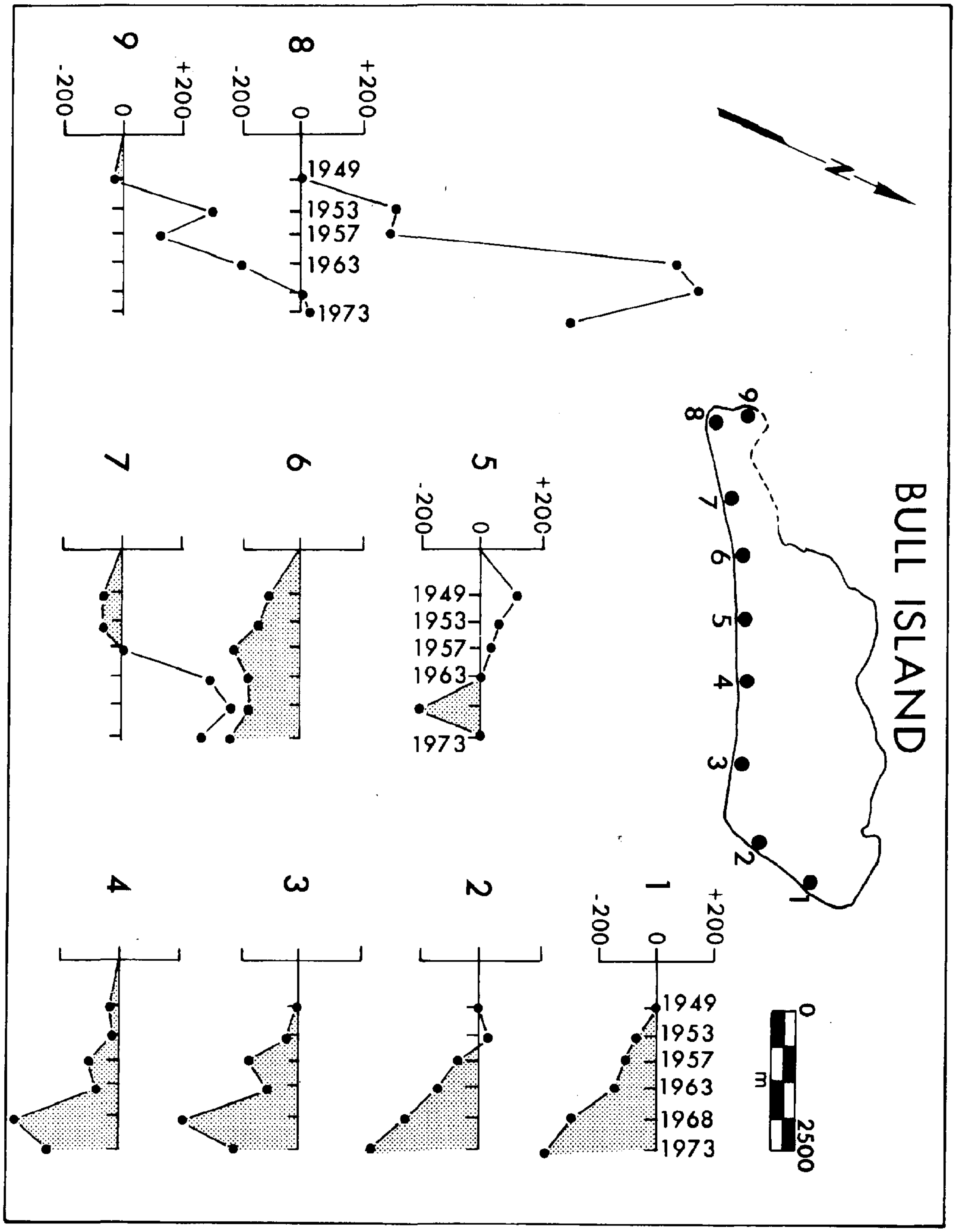
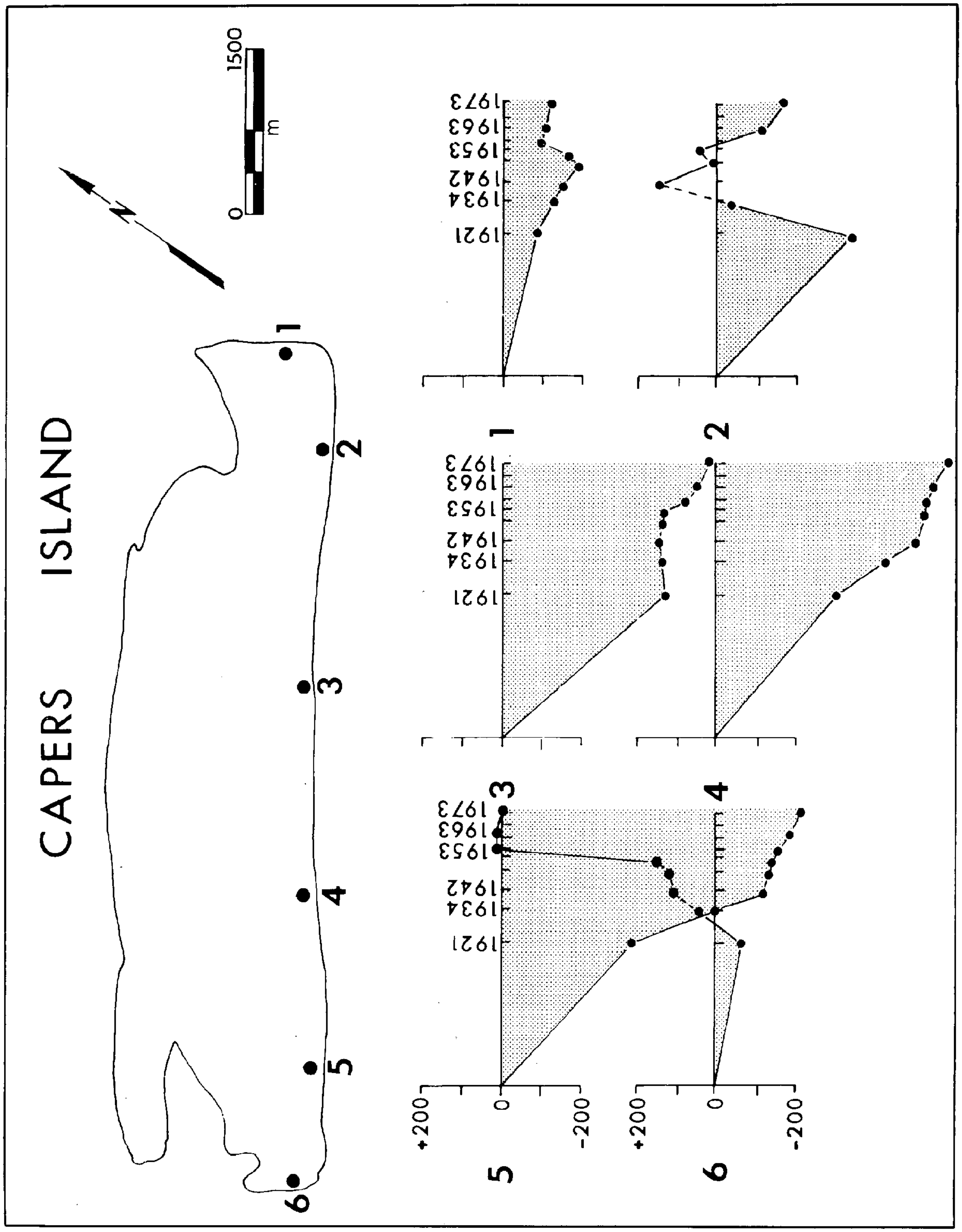

BULL ISLAND
N
0
m
2500
1
2
3
4
5
6
7
8
9
+200
0
-200
1949
1953
1957
1963
1968
1973

Figure 51. Erosion-deposition curves for Capers Island. Note that all stations come within the effect of adjacent inlets and exhibit an unstable or erosional character. The central and southwestern beaches have been strongly erosional since historical coverage. In-place palmettoes can be seen on the present beach-face. The accretion which occurred at station 6 was due to spit growth between 1921 and 1953 which narrowed Capers Inlet by 1000 feet. Graph 1 is measured northeast into the inlet and exhibits erosion and deposition associated with slight oscillations of the inlet channel. The erosional trends of the seaward side of the island are clearly shown by graphs 2-5, which show beach erosion ranging from between 300 and 1000 feet over the study period and acceleration of erosion with time as indicated by a steepening of the downcurve. Graph 5 measures the accretion of a spit system which is building into Capers Inlet to the southwest. The trend for graph 6 indicates a southward migration of Capers Inlet between 1949 and 1958, then a gradual retreat to the north over the past fifteen years.



