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# PAPERS PRESENTED AT
# BEACH SEMINAR '78

October 4 through 7, 1978
South Seas Plantation, Captiva Island, Fla.

Joint annual meeting of American Shore & Beach Preservation Association and Florida Shore & Beach Preservation Association. Co-sponsored by The Coastal Plains Center, Wilmington, NC; Florida Sea Grant Marine Advisory Program, and the Coastal & Oceanographic Engineering Department, University of Florida.

Compiled and Edited by
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TECHNICAL PAPER NO. 7
October 1978

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[1]Papers not received by press time will be published at a later date

# THE PROGRAM

## Wednesday, October 4

9:30 a.m. Board of Directors meeting, ASBPA

9:30 a.m. Board of Directors meeting, FSBPA

1:30 p.m. Opening Session

**"Tidal Inlet Control of Beach Erosion — Deposition Cycles,"** *Dr. Miles Hayes, Professor of Coastal Processes, University of South Carolina.*

**"The Coastal Engineering Research Center's Field Research Facility in North Carolina,"** *Curt Mason, Research Coordinator, CERC*

**"Investigation of Sinesh Breakwater Failure (Port Sinesh, Portugal),"** *Orville Magoon, Chief, Coastal Engineering Branch, South Pacific Division, U.S. Army Corps of Engineers and Dr. Billy Edge, Department of Civil Engineering, Clemson University.*

6:30 p.m. Welcoming Cocktail Party, sponsored by South Seas Plantation

## Thursday, October 5

8:30 a.m. Second Session

**"Storm Effects on Barrier Islands,"** *Dr. John Fisher, Associate Professor, Clemson University.*

**"The Hurricane Threat to the Shoreline,"** *Dr. Neil Frank, Director, National Hurricane Center, Miami.*

**"Simplified Methods for the Prediction of Hurricane Surge and Wave Runup,"** *Dr. Bruce Taylor, PE, Tetra Tech, Inc., Jacksonville, Fla.*

**"Emergency Beach Protection for Counties, Cities and Towns,"** *Jon T. Moore, PE, Dames & Moore, San Francisco.*

**12:30 p.m. Luncheon**

2:00 p.m. Third Session

**"Low Cost Protective Devices for Erosion Control,"** *Col. John H. Cousins, Director, Coastal Engineering Research Center, Fort Belvoir, Va.*

**"An Alternative to Terminal Groins — the Artificial Offshore Headland,"** *Kris Dane, PE, Coastal Engineering Consultants, Inc., Naples, Fla.*

**"Nature Assisted Beach Enhancement,"** *Dr. Morton Smutz, Associate Director, Engineering & Industrial Experiment Station, University of Florida, Gainesville, Fla.*

6:00 p.m. Cocktail party

7:30 p.m. President's Banquet

## Friday, October 6

8:30 a.m. Fourth Session

**"Beach Erosion in Florida — Long and Short Term Implications,"** *Todd Walton, Florida Sea Grant Program, Gainesville, Fla.*

**"Rebuilding the Beaches of Florida"** *Col. James W. R. Adams, District Engineer, U. S. Army Corps of Engineers, Jacksonville, Fla.*

**"Environmental Monitoring Program for the Delray Beach Nourishment Project,"** *Richard H. Spadoni, Ocean Engineer and Biologist, Arthur V. Strock & Associates, Inc., Deerfield Beach, Fla.*

**"State of the Art of Oil Spill Protection,"** *Lt. Michael Donohoe, Executive Officer, Gulf Strike Team, U. S. Coast Guard, NSTL Station, Mississippi.*

**12:15 Luncheon**

2:00 p.m. Fifth Session

**"Shoreline Stabilization,"** *Cherie Down, County Biologist, Brevard County, Florida.*

**"Vegetation as a Means of Shoreline Stabilization and Erosion Control,"** *Otto Bundy, President, Horticultural Systems, Inc. Parrish, Fla. and Jedrey Carlton, Biologist, State Marine Research Laboratory, St. Petersburg, Fla.*

**"Political Problems of Erosion Control,"** *Dr. Lee Koppelman, Executive Director, Long Island Regional Planning Board, Hauppauge, N.Y.*

6:30 p.m. Cocktail party

## Saturday, October 7

10 a.m. Annual Business Meeting, ASBPA

10 a.m. Annual Business Meeting, FSBPA

Noon Board of Directors Meeting, ASBPA

noon Board of Directors Meeting, FSBPA

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# THE COASTAL ENGINEERING
# RESEARCH CENTER'S
# FIELD RESEARCH FACILITY
# AT DUCK, N. C.

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ABSTRACT

The Coastal Engineering Research Center is building a Field Research Facility at Duck, N.C., consisting of an 1800 ft long pier and a laboratory building. The facility is designed to fulfill four objectives: 1) to provide a platform for measuring waves, currents, water levels, and bottom elevations, during normal and storm conditions; 2) to provide a base of operations for research studies by CERC and non-CERC investigators; 3) to provide field data to complement laboratory and analytical studies and 4) to provide a facility for field testing instrumentation.

The pier deck, extending from behind the dunes to about the 25 ft water depth, is 20 ft wide, 25 ft above MSL, and is supported by 3 foot diameter steel pilings. The main building has 4,500 square feet of floor space for offices, a data acquisition room, a vehicle shelter, and visiting scientists' overnight accommodations.

Meteorological and oceanographic conditions at the site are being routinely monitored using wave and tide gages, current meters, anemometers, and related instruments. Periodic surveys of the ocean bottom and beaches are also being obtained. Annual data summaries will be published, and selected short-term data are available for interested users.

# THE COASTAL ENGINEERING RESEARCH CENTER'S FIELD RESEARCH FACILITY AT DUCK, N.C.

## 1. Introduction and Purpose

In August, 1977, construction of the 1800 foot long pier shown in Figure 1 was completed on the Outer Banks of North Carolina, 15 years after the concept of a coastal field research facility was orginally proposed. This paper reviews the background of this effort; the physical characteristics of the site; the status of the facility; and related data collection, analysis and display capabilities. Scientific projects underway and planned for the facility are also discussed.

The U.S. Army Coastal Engineering Research Center (CERC) conducts research and development in coastal engineering to provide a better understanding of coastal processes, winds,

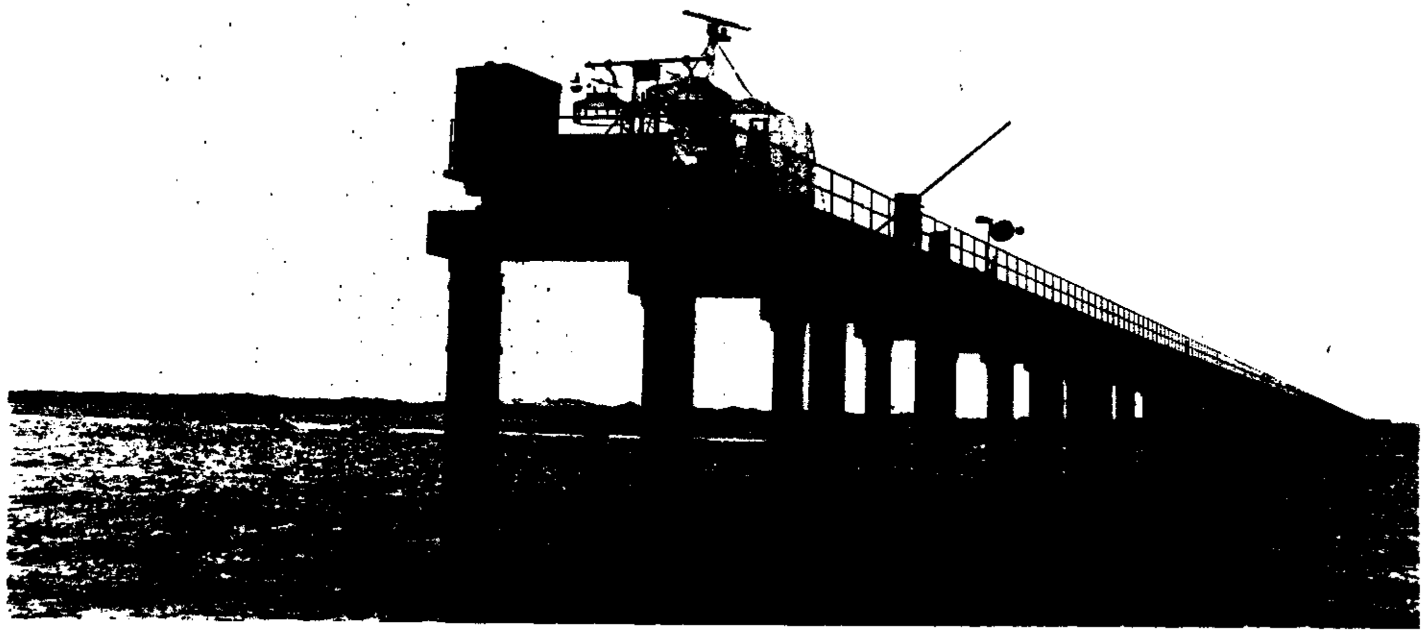

Figure 1. CERC Field Research Facility Pier

waves, tides, currents, and sediments as they apply to navigation, recreation, storm flood protection, erosion control, and coastal structures. CERC's mission includes conducting research on the effects of engineering activities on the ecology of the coastal zone, as well as collecting and publishing information and data concerning coastal phenomena and research projects which are useful to the Corps of Engineers, other federal and state agencies, universities, and the public.

Much of CERC's past coastal engineering research has been laboratory experimentation and theoretical investigations. Supportive field work has been hampered by the lack of a dependable means of obtaining high-quality wave, beach, and water level data, including data during storms. Therefore, the CERC Field Research Facility has been designed to fulfill four major objectives:

a. To provide a rigid platform from the land, across the dunes, beach, and surf zone, to the 25 foot water depth, from which waves, currents, water levels, and bottom elevations can be measured, especially during severe storms.

b. To serve as a permanent field base of operations for physical and biological studies of the site, the adjacent sound, and nearby islands, bays and ocean regions, by CERC and other agencies and universities.

c. To provide CERC with field experience and data that will complement laboratory and analytical studies, and provide a better understanding of the influence of field conditions on measurements and design practices.

d. To provide a manned field facility for testing of new instrumentation.