CAPERS ISLAND
N
0
1500
m
1
2
3
4
5
6
1921
1934
1942
1953
1963
1973
+200
0
-200

Figure 52. Erosion-deposition curves for Dewees Island. The northeastern portion of the island (stations 0-2) has been characterized first by accretion since 1921. In contrast, the southwestern half of the island (graphs 3-5) has experienced continuous erosion up to 2000 feet since 1972. The accretion at stations 0 and 1 is related to the progradation of the large spit subsequent to the shifting of Capers Inlet.

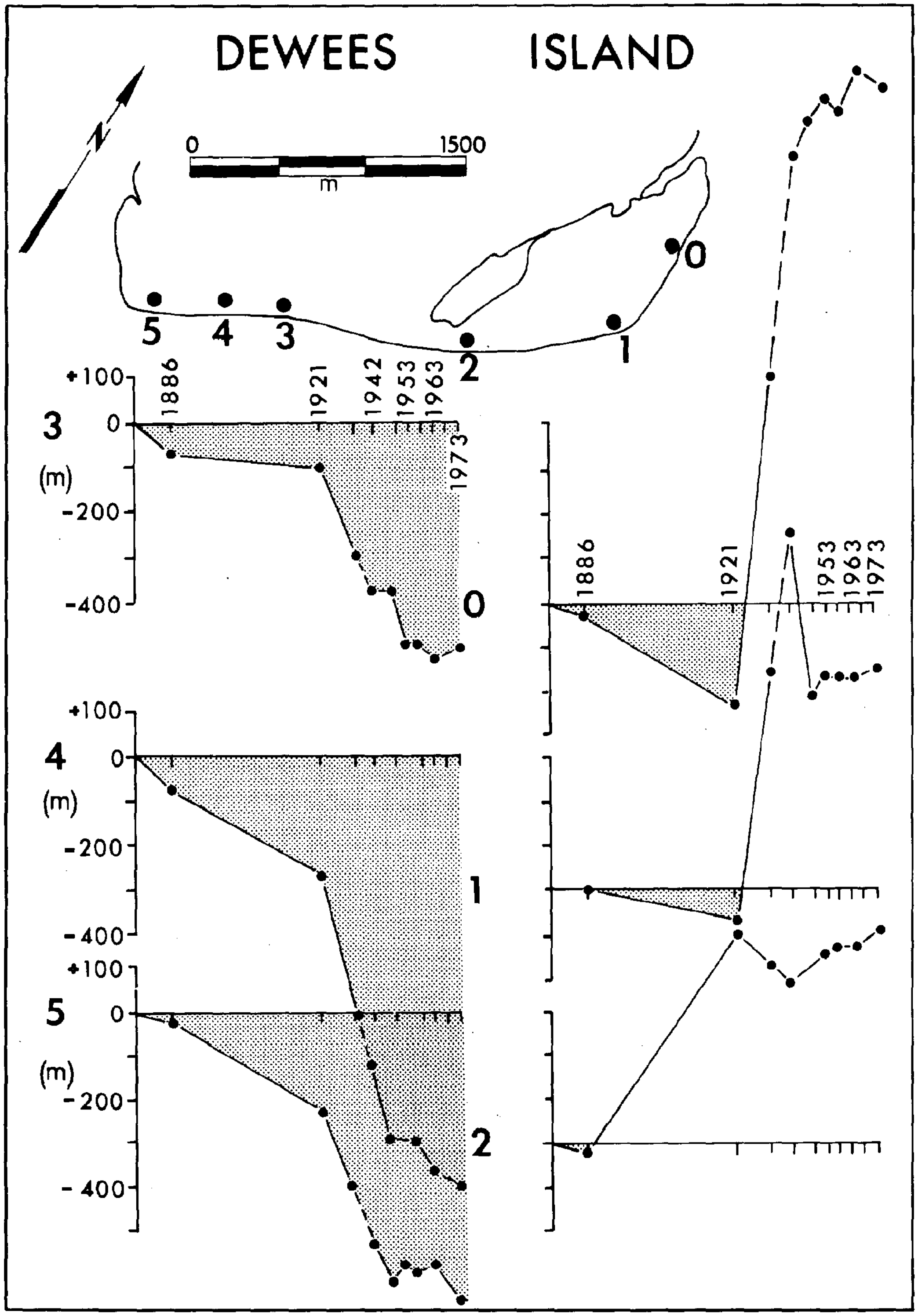

DEWEES ISLAND
N
0
1500
m
0
1
2
3
4
5
+100
0
(m)
-200
-400
1886
1921
1942
1953
1963
1973

Figure 53. Erosion-deposition curves for the Isle of Palms. During the past 100 years, the northeastern end of the island (graphs 3-13) has been characterized by periods of erosion followed by periods of accretion. This has been caused, in part, by changes of Dewees Inlet and its ebb-tidal delta. The central and southwestern shorelines (graphs 15-25) have been accretional or stable since 1872. A field of groins located along these beaches has been partially responsible for this stability.

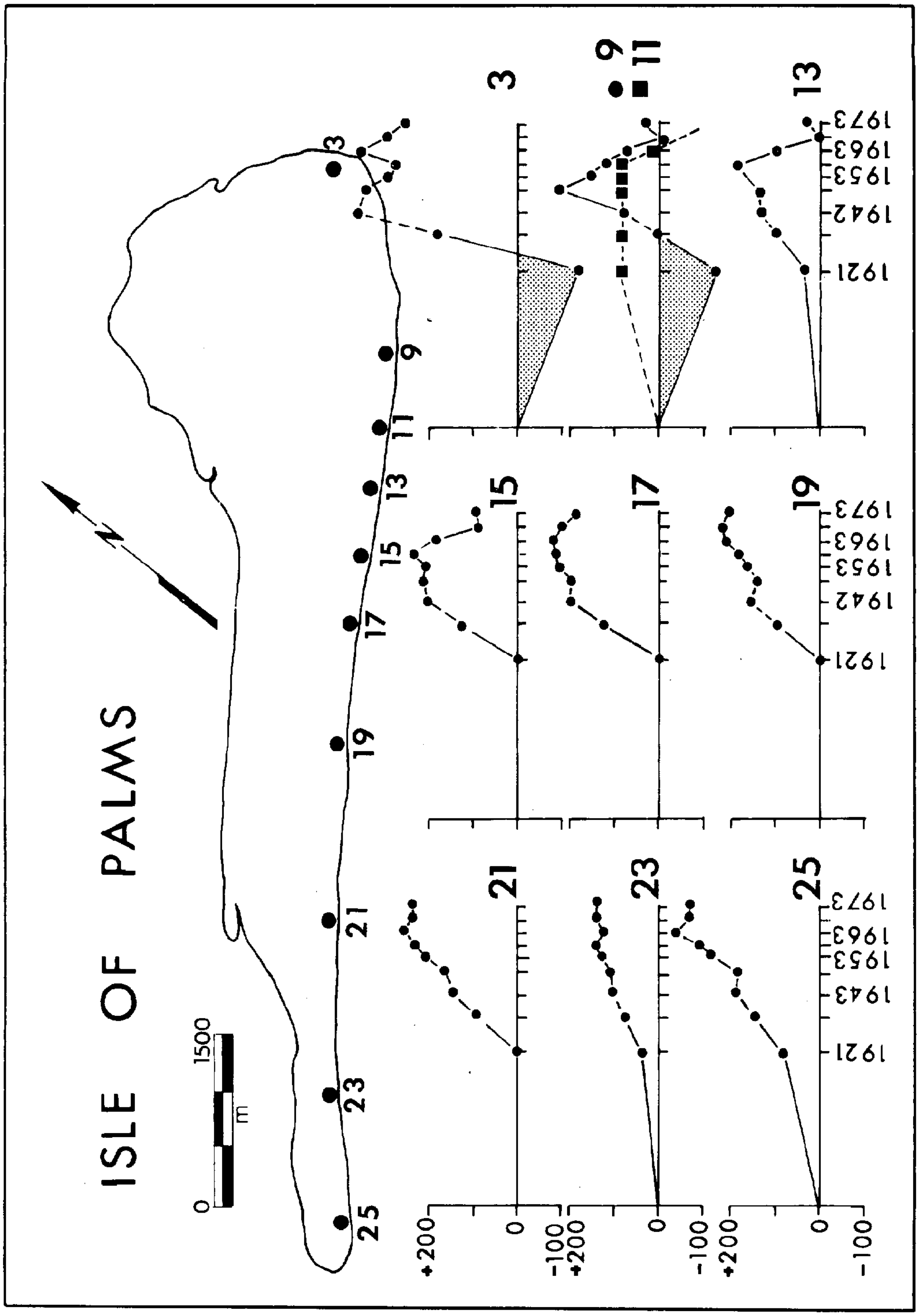

ISLE OF PALMS
0
m
1500
3
9
11
13
15
17
19
21
23
25
+200
0
-100
1921
1942
1943
1953
1963
1973

Figure 54. Erosion-deposition curves for Sullivans Island. Generally, the island beaches have been relatively stable. The northeastern end of the island (stations 2 and 4) has fluctuated in response to changes in the Breaches Inlet ebb-tidal delta. The middle of the island (stations 6 and 8) was accretional between 1972 and 1921. Since that time, the shoreline has been variable. The beaches of the southwestern end of Sullivans Island (graphs 10 and 12) have prograded more than 200 m since 1972.

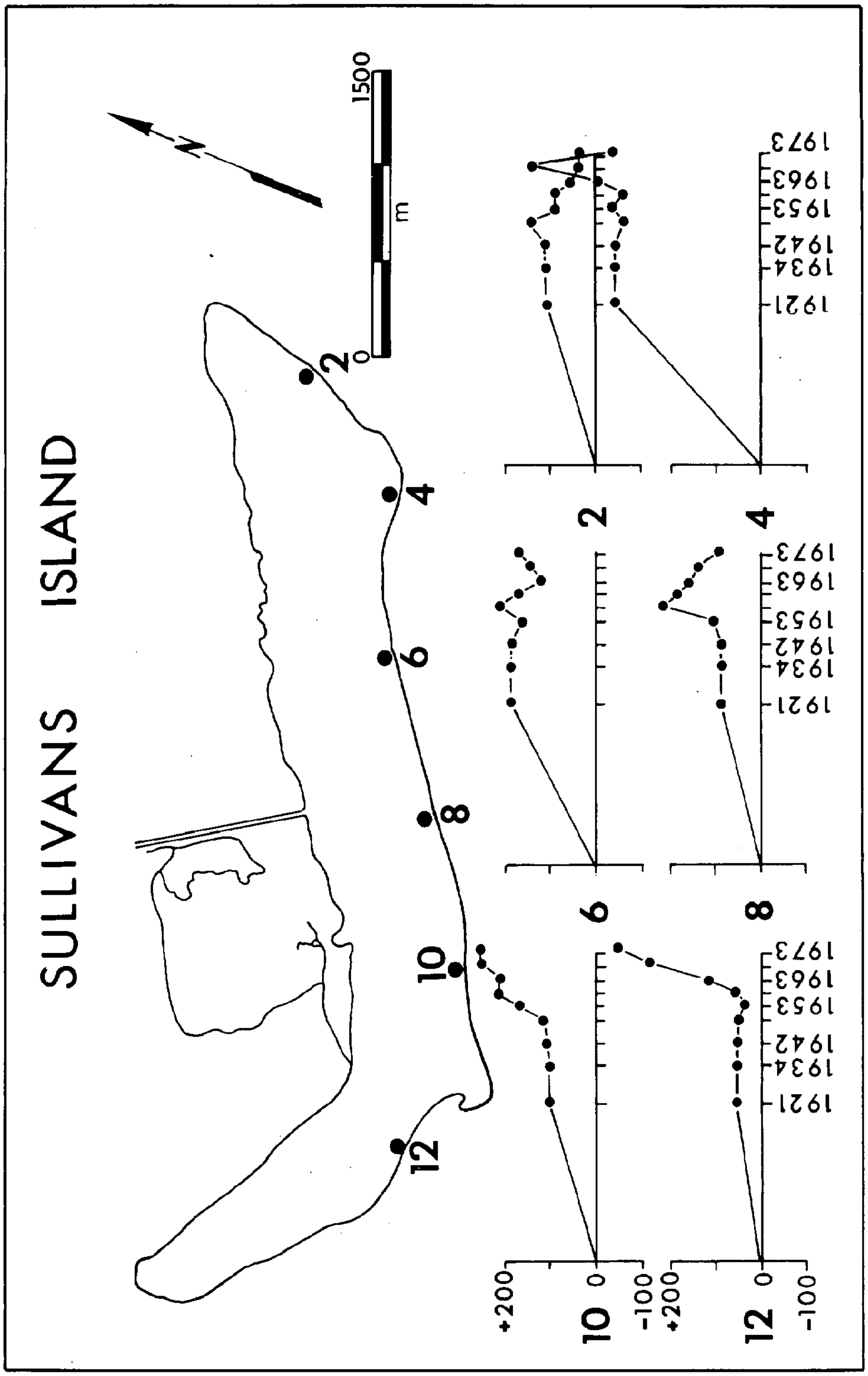

SULLIVANS ISLAND
N
0
1500
m
2
4
6
8
10
12
+200
0
-100
1921
1934
1942
1953
1963
1973

Figure 55. Erosion-deposition curves for Morris Island. The shoreline progradation at station 1(1909-1939), 2 (1900-1953), 3 (1900-1939) and 4 (1900-1939) was due to the recurved spit building into Charleston Harbor. The nearly constant shoreline recession is probably a consequence of the Charleston Harbor jetty construction. The project which was begun in the early 1860's and completed in 1896 caused less sediment to be contributed to Morris Island and to the shoals which fronted the island. Since emplacement of the jetties, these shoals have gradually disappeared, and the resulting beach erosion has totalled 200-1250 m since 1864. The lack of a well-developed foredune ridge on Morris Island has also contributed to the problem.

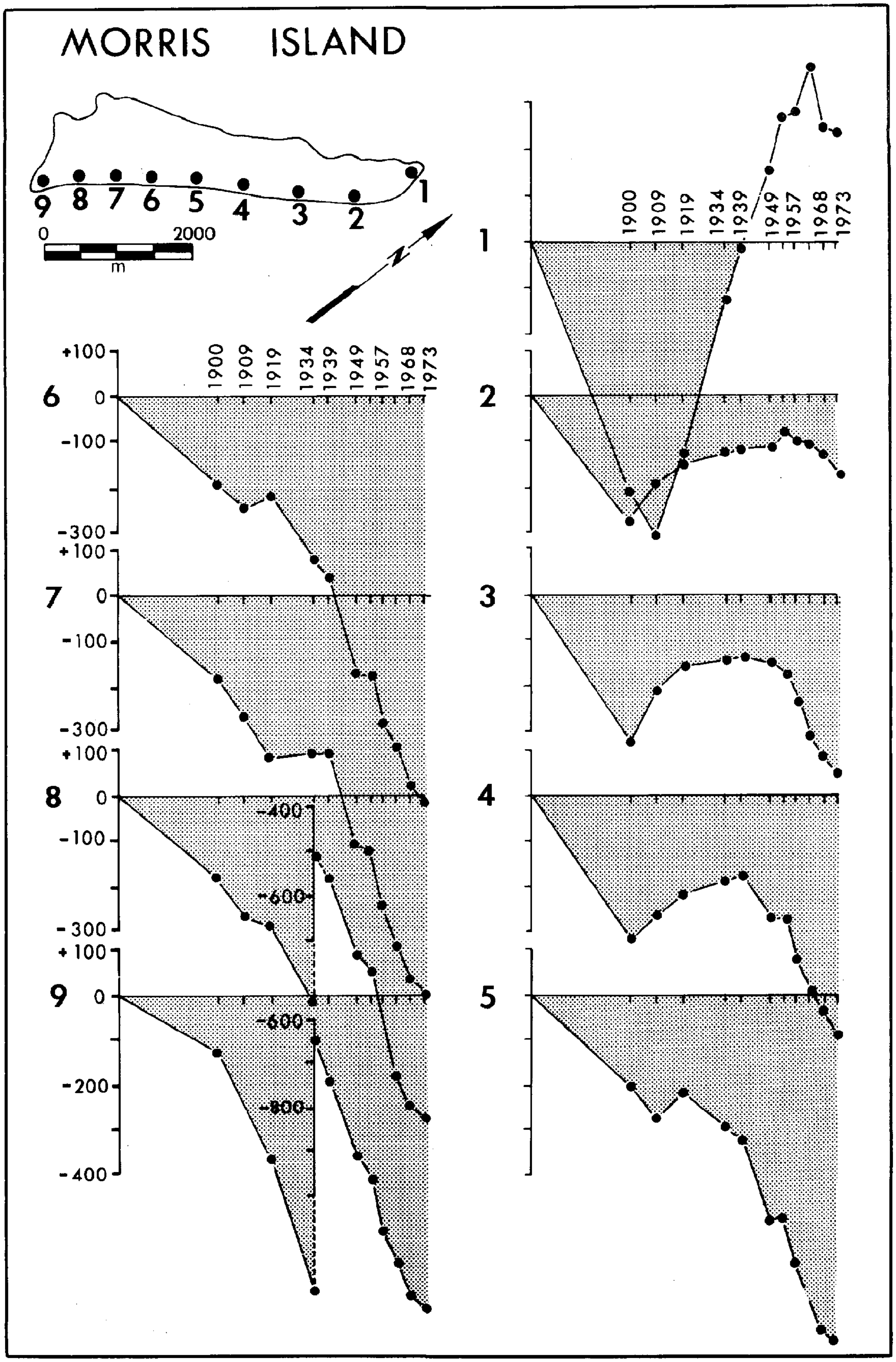

MORRIS ISLAND
9 8 7 6 5 4 3 2 1
0 2000
m
N
1900 1909 1919 1934 1939 1949 1957 1968 1973
+100
0
-100
-300
+100
-400
-600
-800
-200
1 2 3 4 5 6 7 8 9

Figure 56. Erosion-deposition curves for Folly Island. Jetty construction at Charleston Harbor between 1860-1869 and channel migration at Lighthouse Inlet have affected shoreline changes at stations 2, 4, 5 and 8. Beach erosion was continuous in the middle section of the island (graph 10 and 12) from 1857 to 1963, followed by a period of accretion and stabilization. The shoreline at stations 14 and 16 have experienced serious erosion from 1857 to 1921. Since that time, this section has been fairly stable. Shoreline stabilization at Folly Island has been partially accomplished by the construction of breakwaters and groins. Major shoreline changes can be expected after the next hurricane and/or large storm. Because beach houses and other structures are so close to the high water mark, the effect of a hurricane will be devastating.