2. Historical Background

The requirement for a field facility to complement CERC's analytical and laboratory efforts was first recognized in the early 1960's, and a site on Assateague Island, Maryland, about 100 miles from CERC was selected. However, funding limitations and problems in obtaining bids for construction delayed selection of contractors to design and build the pier until 1971.

During the intervening years, the site and adjacent beaches had become part of the Assateague Island National Seashore, and when plans for construction of a research facility became public, objections were raised regarding the environmental and aesthetic suitability of such a structure in the Seashore. As a result, in late March 1972, it was decided that the facility would not be built at Assateague, and a comprehensive study was begun to select a replacement site somewhere on the U.S. Atlantic or Gulf coast.

The first step in this effort was to develop a list of criteria which should be met by proposed sites. In general, the final criteria required that wave and beach conditions at the site be representative of U.S. coastal locations; that complicating factors related to the hydrography and shoreline stability be minimized; and that the site location and size optimize opportunities to conduct a broad spectrum of coastal studies. Nontechnical criteria specify CERC control of the property, land access, adequate support, and minimized construction costs. It was recognized that an ideal site, fulfilling all criteria, might not be possible, but these gave us a starting point for an evaluation.

Following criteria selection, eleven coastal regions of the Atlantic and Gulf coasts were ranked according to the extent to which each region generally satisfied the technical criteria. Seven of the eleven regions were found to be favorable.

Eleven sites within the seven regions (ranging from Ocean City, New Jersey to Slidell, Louisiana) were then selected for specific evaluation following recommendations by federal and state officials, private citizens, and CERC staff members. The Outer Banks site near Duck, North Carolina, was finally determined to best meet the various selection criteria, although it does not completely meet all of them.

## 3. Site Description

The coastal plain of North Carolina is a low, partially submerged area varying in width up to 125 miles and confined between the Piedmont plateau on the west and the continental shelf on the east. The area contains a series of marine deposits, attesting to several cycles of emergence and submergence. Formation of the Outer Banks barrier island chain along this coast has been comparatively recent. The islands are composed of marine deposits of sand and shell in varying mixtures. The lagoons and sounds inland of the barriers gradually accumulated sediment derived from erosion of the adjacent mainland and were converted to marshes, a trend which presently continues.

Native vegetation of the Outer Banks consists of sea oats along the dunes, grading landward into thickets typically composed of wax myrtle, yaupon, willow, grapevines, and other plants, Behind this outer protective shrub thicket, maritime forests consisting mainly of pines, cedar, and live oak once covered much of the islands. However, deforestation for ship timbers and buildings have reduced these forests to widely scattered patches of woods, such as those found at the town of Duck.

The Field Research Facility site one mile north of this town lies on the northern end of Bodie Island between Currituck Sound and the Atlantic Ocean (See Figure 2). The site is about 1.5 hours by automobile south of Norfolk, VA and about 6 hours south of Washington, D.C. The nearest airport is a small, non-instrumented, paved strip at the Wright Brothers Memorial in Kitty Hawk, about 10 miles to the south. The property borders 3300 ft of Atlantic Ocean on the east and Currituck Sound on the west, and is about 2400 feet wide.

The Duck site was selected because it collectively met the following eight essential criteria better than other sites evaluated:

a. The site must have a typical size sand beach with sand to a sufficient depth over differing substrate to prevent exposure of the underlayer during the expected research life of the pier, which is 40 years. Sand from the foreshore and surf zone in this region is quite coarse (median diameter about 0.75mm) and typically bimodal. Dune sands are finer, averaging about 0.3 mm median diameter. Offshore, sands decrease in median size from 0.75 mm at the surf zone to less than 0.1 mm at the 60-ft depth. Indications are that the surf and foreshore surficial sands form a wedge-shaped cross section which pinches out on top of finer sands just seaward of the surf zone. The composite thickness of alternating layers of 1 and 0.3 mm material on the foreshore is at least 6 feet. No consolidated subsurface strata were observed to crop out and none was indicated on well logs available from local developers. Surficial beach sand at the site is considerably larger than the 0.15 to 0.5 mm considered typical of U.S. beaches.

b. The site must have exposure to a wave climate, including storm occurrence and wave directions, that is representative of U.S. coasts. A summary of weather features affecting Cape Hatteras, 65 miles south, indicates that the sky should be clear at Duck about 100 days per year, and that the annual rainfall of 55 inches will be evenly distributed throughout the year. Mean daily temperatures range from 78° during July and August to 53° in January and February. Mean monthly wind speeds of about 12 miles per hour

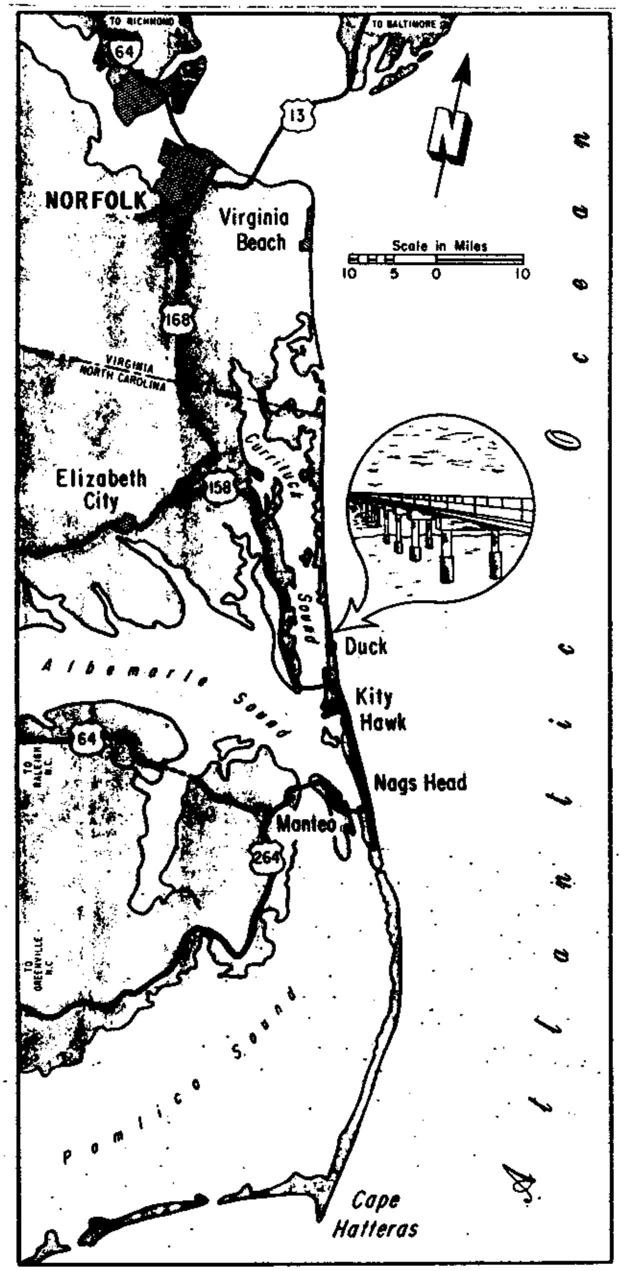


Figure 2. Location Map.

prevail from the northeast between September and February, and from the southwest the remainder of the year. Because of this wind pattern, waves generally approach the Duck site from the northeast during the winter and from the east and southeast during the summer. This bi-directional wave climate is representative of many U.S. coastal locations. Data from a wave gage at Nags Head, 13 miles south, show the mean annual significant wave height to be about 1 meter, with a standard deviation of 0.7 meters. The mean significant wave period is about 8 seconds, with a 2.5 second standard deviation. Longshore sediment transport rates are estimated to be about 1.5 million cubic yards per year southward, and about 750,000 cubic yards per year northward, for a 2:1 southward predominance, due primarily to the effects of winter storms (northeasters). Over the past 70 years, hurricanes have affected the area to some extent about once every two years.

c. The site must have a significant astronomical tide (i.e., range on the order of 0.5 to 2 meters). Ocean tides at the site are semi-diurnal, with a spring range of about 1.5 meters and a neap range of about 0.7 meters. Water levels in Currituck Sound are wind-dominated: high during periods of southwest winds, and low when winds are from the northeast.

d. The nearshore slope must be representative of sandy U.S. coasts, and such that the 20-ft-depth contour is not appreciably more than 2000 ft from the mean sea level intercept. The nearshore slope is reasonably typical of other U.S. coastal profiles, and the 20 ft contour is about 1000 ft from the mean sea level contour.

e. The site must be located on a straight coastline outside the range of effects of any significant littoral barrier. The coastline is relatively straight, curving gently to the east south of the site, and with an indentation about 3.5 miles north at the location of a former inlet. No inlets or structures exist on the coast within 5 miles of the site.

f. The site must be free of offshore bottom features which may lead to severe anomalies in the wave climate in the nearshore area. Hydrographic charts show that no unusual offshore bottom features exist in the immediate vicinity of the pier, but that waves approaching from the northeast may be refracted by shoals near False Cape.

g. The site must be accessible by land vehicles. A paved state highway is connected to the site by a crushed gravel road.

h. CERC must have control of the use of the pier and adjacent beaches to ensure lack of interference with research programs. Although visitors are allowed at the site, public access to the pier is restricted. The pier ramp and all shore facilities are surrounded by a chain link fence which is locked during non-working hours. Ramps at the north and south edges of the property allow beach vehicles to transit from the beach, over the dunes and around the facility so that on-going beach studies will not be affected.