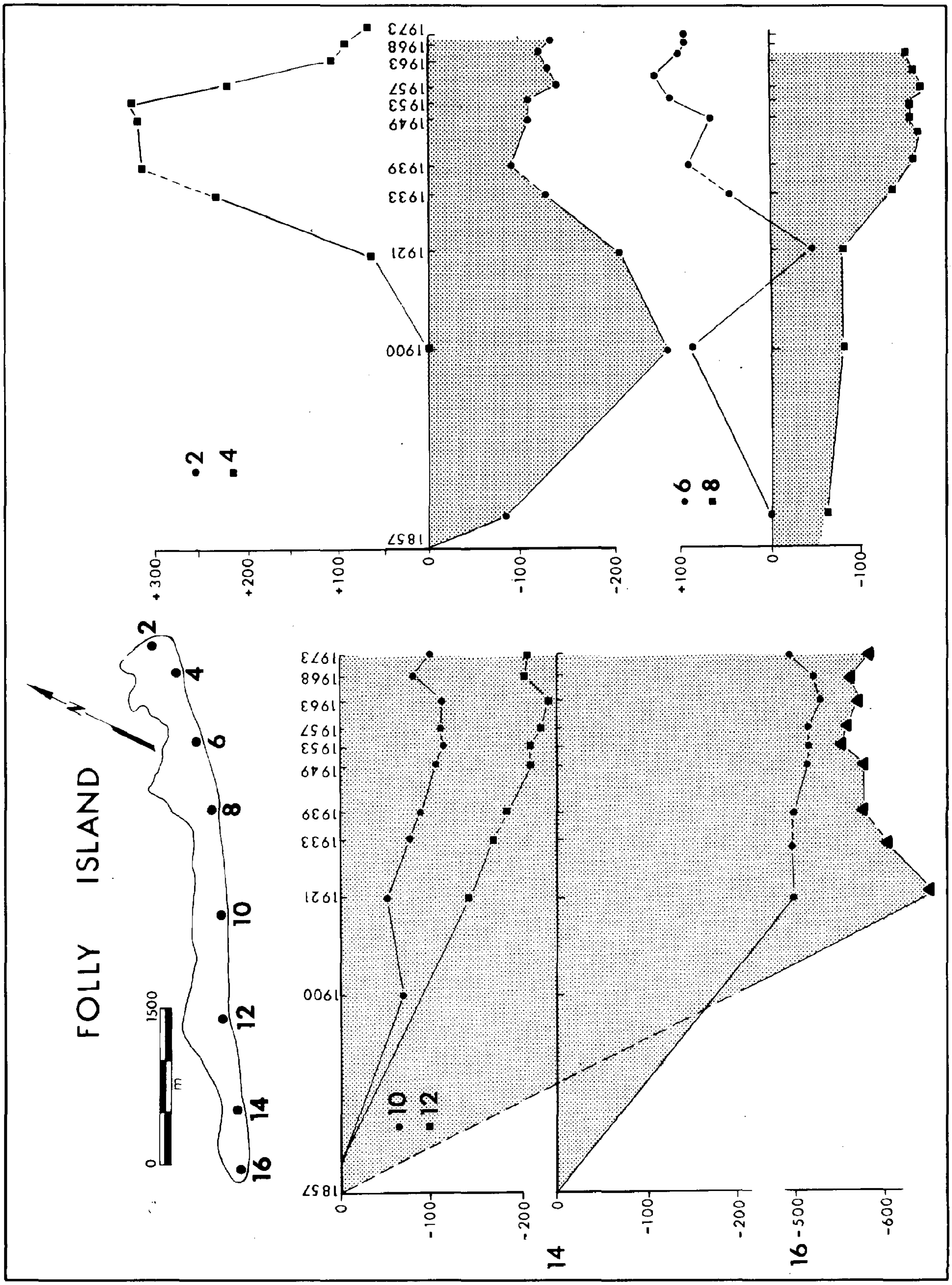
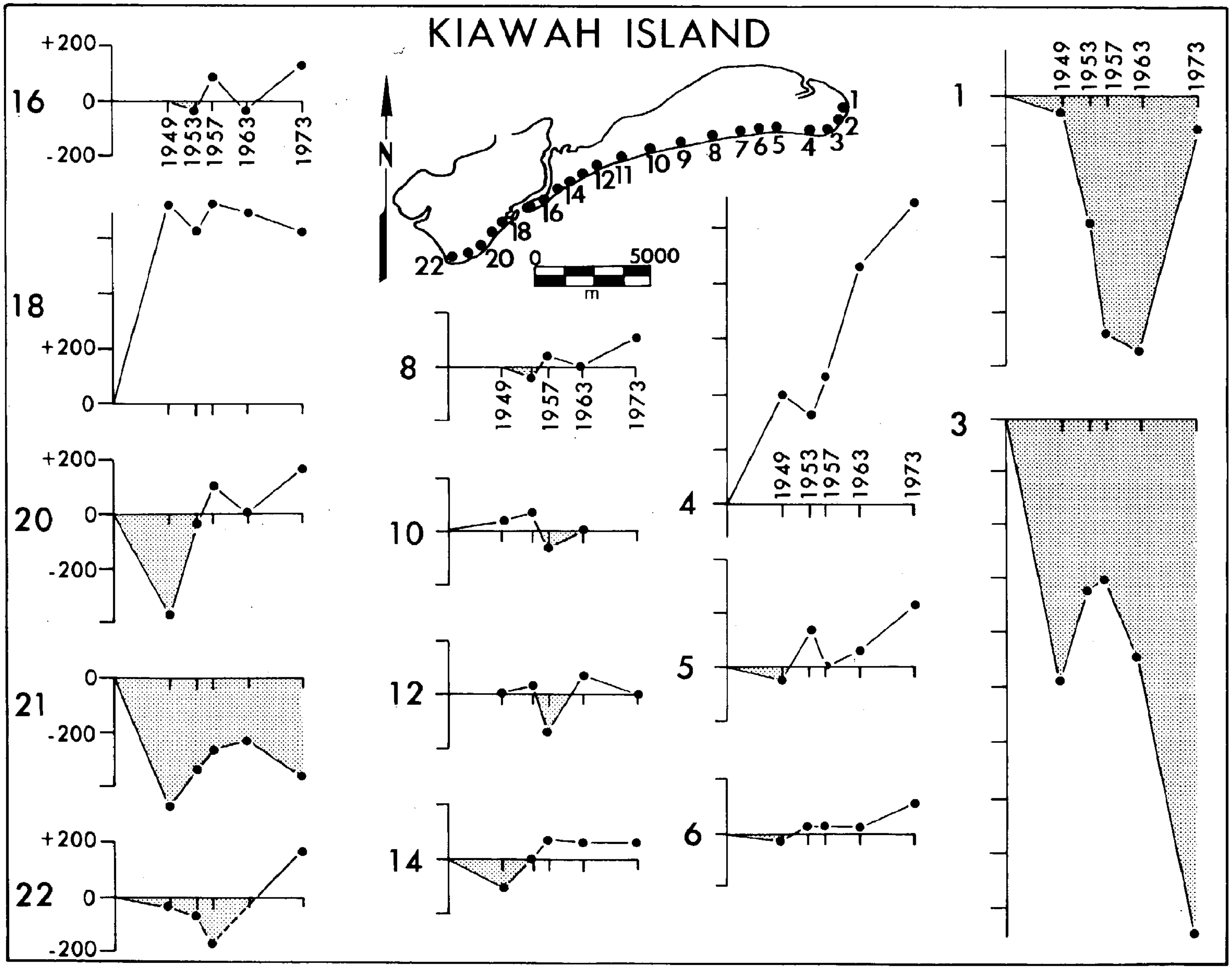

FOLLY ISLAND
0
1500
m
2
4
6
8
10
12
14
16
•2
▪4
•6
▪8
•10
▪12
1857
1900
1921
1933
1939
1949
1953
1957
1963
1968
1973
+300
+200
+100
0
-100
-200
-500
-600

Figure 57. Erosion-deposition graphs for Kiawah Island. Graph numbers refer to the reference points illustrated on the map above the graphs. Erosional areas are shaded. Note the large scale erosional (graphs 1 and 3) and depositional (graph 4) trends at the north end of Kiawah Island. These fluctuations are related to changes in Stono Inlet. The midsection of Kiawah Island is stable.



KIAWAH ISLAND
N
0
5000
m
1 2 3 4 5 6 7 8 9 10 11 12 14 16 18 20 22
16
18
20
21
22
8
10
12
14
4
5
6
1
3
+200
0
-200
1949
1953
1957
1963
1973

Figure 58. Erosion-deposition graphs for Edingsville Beach. Graph numbers indicate the reference points illustrated on the map above the graph. Erosional areas are shaded. To avoid repetition, selected graphs are presented. This section of coastline has undergone continual erosion throughout the entire study interval. Erosion-deposition graphs indicate 200 - 300 feet (60-90 m) at all localities except station G6. Between 1949 and 1954, the closing of a small inlet permitted accretion of over 200 feet at station G6. Since that time, this area has eroded approximately 500 feet (150 m).

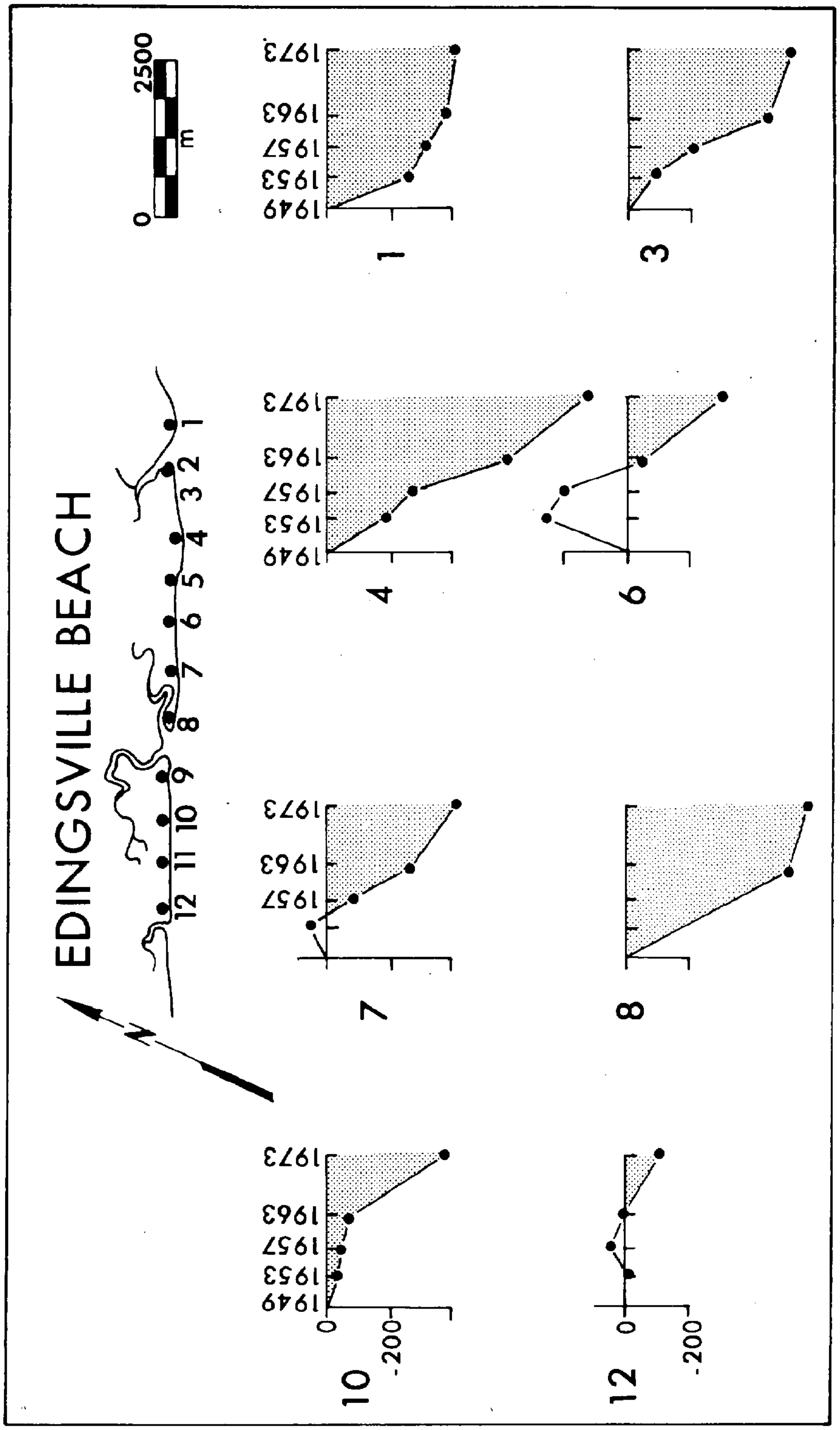

EDINGSVILLE BEACH
N
0
2500
m
1 2 3 4 5 6 7 8 9 10 11 12
1949
1953
1957
1963
1973
0
-200
1
3
4
6
7
8
10
12

Figure 59. Erosion-deposition graphs for Edisto Island. Graph numbers indicate the reference points illustrated on the map above the graph. Erosional areas are shaded. Note the overall stability (graphs 5-11) of this island. The beach is dotted with a series of groins which help stabilize the shoreline. Graphs 12 and 13 both indicate over 200 feet (60 m) of erosion during the study interval. One hurricane, which occurred in 1940, caused erosion ranging between 30 and 100 feet (10-30 m) at Edisto Beach. However, recovery has occurred between the years of photographic coverage so the presented graphs do not show this change.