Secondary criteria which were felt to be desirable were also met by the Duck site. These relate to site size and proximity to other study areas and to CERC, availability of power and telephone lines, presence of natural dunes, generally good weather conditions and relatively stable shorelines.

4. Facilities

The physical characteristics of the major structures of the Field Research Facility, the main building and the research pier, are as follows: The 4600-sq.-ft laboratory building of the Facility will have four rooms for data collection and preliminary analysis efforts, an instrument repair shop, a vehicle shelter, a diving locker, and a two-bedroom living area with kitchen. This building will be 90 ft long parallel to the ocean, 51 ft deep, and about 21 ft high. A platform for outside work and access to the pier will surround the building. The research pier is a reinforced concrete structure supported with 3 feet diameter steel piles spaced 40 ft apart along the pier length and 15 ft below the ocean bottom. The pier deck is 20 ft wide and extends 1840 ft from behind the dune line to about the 25-ft water depth. The deck is 25 ft above mean sea level. Concrete erosion collars protect the steel pilings against sand abrasion, and a cathodic protection system protects the steel pilings against corrosion. Railroad rails set 10 ft center to center run the full length of the pier and can support a 16-ton load. The safe load between the rails is limited to a vehicle such as a pickup truck with a maximum wheel load of 2000 lbs. The electrical power outlets are presently 120 volts, 20 amperes and 240 volts, 30 amperes but these will be increased to a total of 200 amps. Outlets are spaced in sets along the pier approximately 40 ft apart. Two telephone stations are to be installed on the pier, one at the seaward end and one about mid-point.

A basic environmental measurements program has been established to routinely measure, record, and publish data on the meteorological and oceanographic conditions at the site. Following data collection and editing, certain routine analyses are made. The data and results are made available to other CERC studies and to the scientific and engineering community upon request by the CERC Coastal Engineering Information and Analysis Center. Annual inhouse reports summarizing the data acquired during the previous year and describing related aspects of data collection, analysis, and storage will be prepared.

Meteorological data presently being collected on pen and ink records from a National Weather Service onshore climatological station are wind speed and direction, barometric pressure, accumulated precipitation, total solar radiation, and air temperature and relative humidity. An anemometer linked directly to NWS headquarters will also be installed on the pier about 1000' offshore. Visual observations of related weather conditions and checks of the recording instrumentation are made once a day.

Tide data are collected by National Ocean Survey (NOS) tide gages at the pier end and at about the 8-ft water depth. Paper tape is punched at six minute intervals giving the time and instantaneous water level reading. The data are reduced by the Tides Branch at NOS, and data records and summaries are routinely forwarded to CERC. A CERC tide gage gives an analog record of water levels in the sound just behind the site.

Daily ocean water temperature and salinity measurements are made at the seaward end of the pier, three feet above the bottom and six feet below MSL.

To measure changes in the beaches and ocean bottom, weekly lead-line soundings on each side of the pier are being made, as are pre- and post-storm profiles.

Quarterly surveys from behind the dunes to the -40 foot contour and extending a mile north and south of the pier are also conducted.

Aerial photographs of the coastline from Cape Hatteras to Cape Henry, with a perpendicular flight at the Facility, are being flown quarterly and after major storms. The multi-spectral imagery employed include black and white, color, color infrared exposed for land and color infrared exposed for water.

Wave data are obtained from two Baylor-type gages, suspended on the pier centerline, one at the pier end and one in about 8 feet of water, and from one pressure transducer at the pier end. In addition, a wave rider buoy is anchored near the pier's seaward end, with a second one approximately 1-1/2 miles offshore. A wave gage at Nags Head will continue to operate for about one year, or until such time as a relationship between the wave characteristics at both sites can be established. Visual observations of wave height, period, and direction are also taken twice a day from the pier.

Wave and ocean currents are measured by two x-y electromagnetic current meters positioned two feet above the bottom. One of these meters is at the seaward end of the pier, and the other is at the same depth but 500 feet north, to assess the effect of the pier on currents.

At present, wave and current data are transmitted by leased telephone line to CERC and recorded on magnetic tape by the CERC Data Acquisition System. The data are sampled four times a second for twenty minutes, four times per day. The present system provides two non-overlapping sequences of 4 channels each. An additional 4 channels could be added for other observations in the same format. An expanded data acquisition system is presently being designed for the Facility. However, it will primarly be for CERC field studies, and outside users should plan to provide their own data acquisition systems.

One important item is the policy of assessing costs to the outside user. If a project is proposed that is directly applicable to CERC's mission in coastal engineering research, free use of the pier will be offered, as will limited support by on-site CERC personnel. CERC data from the basic environmental measurements program will also be furnished free of charge. Costs for extensive use of pier personnel and for projects not related to CERC's mission will be assessed at a rate dependent upon the degree of public interest served and the user's financial resources. Work priorities for the on-site CERC personnel are established by the Research Coordinator, subject to the concurrence of the Technical Director.

5. Existing and proposed studies

The studies classified as desirable are those we feel should be done either by CERC at some later date, or sooner by interested outside users. Although CERC funding limitations preclude direct support for these studies, we would endorse attempts by qualified investigators to obtain funding from other sources.

Prior to initiation of pier construction, a complete topographic survey was made of the beaches and dunes, and a hydrographic survey was made of the adjacent ocean bottom. Borings were made to a depth of 70 feet below sea level and a geophysical survey was conducted to establish the geologic and engineering subsurface conditions in the pier construction area.

A beach profiling study was also initiated before pier construction, and these profiles continue to be monitored to assess the effect of the pier on the adjacent beaches.

Baseline studies of the native flora and fauna of the island and nearshore zones have been made, and study results will be used to evaluate the ecological effects of pier construction and site habitation. Experimental marshes have been planted on the edge of Currituck Sound to evaluate the use of vegetation in preventing or minimizing shore erosion. As part of this effort, a tide gage was installed in the sound in September 1973 which has provided useful information on the characteristics of water level fluctuations.

Research studies presently underway or planned for the next 3 years and those which are desirable are grouped into five areas: Nearshore Wave Transformation, Nearshore Sediment Transport, Coastal Ecology, Remote Sensing, and Supplemental.

In the Nearshore Wave Transformation subprogram, recent CERC field studies have shown radar to be a promising tool to measure wave direction. This concept will be further evaluated at the Field Research Facility within the coming year in conjunction with an evaluation of sensors aboard the SEASAT-A satellite.

A CERC study is underway to measure the transformation of waves as they enter shallow water and break. Five Baylor wave gages have been installed to define the shore-normal changes in wave characteristics. A related research effort involves the prediction of wave transformation from deep water areas to the breaker zone. Data from the offshore wave gage and aerial photographs will be used to improve refraction and shoaling models.

An analysis to assess the relative contributions of sea and swell, wind, and tides on the nearshore current regime is planned which will be supplemented by empirical data from measurements at the Facility.

The wind-driven component of coastal currents has been studied by a graduate student from Old Dominion University.

Wave run-up will be measured at the site to supplement laboratory data collected in an ongoing wave run-up and overtopping study.

Offshore and nearshore wave data from the FRF will be used in an investigation to define sources of wave reflection and attenuation. Several additional studies in Nearshore Wave Transformation are desirable. Although CERC funds are not presently available for these, we believe they merit support from other agencies. These include wave set-up on beaches, water level changes across the surf zone, wave transformation and reflection on submarine bars, wind effects on breaking waves, long period waves in the nearshore zone, internal waves, standing waves in shore-normal direction, edge waves, and wave/current interaction.

In the Nearshore Sediment Transport subprogram, field measurements are being made at a number of coastal locations, including the FRF, just before and after coastal storms. These, together with data on winds, waves, and water levels, will be used to establish relationships between beach erosion and storm intensity.

The state-of-the-art of measuring longshore sediment transport rates will be assessed, and the two most promising techniques will be applied at the FRF.

Later stages of a seaward limit of effective sediment transport study will involve field determinations of such a limit, and the Facility will provide supportive data for this study.

The objectives of the Nearshore Placement of Sediment for Beach Nourishment Study are to examine changes in profile shape and sediment distribution along the nearshore profile in relation to winds, waves and currents, and to provide guidelines for placing sand in the nearshore zone for beach nourishment purposes. Much of the field work for this study will be done at the site.

Little is known about shore response to offshore dredging. Therefore, guidelines are being developed for determining the optimum distance from shore, the shape, and the water depth of a dredged hole, such that it will not adversely affect the shore. Plans call for qualitatively determining the rate of sediment transport at various locations in the nearshore zone at the site, and to quantify the processes controlling these rates.

The following Nearshore Sediment Transport studies at the Facility are desirable: wind blown sediment transport; time scale of beach response; response of nearshore bottom to storms; barrier island migration; occurrence and stability of various sand sizes on beach profile; develop low cost seismic reflection technology for surf zone; effect of temperature on field sediment transport; evaluate movable bed model technology; and sediment budget for the FRF.

In the coastal ecology subprogram, CERC studies concern use of vegetation for bank erosion control in Currituck Sound, and assessing the effects of pier construction on the environment.

In remote sensing, a SEASAT-A evaluation is being conducted by CERC and many other agencies. Data from instruments located on the satellite and aboard airplanes will be compared with ground truth data from sensors on the pier and with various radars under development by CERC, the Naval Research Laboratory and NASA. An evaluation of the state-of-the-art of remote sensing techniques for coastal engineering may utilize the pier site to meet its objectives.

The final group of supplemental studies are those which do not readily fall into the previous groups. The basic environmental measurements program and North Carolina inlet research are two inhouse efforts. The others are less directly connected with the CERC program, and therefore are proposed for outside funding. These include studies of the tidal characteristics of ocean and sound, wind characteristics and changes near the shoreline, temperature and salinity characteristics of ocean and sound, solar radiation characteristics, and sea/air interaction.

6. Summary.

The purpose and capabilities of the Field Research Facility have been reviewed, and the research program outlined. CERC encourages the use of the facility by outside investigators, for we feel it offers a unique opportunity to study coastal phenomena during both normal and storm conditions.