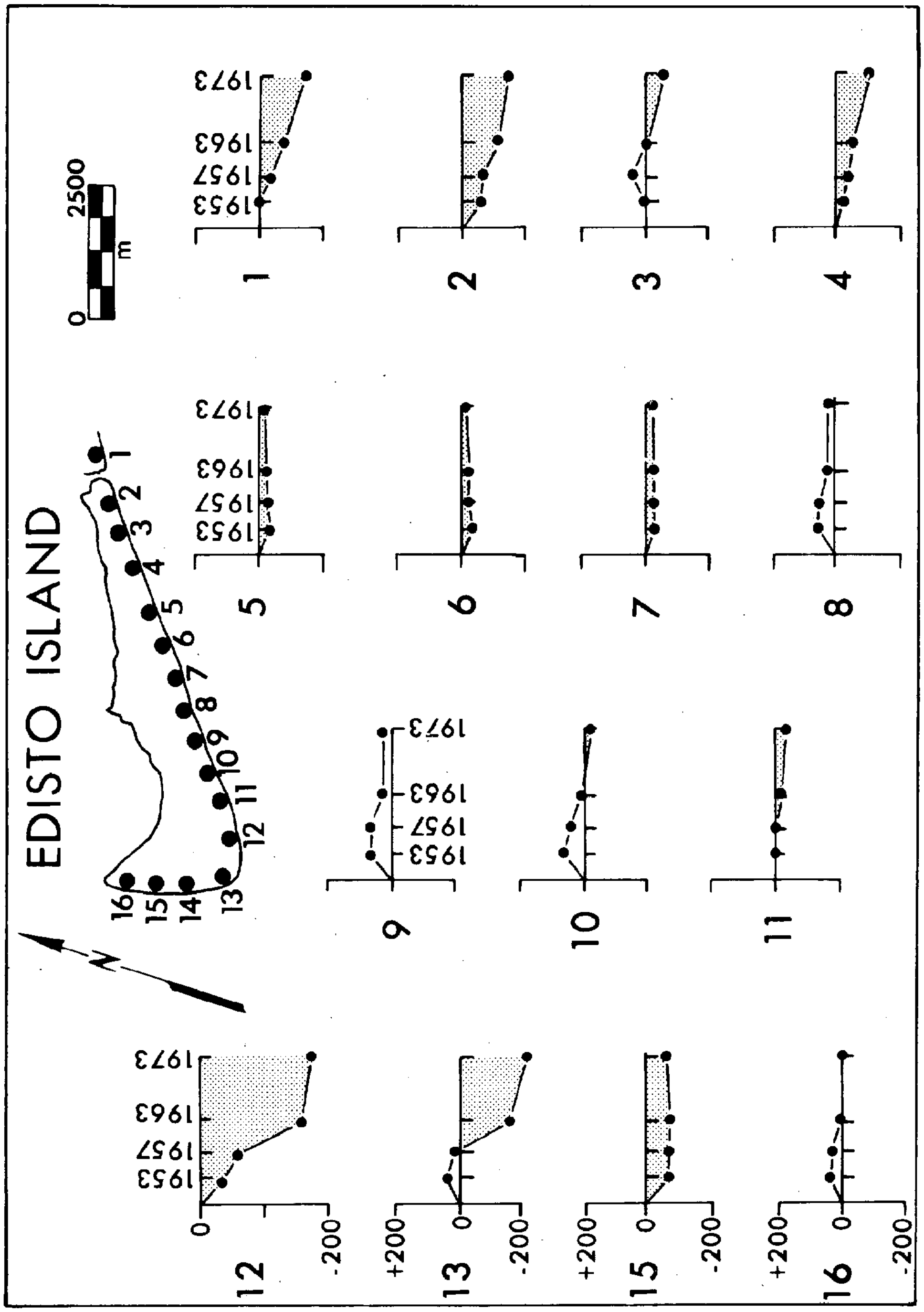

EDISTO ISLAND
0
2500
m
N
1953
1957
1963
1973
+200
0
-200
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Figure 60. Erosion-deposition curves for stations H-1 (Hunting Island) to B-7 (Baypoint Island). The overall trend in this area is one of continued and, in many cases, severe, erosion. This is largely due to the effect of tidal inlets. The hardest hit areas are stations H-1 through H-6 (Hunting Island) and A-1 through A-3 (Capers Island). The retreat of Hunting Island is related to a reorientation of the beach in response to waves traveling across open St. Helena Sound. We feel that the rapid erosion at stations A-1, 2 and 3 is a function of coastal geomorphology. Unlike other barriers in this area, there are no beach ridges on Capers Island. Elsewhere along the South Carolina coast, areas lacking beach ridges have the highest erosion rates measured. This area is characterized by severe washover and erosion rates in excess of 95 feet (29 m) per year.

The only place not undergoing serious long-term erosion is the beach immediately to the west of Fripp Inlet (stations F-1 through F-3). This is a natural process in which the beach immediately downdrift of tidal inlets can build out due to the refraction of waves around the ebb-tidal delta (outer bar). According to this concept, storm waves approaching from the northeast would cause southward longshore sediment transport along Hunting Island which is gradually realigning itself in response to these waves. Upon encountering the shoals (ebb-tidal delta) of Fripp Inlet, however, the waves would be refracted (bent) so that they would be approaching the beach from the south in the vicinity of stations F-1, 2 and 3. This reversal in wave approach direction causes easterly transport at these stations and the gradual building out of the beach in the area near the inlet. Despite the long-term accretional tendency in this area, rapid erosion can occur (station F-1, 1955-60). Field studies have shown this area subject to frequent erosional episodes.

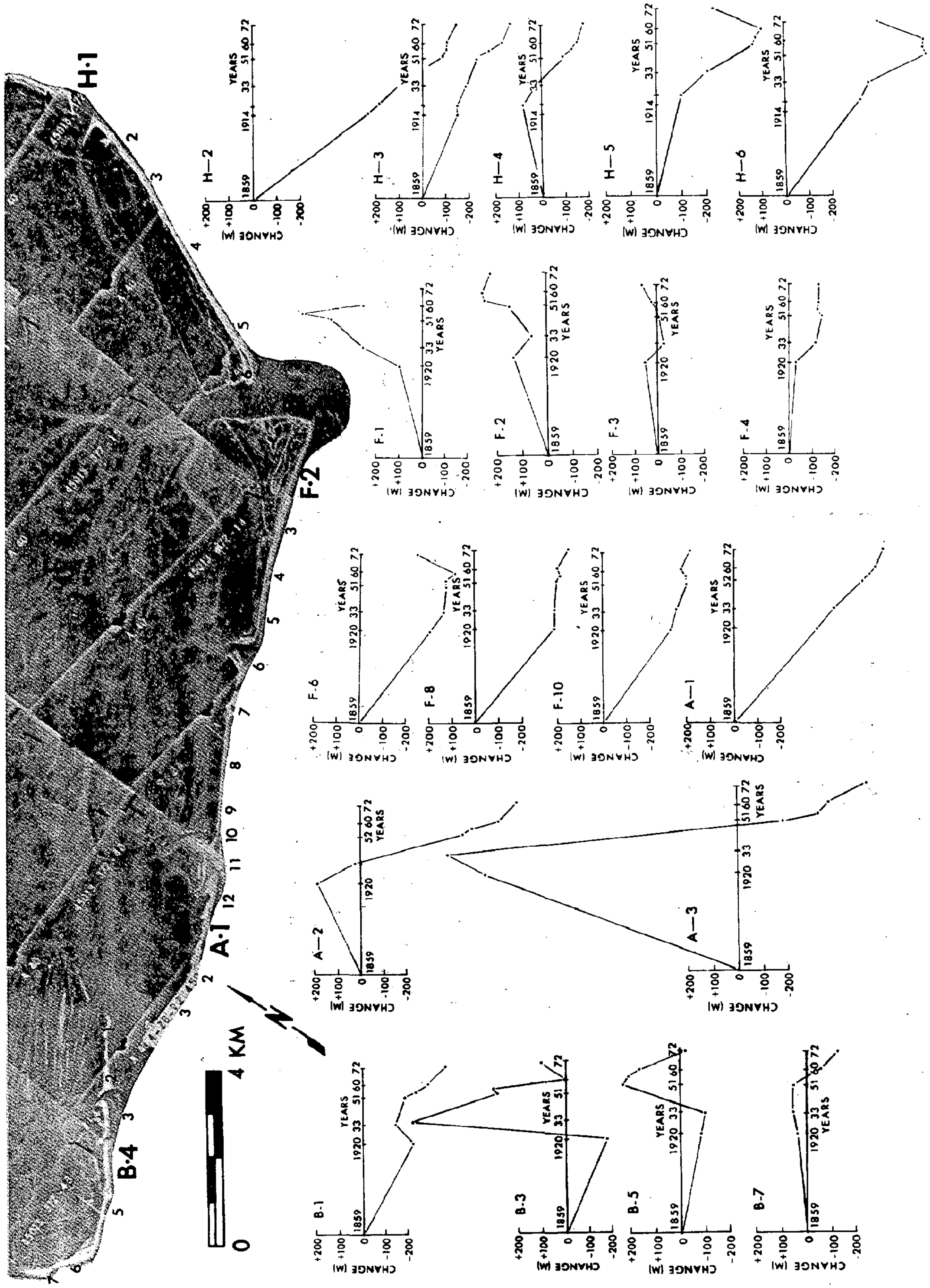
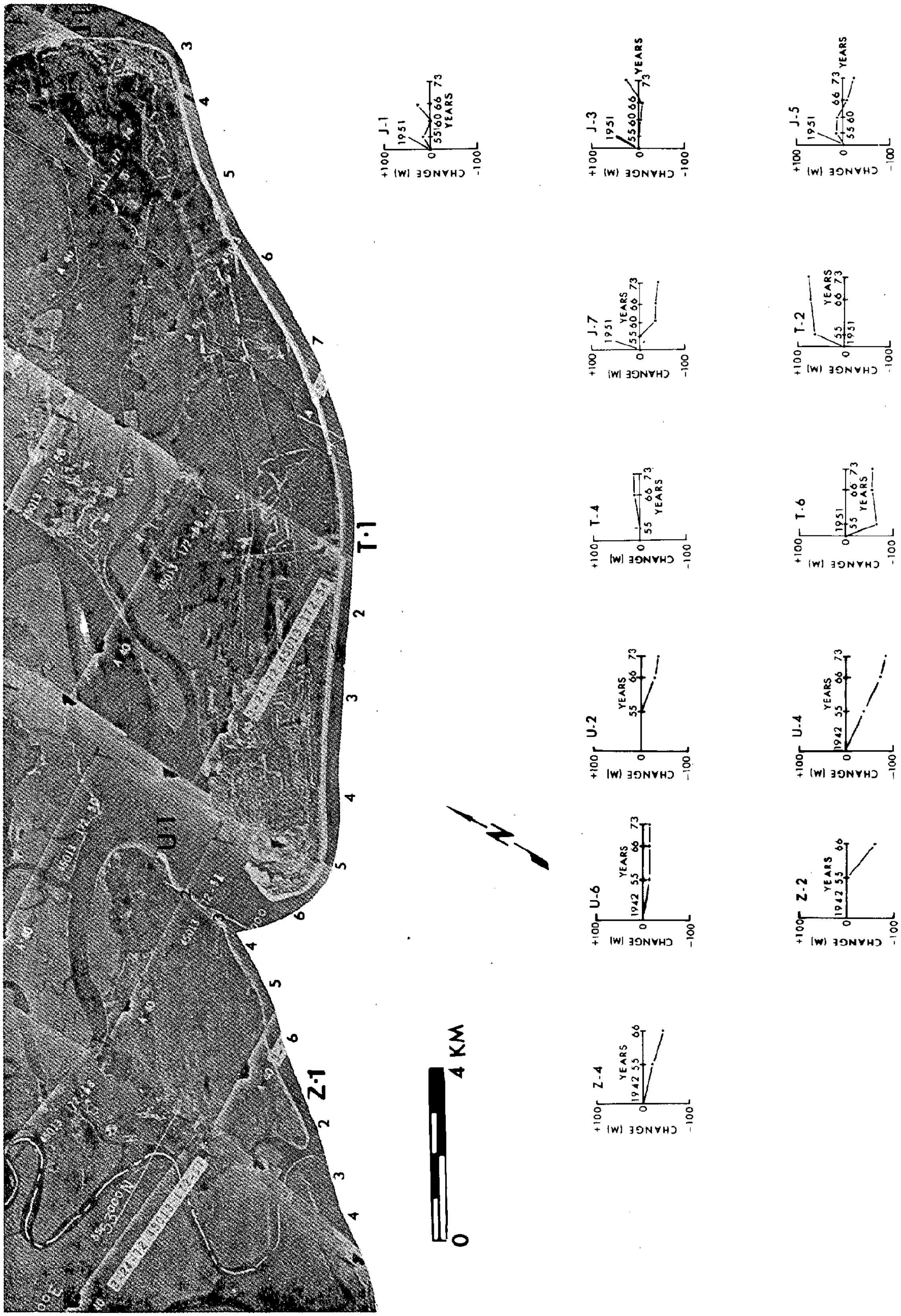