ACKNOWLEDGEMENT

This paper was prepared under the Coastal Engineering Research program of the U.S. Army Corps of Engineers.

# EMERGENCY BEACH PROTECTION FOR COUNTIES, CITIES, AND TOWNS

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## ABSTRACT

Coastal erosion management has not directed much attention to emergency beach protection methods. The extent of private shoreline ownership in the country exempts many developed areas of the coastal zone from public assistance. Consequently, implementation of protection measures to combat storm erosion events are generally ill conceived and plagued by a confusion of who is responsible for coping with the problem. This paper suggests that erosion contingency plans be authorized to develop, with multidisciplinary input, preselected plans of action to handle future erosion events. In this manner, intelligent management decisions can be made as to appropriate storm erosion mitigation measures to adopt thereby contributing to a most efficient program of action.

## INTRODUCTION

Storm related erosion is an ever present threat to coastal structures located in vulnerable backshore regions. The gradual rise in sea level has perhaps aggravated the problem in recent years, but it is coastal storms coincident with high tides which cause the worst damage. Traditionally, shoreline erosion is dealt with by long term mitigation measures such as beach nourishment programs to replenish lost materials or coastal structures such as seawalls to cease further encroachment landward. Coastal storm erosion is often concentrated within relatively short periods of time which implies that emergency measures to arrest a particular storm event(s) may be feasible in protecting property from damage. By investigating the coastal processes of a region and projecting the return period of probable erosion events, a systematic program of appropriate action could be adopted ahead to time to protect threatened structures. Decisions concerning the emergency mobilization of materials and labor could be pre-established such that the most feasible and practical utilization of funds and effort would be expended corresponding to the severity of the storm event.

The need for such a planning program is evident from the extent of coastal erosion in the United States, as about one-forth of the nation's shoreline is significantly affected by erosion. The Corps of Engineers has reported in its National Shoreline Inventory that critical erosion occurs along 2700 miles of coastline (1). Located mainly on heavily populated Atlantic and Great Lakes shores, the problem is caused by a combination of natural and man-induced factors such that shoreline recessions of less than one foot per year may be destructive. Not all areas are equally threatened since the significance of the erosion depends upon the population of the coastline. Consequently, areas in the Pacific Northwest, Alaska, and Hawaii suffer the least social and economic loss from erosion. More than 75 percent of the country's total citizens resides in the coastal states, and growth estimates indicate population within one mile of shorefront areas has been increasing at more than three times the national rate (2). Average annual losses due to erosion are high and stems mostly from damage to private homes, beaches, and shore protection structures. As the shoreline continues to attract industry, offshore continental shelf support activities, power plants, and second home owners and retirees, the damage costs are certain to increase (3).

Approximately 70 percent of shoreline lands are privately owned and herein lies the dilemma and controversy. This ownership criteria disqualifies the property from receiving public assistance for shoreline protection, and this often results in privately coordinated erosion protection schemes that are ill conceived and aggravate the situation (4). There is generally no clearly established responsibility or program available to cope with erosion events, and panic can prevail to compound and delay mitigating the desperate situation.

The author suggests that multidisciplinary contingency planning for future erosion events may be a prudent policy to enact. The coastal engineer, environmentalist, economist, and regulatory official could, with geographic specificity, analyze the particular characteristics of a coastal region, determine what storm erosion mitigation measures could be utilized, and establish the financial and managerial responsibility for their implementation. In this manner, the very least the property owner would receive, would be a document clearly describing the risk he assumes at his property and the acceptable and specific steps he could take to combat a storm erosion event.

## EROSION MECHANISM

The severity of beach erosion is generally attributed to the degree and duration of short period wave attack on the beach in conjunction with the stillwater level (astronomical tide level plus wind tide or storm surge). A schematic diagram illustrating the process may be seen in figure 1-7 of Reference 5 which basically shows the removal of the protective beach berm to an offshore bar thereby exposing the backshore areas to erosion. Domurant and Moore summarized in their respective papers the characteristics and affects of a series of severe winter storms which impacted on the California coastline in 1978 (6,7). In general the erosion progressed from erosion of the beach berm sands to exposure of backshore areas which were commonly attacked in a toe undermining process. This type of erosion is feasible to arrest and has been successfully accomplished in California.

The intensity of the storm and the degree of storm surge governs the practical limits of protection of coastal structures. As an extreme upper limit, the coastal storm of March 1962 which devastated Fire Island, New York was so overwhelming that no emergency methods could have been economically or feasibally mobilized to combat the situation. Review of record storm surges, storm erosion, and damage for several east coast areas (8) also implies that little short term measures could be enacted to combat the severe event, but a statistical evaluation of the probable return periods for less intense storms may conclude that emergency measures would be economically viable. Furthermore, the general characteristics of the beach profile before and after a Class 3 hurricane in Florida indicates that toe erosion was a typical mechanism of shoreline retreat (9), and that it may have been feasible to mitigate recession had coastal structures been threatened.

## EMERGENCY BEACH PROTECTION METHODS

Edge et al have summarized the current devices and methods that have been proposed for low-cost shoreline protection (10). These methods were specifically addressed for demonstration in sheltered waters (wave height less than 6 feet at coastal shores) and represent the variety of alternatives available to resist erosion until long period waves begin to restore the depleted shoreline. From an emergency mobilization standpoint, feasible methods would probably be limited to a form of revetment or seawall. Graded rock riprap is the most common material that can be placed, and if properly sized, can resist storm erosion. Other means such as longard sand-filled tubes have been effective in arresting dune erosion.

Under a storm erosion event, one can be limited to workable conditions only during time of low water since the presence of structures and soil stability criteria may preclude the necessary heavy construction equipment from the bluff top. Therefore, depending on the specific site conditions, the particular method of erosion protection will be limited to its availability and placement time. At Stinson Beach, California, a combination of longard sand-filled tubes and rock riprap was placed over a 5 day period to protect 600 feet of severely threatened homesites (11). Had a specific plan of action been thought out prior to the winter storms, a more timely and less costly program of action could have been carried out with the same success.

## EMERGENCY EROSION CONTINGENCY PLANNING

The basic concept of emergency erosion contingency planning (ECP) is patterned after that already adopted for spills of oil or hazardous substances. The specific area in question is analyzed for its particular characteristics and carefully thought out mitigation measures and decision points are preplanned for implementation as the situation warrents. Thus, in the case of coastal erosion, the characteristics of a shore are appraised, feasible protection methods preselected, cost-benefit analysis and environmental consequences evaluated, and a detailed plan of action formulated outlining the series of steps to be followed.

Such plans could be incorporated as part of the shoreline erosion elements of state and local coastal programs. At present, there is generally no recourse available to the private property owner to address the situation until it is too late. The Federal Insurance Administrative has labored hard over the question of equitable insurance programs for coastal zone flood damage (12), and has encountered difficulty in establishing proper set back distance criteria and insurance rate concept so that the property owner might insure his structure against probable loss. The ECP would perhaps help in clearing this question by offering an alternative method of approach via its study results. The ECP would address itself to the specific behavior of a coastal area with an estimated probability of events that could occur together with the degree of feasible methods, if any, that might protect the property during the storm period. By evaluating the cost-benefits of the area and its protection plan, the regulatory official can then make intelligent decisions regarding the worthiness of government sponsorship to underwrite the developed shore.

The basic steps of an ECP would be as follows:

1. Document the area's shore erosion history
2. Statistically determine return periods of coastal storms
3. Formulate most probable scenarios of light, moderate, and severe storm erosion
4. Analyze and determine most feasible emergency measures to combat storm erosion.
5. Conduct cost-benefit analysis to compare construction costs with socioeconomic benefits to be derived.

6. Prepare detailed ECP with step by step procedural plan of action for implementation of various levels of emergency action corresponding to storm intensity.
7. Adopt level of government sponsorship, i.e. the degree of funds to be appropriated and support to be offered.

Formulation of ECP's requires the bringing together of various disciplines to address the task. Coastal engineers will be called upon to stretch state-of-the-art technology in making decisions regarding erosion prediction and mitigation. Economists and insurance adjusters will be needed to evaluate and compare the different levels of emergency action in terms of benefits gained. Environmentalists will need to comment on the different alternatives proposed for action so that the quality of the shoreline is not damaged. Finally, the regulatory official will need to adopt the appropriate legal action to enact an equitable program that once and for all lets the property owner know exactly where he stands.

The extremes of policy proceedure are as follows:

1. Full government construction funding of emergency protection measures.
2. Non-intervention and zero funding, but sponsorship of the preparation of the ECP offered for private implementation.

It is likely that the final program would fall somewhere between 1 and 2. In the opinion of the author, all the components are available to make reasonable professional estimates, and therefore it would be appropriate to adopt ECP's for the nation's shoreline. As a result, it may be concluded that emergency measures, feasible at one location, are totally useless at another, therefore leading to long term measures as the only adoptable means of coastal protection. Similarily, an ECP could provide the necessary economic input leading to the means of financial sponsorship, if any, by a government agency or an erosion protection tax assessment district specially created to fund storm damage prevention.

The possibilities are many. It is hoped that this paper will provide some momentum toward handling the shoreline erosion controversy. In the opinion of the author, it is time to bite the bullet and coalesce the different components into a unified product.