H·1
F·2
A·1
B·4
0
4 KM
N
H—2
H—3
H—4
H—5
H—6
F.1
F.2
F.3
F.4
F.6
F.8
F.10
A—1
A—2
A—3
B.1
B.3
B.5
B.7
CHANGE (M)
YEARS

Figure 61. Erosion-deposition curves for stations J-1 (Hilton Head Island to Z-4 (Daufuskie Island). Despite the variability in shoreline change from station to station, the overall trend in this area is one of stability. When erosion occurs, it is generally slight. It appears that Hilton Head is gradually becoming reoriented by erosion along its northern half (note the truncated beach ridges at stations J-5, 6 and 7). Much of the sand being added to the beach at stations T-1 through T-4 probably was derived from this area. Daufuskie Island has undergone gradual retreat over the period of record. In addition to wave action, tidal currents from Calibogue Sound can be effective in removing sand from this beach.


T·1
U1
Z·1
0
4 KM
N
J-1
J-3
J-5
J-7
T-2
T-4
T-6
U-2
U-4
U-6
Z-2
Z-4
CHANGE (M)
YEARS
+100
-100

SUMMARY

Analyses of chart and aerial photographic data has been used to determine short- and long-term beach erosion-deposition trends in South Carolina. These data are a necessary consideration in the planning and development of the coastal zone, inasmuch as they can help to minimize economic losses resulting from construction in unstable areas.

Users of this information are reminded that the relative stability of a shoreline must be considered on two levels:

First: The long-term stability of a beach area is the rate at which it is either prograding or retreating over a period of, say, 50 or 100 years. It is reflected in major reorganizations of the shoreline morphology and is probably caused by changes in local wave climate or sediment supply. Considerations of these rates of change are important but certainly not all-inclusive, because they only indicate the net change in a shoreline position and shed no light on shorter-term events.

Second: The short-term stability of a beach area is the extent to which the shoreline fluctuates over periods of months or years, usually in response to storm conditions. These fluctuations are superimposed on the longer-term changes and are probably the most important to consider in terms of where to best locate a home or business.

Certain generalizations are possible regarding the overall trends of erosion and deposition on the South Carolina coast:

The grand strand area is relatively stable. Exceptions occur in the vicinity of Little River, Murrells and other small tidal inlets. The extent of the inlet's influence is a function of the size of the inlet and the distance over which it migrates.

Other portions of the coast exhibit varying degrees of stability, depending upon inlet size and frequency. In areas where moderate sized tidal inlets are separated by more than 6-9.5 miles (10-15 km), the area midway between the inlets generally exhibits the greatest stability. Shoreline variations increase in either direction toward the inlets. In areas where inlets are much closer together and much larger (Beaufort County), few sections of beach are outside the effects of the neighboring tidal inlets. In these areas, a complex history results which is closely tied to changes in the patterns of movement of the nearby inlets.

ACKNOWLEDGEMENTS

This report was prepared for the South Carolina Coastal Council (Dr. Wayne Beam, Director). Much of the original data upon which this report is based was collected as part of two research projects sponsored by the South Carolina Sea Grant Program (Contract nos. 04-6-158-44096 and 04-6-148-44096, Miles O. Hayes, Principal Investigator). Other data were collected while under contract with the Coastal Engineering Research Center (Contract No. DACW72-74-C-0018) and the Army Research Office (Contract No. DAAG-29-76-6-0111). Other funds were provided by the Dept. of Geology, University of South Carolina.

Many of the ideas and much of the field work and data analysis that contributed to this project were provided by members of the Coastal Research Division, Dept. of Geology (U.S.C.), including: Dag Nummedal, Michael Stephen, Duncan FitzGerald, Timothy Kana, Robert Finley, Carey Fico, P. Jeffrey Brown, Stan Humphries, Jeff Knoth, and John Barwis. Timothy Kana is acknowledged for his assistance in editing the manuscript. The authors would also like to thank Pris Ridgell, Nannette Muzzy, Burk Scheper and Helen Mary Johnson for their skilled technical assistance in preparation of this report.

GLOSSARY OF TERMS

Accretion - The build up of sand on a beach causing the shoreline to move seaward. An advantageous situation if you are a property owner at an accreting beach site.

Barrier Island - A long, generally narrow, island separated from the mainland by a lagoon, tidal creeks or marsh, which protects inland areas from destructive ocean waves.

Bathymetry - The measurement of water depths and charting of the topography of the sea floor.

Beach - A gently sloping zone of loose sand or shell material exposed to waves along a shoreline.

Beachface - The portion of the beach ordinarily traversed by the uprush and backrush of waves as the tide rises and falls.

Beach profile - A cut-away view of a section of beach drawn perpendicular to the shoreline, which shows changes in topography.

Beach ridge - A long, low mount of sand located landward of the active beach, which is no longer building up and may be heavily vegetated. It generally marks the position of an ancient shoreline and often occur in sets of nearly parallel ridges.

Berm - The zone of beach between the foredunes and the beachface, generally flat and nearly horizontal. Indicative of an accretional beach. The wider the berm, the more protection from storm waves. In general, berms are severely eroded during storms but build up again between storms.

Breaker - A breaking wave along the shoreline. Types include spilling, plunging, collapsing and surging.

Coastal plain - In. S. C., it is a broad geologic province of nearly flat, low-lying sedimentary deposits between the Piedmont (e.g. near Columbia) and the ocean coast.

Current - A flow of water generated by tides or waves which is important in moving sand from one place to another.

Downdrift - Direction toward which a current is flowing. Opposite of updrift. In reference to a jetty or groin, the downdrift side is generally erosional since sand cannot efficiently pass through the barrier but is trapped on the updrift side.

Dunes - Wind blown deposits of sand common along the seaward margins of barrier islands (see Foredune ridge).

Ebb-Tidal Delta - A delta-like deposit of sand just seaward of a tidal inlet posing a hazard to navigation, but often protecting adjacent beaches from severe erosion.

Erosion - Removal of sand from the shore by the action of waves during storms, or by tidal currents in an inlet or tidal channel. Opposite of accretion.

Fetch - The area of sea surface over which the wind blows and generates waves.

Foredune Ridge - The seaward-most ridge of sand parallel to the shoreline which protects inland areas from erosion by waves during storms. The higher the ridge, the more protection to the coastal property.

Geomorphology - The study of landforms, their description, classification, origin and development.

Groin - A man-made structure of rocks, pilings, etc., built into the ocean from the beach, intended to trap sand moving alongshore. Tends to accumulate sand on its updrift side, but often accelerates erosion on the downdrift side.

Hurricane - A tropical storm of severe intensity, originating in the Caribbean with counterclockwise winds greater than 75 mph, revolving around a low pressure center (eye).

Inlet - A short, narrow waterway connecting the sea with an inland waterbody.

Intertidal Zone - The area along the shore which is alternately covered at high water and exposed at low water.

Jetty - A structure extending out from the shore into a body of water designed to direct and confine the current or tide. Commonly intended to protect a harbor, prevent shoaling of navigable waterways, etc.

Littoral Zone - The zone along the shore affected by waves and tides.

Longshore Current - (littoral current) The nearshore current, generated by waves breaking obliquely with the shoreline, running parallel to the shore.

Longshore Drift - The sedimentary material moved alongshore under the influence of waves and currents.

Longshore Transport - The active transport of sedimentary material parallel to shore. A typical rate for South Carolina is 100-200,000 cubic yards per year.

Outcrop - The portion of a geologic structure or layer which is exposed at the surface.

Prograde - To build out, as in: A beach which is accreting, progrades toward the sea.

Recurved Spit - Most common at the southern end of South Carolina barrier islands formed by sand transported alongshore and deposited in a curving spit-like ridge near an inlet. Examples - Debidue Island, Bull Island, Isle of Palms, Kiawah Island, etc.