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# LOW COST PROTECTIVE DEVICES
# FOR EROSION CONTROL
# AN OVERVIEW OF ACTIVITIES
# OF THE CORPS
# OF ENGINEERS IN THE SHORELINE EROSION
# CONTROL DEMONSTRATION PROGRAM

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LOW COST PROTECTIVE DEVICES FOR EROSION CONTROL
An Overview of Activities of the Corps of Engineers
In The Shoreline Erosion Control Demonstration Program
by

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## ABSTRACT

The pressures of increased recreational use and development of the shorelines has led to public demands for effective shoreline erosion control. Federal involvement in this problem began in 1930 with the formation of the Beach Erosion Board. This involvement has expanded through the years as evidenced by the Shoreline Erosion Control Demonstration Act of 1974. This Act appropriated $8 million to be spent over 5 years in demonstrating means of "low-cost" shore protection (including vegetation) in sheltered waters. The Act also authorized the formation of a Shoreline Erosion Advisory Panel to assist the Chief of Engineers in carrying out this program. With the assistance of this 15-member panel, the Chief of Engineers approved demonstration projects at 15 sites on the coastlines of the Delaware Bay, the Atlantic, the Gulf of Mexico, the Pacific, Alaska, and the Great Lakes. Six of the sites are located on Delaware Bay (as required by the legislation) and the remaining coastlines will each have two. One site remains to be chosen for the Atlantic which will make a total of 16 demonstration sites. These sites are described briefly with emphasis given to noteworthy devices which are being demonstrated. Construction should be complete at 14 sites by the end of this year and all 16 sites should be finished by the summer of 1979. If enough funds remain, approximately 20 additional sites with existing shore protection devices (constructed by others) will be monitored to gather additional data.

## INTRODUCTION

Increased development and usage of our coastlines for recreational purposes, which began early in this century, spawned a continuing public demand for shoreline erosion control. The formation and long distinguished history of the ASBPA testifies of this interest in beach erosion control.

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## FEDERAL INVOLVEMENT IN BEACH EROSION CONTROL

The early history of Federal involvement in beach erosion control began in 1930 with the establishment of the Beach Erosion Board. The function of the Board however, was limited to studying beach erosion problems; the Federal government was not yet involved in construction. In 1936, Congress granted authority for Federal participation in construction, but only where Federal lands or investments required protection.

Federal participation in beach erosion projects was authorized in 1946. The Federal share of the costs however, was limited to one-third of the total. This was later changed, in 1965, to 50 percent; 70 percent if public parks or conservation areas are involved. Also, in 1963, the Beach Erosion Board was replaced by the Coastal Engineering Research Center and authorization was given for the formation of the Coastal Engineering Research Board.

The Federal government therefore, has been relatively slow in stepping into the problem of beach erosion; at least in funding construction of mitigation measures. A critical problem which still remains is that the erosion which is most conspicuous occurs along highly developed shorelines, and most of these are privately owned.

Briefly consider the damages which occurred on the east coast as a result of the February storm this year. For instance, Dunewood, which was typical of much of Long Island, suffered severe beach erosion and a prominent scarp was formed. The Scituate-Marshfield area in Massachusetts also suffered severe and extensive damage.

Congressman Jack Kemp of New York has been a supporter of Federal involvement in shoreline erosion control. In a statement to the Congress on 20 May 1976 when he introduced legislation to allow tax deductions for losses from shoreline erosion, he noted: ".... the experiences of the past several years have convinced me that anything more than a minimally acceptable Federal commitment to shoreline erosion damage relief is unlikely in the near future." and, ".... Federal progress in controlling beach and shoreline erosion has been slow. Of a total of 64 projects authorized since 1946 on the Federal level, only 20 have been completed. The average time to complete the 20 projects or project segments has been about 10 years from the date of the local request."

Two Federal beach erosion control projects typify recent Corps involvement in beach erosion control. At Lakeview Park, Lorain, Ohio, three segmented, detached breakwaters were constructed to stabilize and retain a beachfill behind them. Project costs were $1.4 million. One year of monitoring has shown that the beach has been effectively stabilized.

Rockaway Beach, New York is primarily a beach fill project with periodic renourishment required, particularly after major storms. For a beach fill project such as this one which cost $14 million, critics often complain about the great amount of sand, hence money, which can be washed away by one major storm. The only response is, "What would have happened if the project had not been built?" The presence of the beach prevented what may have been extensive damage to back shore developments. Because of the high monetary value of those developments, this damage could easily have approached several million dollars.

## THE SHORELINE EROSION CONTROL DEMONSTRATION ACT OF 1974

The private landowner cannot normally afford such protective projects, and even if he could, his small section of shoreline might not lend itself to such measures. In response to this need, Congress passed the Shoreline Erosion Control Demonstration Act of 1974. This Act is Section 54 of the 1974 Water Resources Development Act. The program operates for 5 years with total funding equaling $8,000,000. Recognizing that "low cost" protection was not consistent with the requirements on the open coast, Congress emphasized control on sheltered or inland waters. In that light, the use of vegetation (as well as structures) was specified as an erosion control device. This led to the requirement that the Corps cooperate with the Department of Agriculture on plans for utilizing vegetation.

The program permits construction on private or public lands if the non-Federal sponsor will contribute 25 percent of the initial construction costs. This requirement has caused problems at several sites which were subsequently dropped from the program for that reason. The local sponsors must also assume operation and maintenance responsibility upon termination of the study. No Federal funds can be used for land acquisition.

A significant aspect of this legislation was the formation of the Shoreline Erosion Advisory Panel. Its general purpose is to advise the Chief of Engineers on how to best implement the

Section 54 program. This would include recommendations on site selection criteria and procedures needed to secure the cooperation of non-Federal sponsors. The panel is also required to perform periodic progress reviews as well as recommend ways to best disseminate the results of the study to the public. Throughout the course of the program it may also be called upon to perform other duties in support of the Chief of Engineers.

The panel consists of 15 members who are not employed by the Corps. They were chosen to represent a broad spectrum of geographic areas and fields of expertise. Mr. Joseph Caldwell, the Panel Chairman, is the former Chief of Engineering at the Office of the Chief of Engineers.

Because of the size of the Panel, it was broken into Committees. The Committees sought the advice of the Corps' District Engineers, the States, and other personal contacts to identify erosion problems that might be typical of the various regions. At Panel meetings, several companies and private individuals gave presentations on concepts, materials, and inventions for controlling erosion. Many of these devices were included in the demonstration program as will be discussed later.

The Panel was also subdivided into working groups for each of the coastlines of the Atlantic, Pacific, Gulf of Mexico and Great Lakes. These working groups visited many sites which were recommended by various sources and reported their observations to the full Panel. The Panel in turn, recommended possible sites to the Chief of Engineers.

The site selection criteria involve legal, social, environmental and economic considerations. The legal criteria must obviously be met, a principal consideration being that the site is on sheltered or inland waters. This means that the waves breaking on the shores have been limited by natural conditions to a significant height that does not preclude the use of low cost protective measures. The Panel generally considered waves of about 6 feet or less as being acceptable, but a specific height criterion was avoided. Also, the law specified a minimum of two sites per coastal region including Alaska.

The social or public relations criteria was primarily concerned with accessibility to the public. If erosion protection is being demonstrated, the public must be able to visit and observe the project throughout its life.

Environmental considerations include such things as: Is the site representative of a large number of areas facing coastal erosion in a region?

The economic criteria address the use of low-cost protection methods. The Panel has defined "low-cost" as $50 per foot of protection for materials, if no heavy equipment is required and $125 per foot, for materials and placement with heavy equipment. The protection is designed for a 10-year life with only minimum maintenance required provided no storm occurs with a recurrence interval greater than 25 years. The cost figures used are mid-1975 levels and the Panel has found it difficult to keep project costs within these limits.

## DEMONSTRATION SITES

The Chief of Engineers, based on recommendations of the Panel, has chosen 16 sites, nationwide, for demonstration projects. There are six sites in Delaware Bay and two each on the coastlines of the Atlantic, Gulf of Mexico, Pacific, Great Lakes and Alaska. The six sites in Delaware Bay reflect the influence of a local Congressman who was instrumental in getting the legislation enacted. They are the only sites specifically identified by the Act for inclusion in the program. The remaining ten sites are distributed, two each, around the remaining coastal regions.

## DELAWARE BAY SITES

The six Delaware Bay sites are Bowers, Broadkill Beach, Lewes, Pickering Beach, Slaughter Beach and Kitts Hummock, all in Delaware. Bowers, Broadkill Beach, and Lewes are already protected by Federal or State erosion control projects and therefore, will not receive additional erosion control devices as part of this program. These existing projects will be monitored during this study.

### Pickering Beach, Delaware

The planned demonstration at Pickering Beach will be a floating, rubber-tire breakwater. Two different designs will be tested. The Type I design will be a "Wave Maze" and the Type II will be a "Goodyear" design. Different breakwater widths are being tested in an attempt to determine how their wave transmission characteristics vary.

The structures will be anchored with concrete blocks about 1100 feet from shore. The depth at the structures will be approximately 6 feet at MHW. The tires in the Goodyear modules will be bound with conveyor belt edging which will then be fastened with nylon bolts and nuts. Foam is used for flotation.

In the "Wave Maze" module the individual tires are bolted together and the planform of the completed breakwater is a parallelogram.

Kitts Hummock, Delaware

At Kitts Hummock, a series of three detached breakwaters are planned. One structure will be conventional rubble-mound, one will be sand-filled bags and the third will be constructed with a row of large, precast, rectangular concrete manhole sections, ballasted with sand. The structures will average about 700 feet from shore and they will be submerged at MHW. The sand bag structure will employ filter cloth and the rubble structure will rest partly on filter cloth and partly on graded stone.

Slaughter Beach, Delaware

A perched beach will be demonstrated at Slaughter Beach. The sill will be constructed with a segment of sand-filled bags, one of wood sheetpiling and a third of rectangular concrete manhole sections ballasted with sand. The crest elevation of this sill will be at MLW and the beach will be an artificial fill rather than the product of natural accretion. The sand bags will only be one bag high and they will be placed on filter cloth.

## ATLANTIC COAST SITES

Fort Raleigh, North Carolina

Bull Island, South Carolina was originally planned as one of the Atlantic Coast sites. The Department of Interior however, withdrew their support of the project because of objections which arose concerning the placement of structures on an undeveloped barrier island. A search for an alternate site was then necessary. Fort Raleigh, North Carolina, on Roanoke Island, is now tentatively planned as a replacement demonstration site. No specific plans have yet been reviewed by the full Panel however.

Jensen-Stuart Causeways, Florida

The other Atlantic coast site is at the Jensen-Stuart Causeways, between Fort Pierce and West Palm Beach, Florida. There are a number of test sites for this project located on the north and south sides of the two causeways connecting Hutchinson Island with Jensen Beach and Stuart. A main cause of erosion at this site has been the Australian pines which are not a native specie. The shade of these trees has killed the native beach grasses, and since, the roots of the pines are not effective for soil retention, erosion has resulted.

Numerous vegetative plans will be tried at this site. In some of these, the pines will be removed from the beach area and other species will be planted. At one vegetation site, a floating tire breakwater will be temporarily installed to determine if it encourages the establishment of the new plantings.

Revetment construction will also be tried using Monoslab, Turfstone and Lok-Gard blocks, all of which are patented. Conventional concrete masonry units will also be used for a section of revetment.

## GULF COAST SITES

Basin Bayou, Florida

Basin Bayou, located on Choctawhatchee Bay in the Florida panhandle is one of the Gulf Coast sites. The site is characterized by a bluff, fronted by a narrow sand beach. Among the structures to be tested will be a Longard tube, installed as an offshore breakwater. Another offshore breakwater will be constructed in three sections with different types of sand-filled bags. A third offshore breakwater will be a "Surgebreaker," which is a patented device. It is constructed of precast, perforated, concrete modules which are usually placed by helicopter.

A "Sandgrabber" will also be constructed at the site. The Sandgrabber is horseshoe-shaped in plan, and is constructed of individual concrete blocks fastened together with steel tie rods. Vegetation will also be tested and an attempt will be made to stabilize the eroding bluff with a bulkhead. It will be constructed with sand-filled bags retained by hog-wire fence stretched between timber piles.

The second Gulf Coast site was originally Sand Point, Texas. It had to be dropped from the program however, because the local sponsors could not meet the required 25 percent contribution of the project costs.

Fontainebleau, Louisiana

The second Gulf Coast site is on Lake Ponchartrain at Fontainebleau State Park, Louisiana. The relief is low with a narrow sand beach fronting extensive marsh lands. The plan of demonstration includes concrete block revetments, a timber-tire breakwater, filter-cloth revetments and extensive vegetative measures. The concrete block revetments will utilize various arrangements of Gobi blocks and Gobi mats. The breakwater will be constructed offshore with timber piles upon which rubber tires will be stacked. The tires will be held down with timbers strung along the tops of the piles.

## PACIFIC COAST SITES

Alameda, California

One Pacific Coast site is located on San Francisco Bay at Alameda, California. This site is located in the most highly developed area of any of the SEAP demonstrations and should therefore be easily accessible to large numbers of people. The site is characterized by a flat sandy beach fronting a bluff at the top of which is a large road. Broken concrete pavement sections are strewn along this bluff in a half-hearted attempt at shore protection. A large part of this demonstration will involve the reuse of this rubble to construct more formal revetments. In some cases, the concrete will be broken into more blocky pieces before reconstruction to determine if that improves performance. Other measures to be undertaken include an artificial tombolo which will be stabilized with vegetation and a Longard tube offshore breakwater, a sand bag sill to protect newly planted vegetation and a sand bag groin to retain a small beach fill.

Oak Harbor, Washington

The other Pacific Coast site is at Oak Harbor, Washington. The problem at the site is bluff recession which occurs during high water levels. Demonstration devices include a gabion revetment, a timber pile - rubber tire bulkhead, a treated timber bulkhead, an untreated timber bulkhead and a sand-cement bag revetment. All of the devices utilize filter cloth for half of their length and graded stone filter for the other half.

The timber pile-rubber tire bulkhead is similar in construction to the structure at Fontainebleau, Louisiana where it is used as an offshore breakwater.

## ALASKA SITES

### Kotzebue, Alaska

The two Alaska sites will be at Kotzebue and Ninilchik. Kotzebue is located north of the Arctic Circle at the tip of the Baldwin Peninsula. The site is firmly ice bound most of the year with open water occurring only during the summer months. The shoreline is gravel and is heavily used by Eskimo fishermen who beach their small craft there. The demonstration will utilize steel fuel barrels which are found in abundance at the site. These have been used as bulkheads in the past and the demonstration will involve their use as revetments and groins. Similar structures will also be constructed of gabions containing gravel-filled bags. The bags are necessary because there is no native rock large enough to be retained by the gabion mesh. One groin will be constructed of gravel-filled bags alone to study the effects of ice on the structure.

### Ninilchik, Alaska

These same materials will be used for groins at Ninilchik to protect the toe of an existing log revetment. Ninilchik was chosen as an alternate site after Seward had to be dropped from the program due to lack of funds for the 25 percent local contribution.

## GREAT LAKES SITES

### Port Wing, Wisconsin

One Great Lakes site will be located on Lake Superior at Port Wing, Wisconsin and the other at Geneva State Park, Ohio. The Port Wing site consists of a high eroding bluff with a highway near the top edge. The demonstration plan includes a bulkhead constructed of railroad ties placed between vertical steel H-piles, and revetments constructed with rubble tires, concrete blocks and conventional riprap.

Geneva, Ohio

The Geneva site is situated on the south shore of Lake Erie. The plan for this site includes three detached breakwaters and vegetation. One of the breakwaters will be constructed of gabions, one of Sta-Pods and the third will be a Z-Wall.

## PROGRESS OF THE PROGRAM

The Corps' Divisions and Districts are now making final plans for construction. The Oak Harbor site is already completed and all but two of the sites should be constructed by the end of 1978. The Jensen-Stuart demonstration site will be completed early in the spring of 1979. The Fort Raleigh site is still being studied and has not yet been approved but if plans proceed as expected, it too, could be completed early in 1979.

In addition to constructing demonstration projects, the program will include monitoring of devices at other sites. In these cases, the structures or vegetation have already been installed by other interests. The panel has nominated 22 sites for monitoring, and they are:

### Atlantic Coast

Charleston, SC
Buckroe Beach, VA
Pine Knolls Shores, NC
Hampton Nat'l. Wildlife Preserve, VA
Duck, NC
Uncle Henry's Fish Camp (Wilmington) NC

### Gulf Coast

Key West, FL
Shoreacres, TX
Holly Beach, LA
Beach City, TX
San Leon, TX

### Pacific Coast

Kualoa Regional Park (Oahu Island), HI
Siuslaw River, OR
Sunnyside Beach (Steilacoom), Puget Sd., WA

Great Lakes

Muskegon State Park, Tawas City, MI
Port Sanilac, MI
Sanilac - Sec. 11 (Lake Huron), MI
Sanilac - Sec. 26 (Lake Huron), MI
Tawas Point (Lake Huron), MI
Ashland, WI
Lincoln Twp. (Lake Michigan), MI
Little Girl's Point, MI

The exact number of monitoring sites will not be known until it is determined how much money is left following construction of the demonstration projects. The costs at many of the sites are running higher than expected. The bids on the floating tire breakwater at Pickering Beach, Delaware, for instance, had to be rejected and the plans modified to reduce costs.

We are confident however, that the program will yield valuable information for the proper design of low-cost shore protection structures in sheltered waters.

# ENVIRONMENTAL MONITORING

# OF THE

# BEACH RESTORATION PROJECT

# FOR THE

# CITY OF DELRAY BEACH, FLORIDA

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## ABSTRACT

In 1978 a Maintenance Beach Restoration Project was completed in Delray Beach, Florida. As part of the beach restoration project, an environmental monitoring program was conducted which investigated the effects of dredging on nearby coral reefs. Five reef monitoring stations were established and monitored prior to, during, and after the construction stage of the project. Water and sedimentation samples were collected and evaluated throughout the monitoring period. Photography and photogrammetry were used to provide visual records of the reef stations in determining if dredging was affecting the reef. In addition to the monitoring stations, diver surveys were conducted over the entire reef to investigate the possibility of reef damage due to contact with the dredge cutter head or positioning anchor. Evaluation of the photographic and physical evidence collected during the monitoring period suggested that turbidity and sedimentation had no observable effect on the reef corals. Diver surveys, however, revealed that reef damage had occurred. The damage appeared to have been caused by a dredge anchor and anchor cable.

## INTRODUCTION

In recent years there has been increasing concern for the effects of mankind's activities on the environment. Preservation of the environment is now an important consideration in any of man's endeavors. Coral reefs living in the ocean waters of Florida may be affected by attempts to preserve yet another natural resource; the beaches.

Since the 1950's the State of Florida has experienced an astounding growth rate, particularly in the coastal regions. Once barren shorelines are now highly developed areas extensively used by residents and tourists alike.

Wide beaches provide recreational area and protect coastal development from flood damage in the event of a major storm. Presently many miles of Florida beaches are in a state of critical erosion because they lack the dimensions to provide either ample recreational area or storm protection.

A number of measures are available to control beach erosion and to restore beaches. The dredge and fill operation is the most accepted method of accomplishing beach restoration in Florida. It is common practice to obtain the sand needed for beach fill from offshore areas where large accumulations of sand occur in depressions in the continental shelf. The fill is removed from these areas, referred to as borrow areas, by dredging and placed on the eroded beaches. The advantages are obvious in that the required recreational space and storm protection are provided with the construction. After the completion of construction an aesthetically pleasing beach remains, similar in appearance to the beach prior to erosion. However, turbidity and the subsequent sedimentation created during dredging can have detrimental affects on nearby coral reefs.

Environmental monitoring of a reef system in close proximity to a dredge-and-fill operation is an important addition to the engineering inspection and supervision. An environmental monitoring program can provide for early warning of possible sedimentation damage to nearby coral reefs. Inspecting and supervising engineers can then institute directives to modify or cease potentially damaging dredging operations. During the 1978 beach restoration project of Delray Beach, an environmental monitoring program was conducted on the coral reef adjacent to the dredge borrow area.