Ridge and Runnel - A long, linear, intertidal bar of sand (ridge) separated from the beachface by a shallow trough (runnel) which tends to migrate up the beach during moderate wave conditions adding new sediment to the shoreline.

Storm Surge - The additional water level added to normal tides caused by winds piling waters against the coast during storms. Allows waves to attack higher elevations. Storm surges up to 10 feet above mean sea level have been recorded in South Carolina.

Surf Zone - The area between the outermost line of breakers and the limit of wave uprush.

Swash Line - A line of debris left at the upper limit of wave uprush on a beach. Important in marking the extent of wave attack during storms.

Swash Zone - The area of wave uprush and backrush along a beachface.

Tide - The normal rise and fall of water levels due to the rotation of the earth around the sun and the moon around the earth. South Carolina has a semi-diurnal (twice daily) tide with two high tides and two low tides occurring each day. Tide range is approximately 6 feet.

Updrift - Direction from which a current is flowing. Opposite of downdrift. The updrift side of a groin is generally a zone of accumulation of sand.

Washover - A flat, fan-shaped deposit of sand washed onshore during a storm, which may cover inland marsh areas. Examples: Morris Island, Edingsville Beach.

LIST OF REFERENCES

1. Aburawi, R. M., 1972, Sedimentary facies of the Holocene Santee delta: unpub. M. S. thesis, University of South Carolina, Columbia, S. C., 96p.

2. Brown, P. J., 1977, Variations in South Carolina coastal morphology: Southeastern Geology, v. 18, no. 4, p. 249-264.

3. Coastal Engineering Research Center, 1973, Shore Protection Manual, 3 vols.: U.S. Govt. Printing Office, Washington, D. C.

4. Crutcher, H. D., and Quayle, R. C., 1974, Mariners worldwide climate guide to tropical storms at sea: Naval Weather Service Command, U. S. Dept. of Commerce, Wash., D. C.

5. Dean, R. G. and Walton, T. L., 1975, Sediment transport processes in the vicinity of inlets with special reference to sand trapping: in Cronin, L, E., ed., Estuarine Research, Geology and Engineering: Academic Press, N. Y., v. 2, p. 129-150.

6. Dunn, G. E., and Miller, E. I., 1960, Atlantic hurricanes: Louisiana State University Press, Baton Rouge, La., 326p.

7. Emery, K. O., 1961, A simple method of measuring beach profiles: Limnology and Oceanography, v. 6, p. 90-93.

8. Fico, C., 1977, Wave refraction studies on the South Carolina coast: in Nummedal, D., ed., Beaches and Barriers of the Central South Carolina Coast, Guidebook for Fieldtrip "Coastal Sediments '77", 73p.

9. Finley, R. J., 1976, Hydraulics and dynamics of North Inlet 1974/1975: GITI Report 10, U. S. Army, Corps of Engineers.

10. Hayes, M. O., 1967, Hurricanes as geological agents: case studies of hurricanes Carla, 1961, and Cindy, 1963: Rept. Invest. 61, Bur. Econ. Geology, Univ. of Texas, Austin, Texas, 54p.

11. _____, Owens, E. H., Hubbard, d. K., and Abele, R. W., 1973, The investigation of form and processes in the coastal zone: in Coates, D. R., ed., Coastal Geomorphology, Publications in Geomorphology, Binghamton, N. Y., p. 11-41.

12. _____, Hulmes, L. J., and Wilson, S. J., 1974, Importance of tidal deltas in erosional and depositional history of barrier islands: (abs.): in Abstracts with Programs, 1974 Annual Meeting, Geol. Soc. of Am., Miami, Fla.

13. _____, FitzGerald, D. M., Hulmes, L. J., and Wilson, S. J., 1976, Geomorphology of Kiawah Island, South Carolina: in Hayes, M. O. and Kana, T. W., eds., Terrigenous Clastic Depositional Environments: Tech. Rept. No. 11-CRD, University of South Carolina, p. II-80 - II-100.

14. _______ and Kana, T. W., 1976, eds., Terrigenous Clastic Depositional Environments: Tech. Rept. No. 11-CRD, University of South Carolina.

15. _______, 1977, Development of Kiawah Island, South Carolina: Proceedings, Conf. on Coastal Sediments '77, ASCE, Charleston, S. C., p. 828-847.

16. Hicks, S. D., 1972, On the classification and trends of long period sea level rise: Shore and Beach, v. 40, p. 20-23.

17. ___________ and Crosby, James E., 1974, Trend and variability of yearly mean sea level 1893-1972: NOAA Technical Memorandum NOS-13, National Ocean Survey, National Oceanic and Atmospheric Admin., U. S. Dept. of Commerce, Rockville, Md., 14p.

18. Hosier, P. E., 1975, Dunes and marsh vegetation: in Environmental Inventory of Kiawah Island, ERC, Columbia, S. C., p. D-1 - D-94.

19. Hubbard, D. K. and Barwis, J. H., 1976, Discussion of tidal inlet sand deposits: examples from the South Carolina coast: in Hayes, M. O. and Kana, T. W., eds., Terrigenous Clastic Depositional Environments, Tech. Rept. No. 11-CRD, Univ. of South Carolina, p. II-128 - II-142.

20. ____________________________, Lesesne, F., Stephen, M. F. and Hayes, M. O., 1977, Beach erosion inventory of Horry, Georgetown and Beaufort Counties, South Carolina: S. C. Sea Grant Tech. Rept. No. 8, 58p.

21. Johnson, H.S. Jr. and DuBar, J. R., 1964, Geomorphic elements of the area between the Cape Fear and Pee Dee Rivers, North and South Carolina: Southeastern Geology, v. 5, no. 1, p. 37-48.

22. Kana, T. W., 1977a, Beach erosion during minor storm: Journal of the Waterway, Port, Coastal and Ocean Division, ASCE, vol. 103, no. WW4, Proc. Paper 13335, Nov. 1977, p. 505-518.

23. __________, 1977b, Suspended sediment transport at Price Inlet, S. C.: Proceedings, Conf. on Coastal Sediments '77, ASCE, Charleston, S. C., p. 366-382.

24. __________ and Knoth, J. S., 1977, Longshore sediment transport rates in South Carolina: in Nummedal, Dag, ed., Beaches and Barriers of the Central South Carolina Coast, "Coastal Sediments '77", Fieldtrip Guidebook, p. 39-44.

25. Kraft, John C., 1971, Sedimentary facies patterns and geologic history of a Holocene marine transgression: Geol. Soc. Amer. Bull., v. 82, p. 2131-2158.

26. Landers, H., 1970, Climate of South Carolina: in Climates of the states: South Carolina: Climatography of the United States, No. 6038, ESSA Environmental Data Service.

27. Millas, Jose Carlos, 1968, Hurricanes of the Caribbean and adjacent regions: 1492-1800: Academy of Arts and Sciences of the Americas, Miami, Fla., 328p.

28. Milliman, J. D. and Emery, K. O., 1968, Sea levels during the past 35,000 years: Science, v. 162, p. 1121-1123.

29. Myers, V. A., 1975, Storm tide frequencies on the South Carolina coast: NOAA Tech. Rept. NWS-16, 79p.

30. Nummedal, D. and Humphries, S. M., (in press), Hydraulics and dynamics of North Inlet, S. C. 1975/76: U.S. Army Corps of Engineers.

31. Pilkey, O. H., Jr., Pilkey, O.H., Sr. and Turner, R., 1975, How to live with an island: Raleigh, North Carolina Dept. Nat. and Economic Resources, 119p.

32. Pore, N.A., 1961, The storm surge: Mariners Weather Log, v. 5, no. 5, p. 151-156.

33. Price, W. Armstrong, 1955, Correlation of shoreline type with offshore bottom conditions: Dept. of Oceanography, A&M College of Texas, Project 53.

34. Shepard, F. P. and Wanless, H. R., 1971, Our changing coastlines: McGraw-Hill, New York, N. Y., 579p.

35. South Carolina Parks, Recreation and Tourism Commission, 1976: South Carolina'a beaches, 10p.

36. Stafford, D. B., 1971, An aerial photographic technique for beach erosion surveys in North Carolina, TM-36, U.S. Army, Corps of Engineers, Coastal Eng. Res. Center, Wash., D. C.

37. Stephen, M. F., Brown, P. J., FitzGerald, D. M., Hubbard, D. K., and Hayes, M. O., 1975, Beach erosion inventory of Charleston County, South Carolina: a preliminary report: S. C. Sea Grant Tech. Rept. No. 4., 79p

38. U.S. Army Corps of Engineers, 1957, U.S. Army Engineer District, Charleston, S. C., Appraisal report - Investigation on hurricanes and associated problems along the South Carolina Coast, 37p.

39. ______________________________, 1971, National shoreline study, Great Lakes Region - Inventory Report.

40. U.S. Naval Weather Service Command, 1970, Summary of Synoptic Meteorological Observations, North American Coastal Marine Areas: National Climate Center, Asheville, N. C., vol. 3.