## DELRAY BEACH EROSION CONTROL PROJECTS

The City of Delray Beach has a recent history of severe beach erosion. In the early 1970's major storms had reduced the beach width over 100 feet and portions of Ocean Boulevard, the coastal state roadway, were undercut and damaged. A concrete revetment was then constructed but was not successful in stopping the advancing ocean; Ocean Boulevard and the new revetment were damaged during a series of Northeast storms in 1972.

A beach restoration project was undertaken in the summer of 1973. Approximately 1.6 million cubic yards of beach fill were dredged from an offshore borrow area onto the eroded beach. The initial construction shifted the average Mean High Water Line 180 feet seaward. The wide beach provided the recreational area and storm protection that Delray Beach had sought.

In 1978 a maintenance beach restoration project was completed; 570,000 cubic yards of beach fill placed over 1.7 miles of shoreline. Beach fill was again obtained by utilizing an ocean borrow area located approximately one-half mile offshore. The dredging began in December of 1977 and continued through May of 1978.

The environmental monitoring program conducted during the 1978 beach restoration project began in October of 1977 and is still underway as of this writing. It is the environmental monitoring program, especially the investigations of the effects of the dredging on the coral reef, that is the subject of this paper.

Dredging operations during the 1978 Beach Restoration Project in Delray Beach, Florida

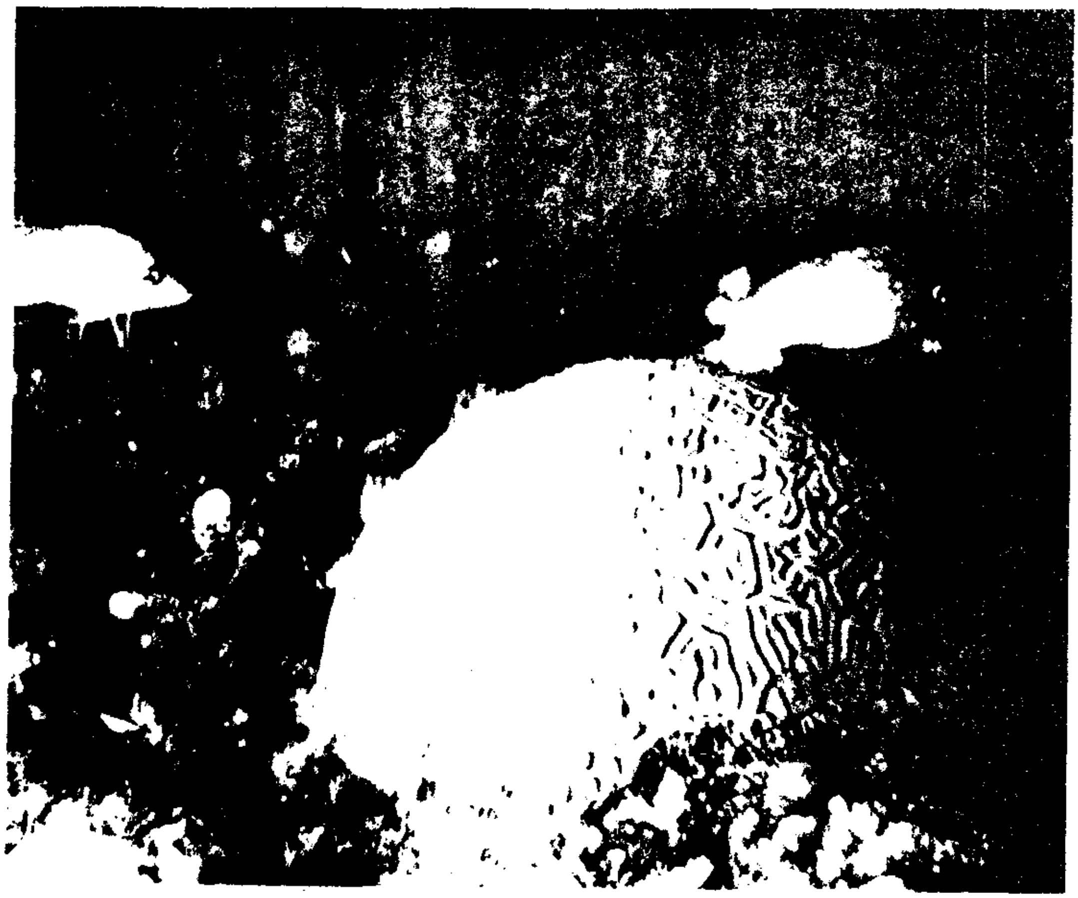
## THE CORAL REEF

Coral reefs are found primarily in warm, clear waters of tropical seas. Tropical corals require water temperatures in excess of 16° centigrade and a relatively low rate of sedimentation to survive. Coral reefs adjacent to southeast Florida are composed primarily of soft corals, sponges and a minor proportion of hard, reef-building corals. These coral reefs are usually found offshore and in deep water where sedimentation and temperature fluctuations are minimal.

A coral reef lies to the east of the Delray Beach coastline. Many of the tropical corals which presently grow on the reef are dependent upon the Florida Current, a major warm-water current which sweeps along the Florida coast from the Caribbean Sea. Delray Beach is situated near the northern limit of the range of many tropical corals; the influence of the Florida Current maintains warm-water temperatures allowing for coral existence.

The western edge of the coral reef lies at a distance of approximately 4,000 feet offshore. In many locations steep, 15-foot ledges rise up from approximately 60-foot depths of water to 45 feet on the reef top, while in other locations the reef crest is only a few feet above the ocean bottom. Live coral colonies grow on the surface of an ancient coral reef, elevated above the sandy ocean floor. Approximately 10% of the reef surface is covered by live reef-building (hard) corals. The most common species to be found include large star coral, Monastrea cavernosa, brain coral, Meandrina meandrites, star coral, Dichocoenia stokesii, large flower coral, Mussa angulosa and some scattered patches of staghorn coral, Acropora cervicornis, among others. The most abundant organisms growing on the reef are the soft corals including gorgonians, sea whips and sea fans, and numerous sponges.

The borrow area for the 1978 Delray Beach Erosion Control Project was situated parallel to the coastline, extending from the northern City limit to the southern City limit, a distance of 6,600 feet. The eastern edge of the borrow area, closest to the reef, was approximately 400 feet from the reef edge (see Plate No. 1). The primary threat to the reef environment stemmed from the potentially damaging sedimentation which resulted directly from dredging. Those organisms which were most susceptible to this type of damage were the benthic marine invertebrates, especially the hard corals, which could not move out of the area as could fish or other motile creatures. Also, the morphology of many species of hard coral is such that sediment can accumulate in depressions on the coral colony. Since hard corals are inflexible, the possibility of currents or other water movements removing sediment from the organism was less than with soft corals



Brain Coral found on the reef out of the Delray Beach coastline.

which could sway and shed the sediment which had settled on them. Sediment can smother the coral polyps, interrupting respiration and feeding resulting in the death of the organism. A second potential threat to the reef during the project was the possibility of physical damage due to accidental collision of the dredge cutter head or dredge positioning anchors with the reef.

## THE ENVIRONMENTAL MONITORING PROGRAM

Reef Monitoring Procedures. Initially, diver surveys utilizing underwater photography were conducted along the natural reef and within proximity of the borrow site to determine the general overall make-up of the reef community. Sediment thickness and water depth charts were used in the location of the natural reef with reference to the borrow site. Five monitoring stations were chosen on the basis of two criteria: first, the general location of the stations were selected to situate three stations adjacent to the borrow area, with two more stations, one north and one south of the borrow area. The stations were spaced at approximately equal distances along the project area (Plate No. 1). The second criterion was to select the station locations to include a variety of hard coral species.

The stations were staked out on the reef as a 10 foot by 10 foot square, providing 100 square feet of reef surface to monitor. A comprehensive program of photography and photogrammetry was conducted at each monitoring station. Each station was photographed prior to, during, and after completion of the dredging project. These photographs provided visual records of the monitoring stations from the pre- to post-construction period. Individual coral colonies were also photographed and rephotographed with a macro-closeup camera which allowed both identification and detailed information as to the relative well-being of the organism.

Sediment jars were placed at each reef station and periodically collected and analyzed as to content. Background information was collected beginning ten weeks prior to dredging and continues to be collected after the completion of dredging operations to establish the natural rates of sedimentation. In conjunction with gathering information on sedimentation rates, turbidity data was obtained from water samples taken at each monitoring station. Background turbidity samples were collected prior to, during, and after dredging to determine the levels of turbidity normally occurring in the vicinity of the coral reef.

A Littoral Environmental Observation Program was conducted concurrently with the monitoring study throughout the life of the project. The ocean variables observed and recorded included data on wave action, currents, water clarity and weather conditions. This information was gathered twice daily, seven days a week and recorded on standardized littoral environmental observation forms, and was used to correlate ocean conditions and sedimentation rates found on the reefs.

## ANALYSIS

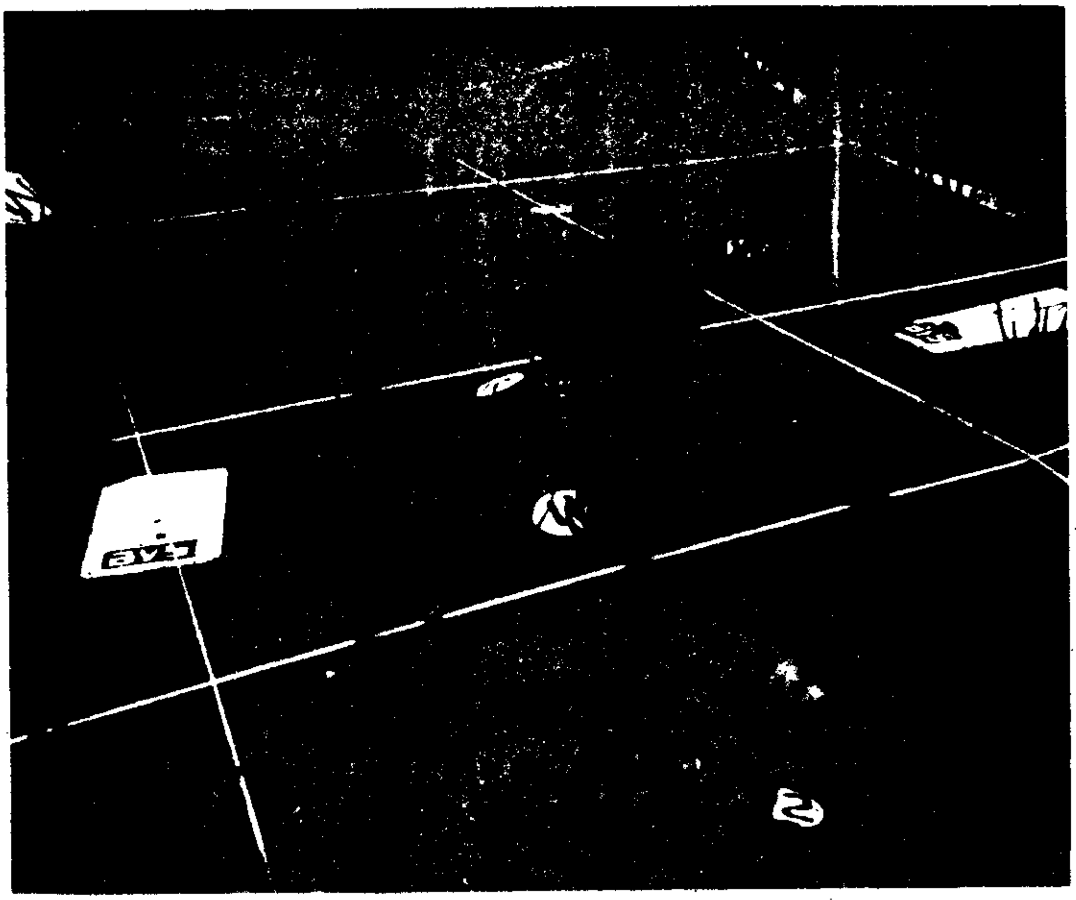
Water Turbidity Evaluation. Water samples were collected at every station during each visit to monitor the reef. Additionally, water sampling and turbidity analysis were conducted by the dredge contractor in the vicinity of the beach and the dredge cutter head. All water samples were analyzed with a Hach 2100A turbidimeter. The results were recorded in Nephelometric Turbidity Units (N.T.U.'s), a measurement of light reflected by sediment suspended in the water sample.

Turbidity measurements taken from water collected on the reef stations demonstrated no discernible increase in turbidity during dredging operations when compared to samples taken prior to or after completion of the project. In only one instance did any of the water samples register a reading of over 1.0 N.T.U., and it occurred prior to the commencement of dredging and followed five days of rough seas. Quite often water samples taken on the reef were found to be of greater clarity than tap-water samples taken in our office.

Monitoring station no. 2 had the highest readings in 60% of the occasions when samples were taken. This can be attributed to the fact that station no. 2 was located on a section of reef which was low in topography compared to the other stations.

Samples taken by the dredging contractor in the vicinity of the beach were occasionally found to exceed the state water quality standards for Class III waters of 50 J.T.U.'s (Jackson Turbidity Units). Samples taken at a distance of 200 feet from the cutter head conformed to Class III water standards.

Sedimentation Rate Evaluations. Sediment samples were collected at each monitoring station in conjunction with water sampling for turbidity measurements. A sediment jar was placed adjacent to each monitoring station on the reef. As with turbidity, sedimentation samples were collected before, during, and after the construction period.



Environmental Monitoring Station prepared for photography

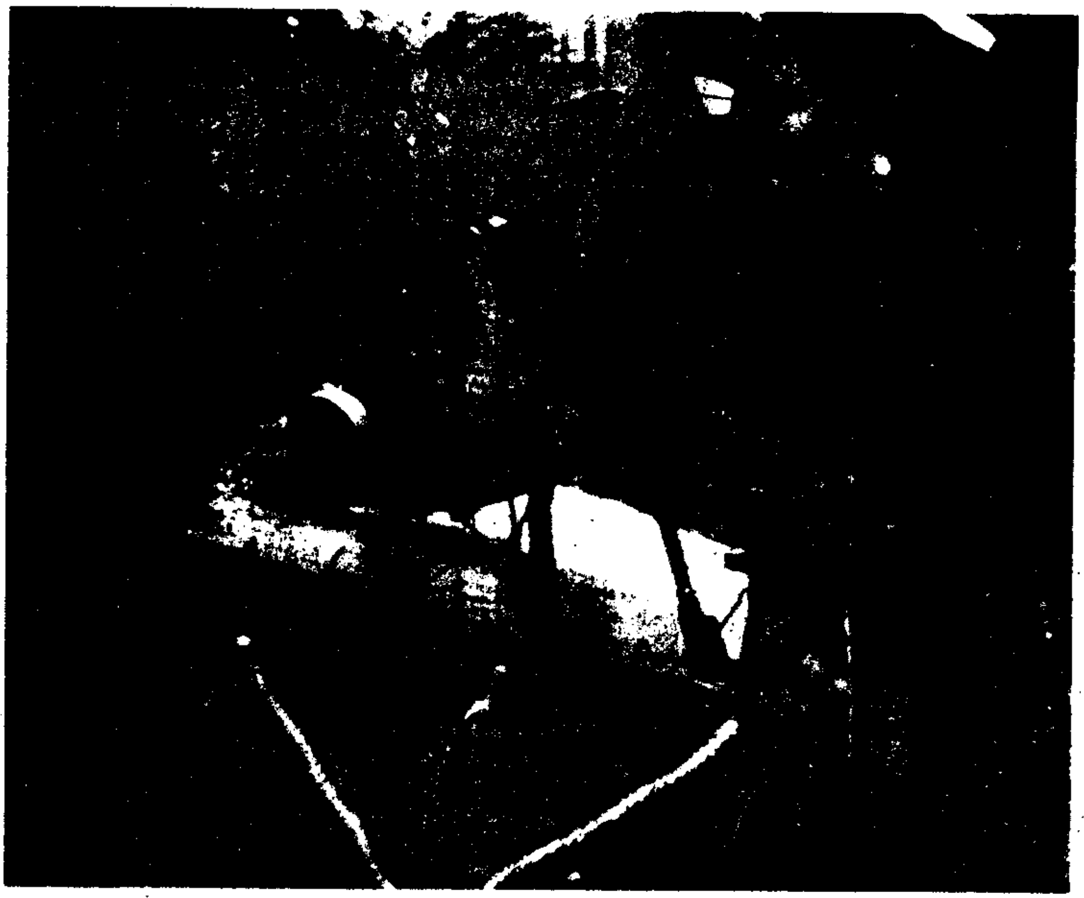
Except in one instance, the sedimentation rates during the construction reflected little change from the natural rates. Sediment samples collected on February 19, 1978 indicated a higher than normal sedimentation rate. The greatest increase occurred at monitoring station no. 2 which was located nearest the dredge. The sedimentation rate prior to the increase was 0.00494 grams/$cm^2$/day but for the time interval from February 4 to February 19, the rate increased to 0.16395 grams/$cm^2$/day. Quality control reports from the dredging contractor revealed that the pipeline which transported dredged materials from the dredge to shore had ruptured on two separate occasions. The incidents occurred on February 8th and again on February 16th during rough seas. The combination of the broken pipeline during a period of active pumping and rough seas spread sediment on the reef, especially in and around monitoring station no. 2. Aside from the exceptions of the ruptured pipeline, sedimentation rates were fairly consistent throughout the monitoring period.

Photographic Evaluations. A program of photography was conducted throughout the monitoring period. Prior to dredging, the photographic technique of photogrammetry was employed to visually record each station. A series of 32 photographs were taken of each 10 foot square station and overlayed to form a visual representation of the entire station. By utilization of this technique before and after the construction period, comparisons were possible to determine if any environmental changes occurred. In addition, individual benthic organisms were photographed and rephotographed utilizing close-up techniques. Close-up photography yielded the detail required for identification of the organism eliminating the need of relying solely on diver identification or the removal of the organism for identification purposes.

Great care was taken to leave each station undisturbed. Trisponder electronic positioning equipment was used to obtain precise location of each station. Thus, it was possible to return to each station after an extended period of time and determine if any long-term changes had occurred.

Close inspection of the photographic evidence revealed no observable damage to the reef stations to date. This information substantiated the results of turbidity and sedimentation measurement which revealed little change from natural conditions on the reef.

Diver Observation. In addition to the comprehensive investigations of the monitoring stations, divers periodically swam along the reef adjacent to the 6,600 foot long borrow area. Diver surveys were performed to observe the reef lying between the environmental stations. Of primary concern was the possibility of physical damage to the reef caused by contact with the dredge cutter head or positioning anchors.



Biologist and Ocean Engineer Richard Spadoni recording the location of photographed corals

On May 31, 1978, while engaged in a diver survey of the reef, an area of damaged reef was discovered. The damage consisted of uprooted soft corals, fragmented sponges and domed coral heads which were overturned or scarred by the dredge anchor and anchor cable. The area damaged was triangular shaped and extended from the western edge of the reef to a point approximately 350 feet to the east. The top of the reef appeared to have been scraped and many of the sessile invertebrates damaged. The most severe damage occurred in the areas of highest topography while low profile organisms growing in depressed areas of the reef were undamaged. Also observed were trenches approximately 6 feet in width and oriented in the east-west direction near the eastern edge of the damaged area. The trenches appeared to have been made by the dragging of an extremely heavy object across the reef.

Further diver surveys found no other areas of the reef damaged.

## CONCLUSIONS

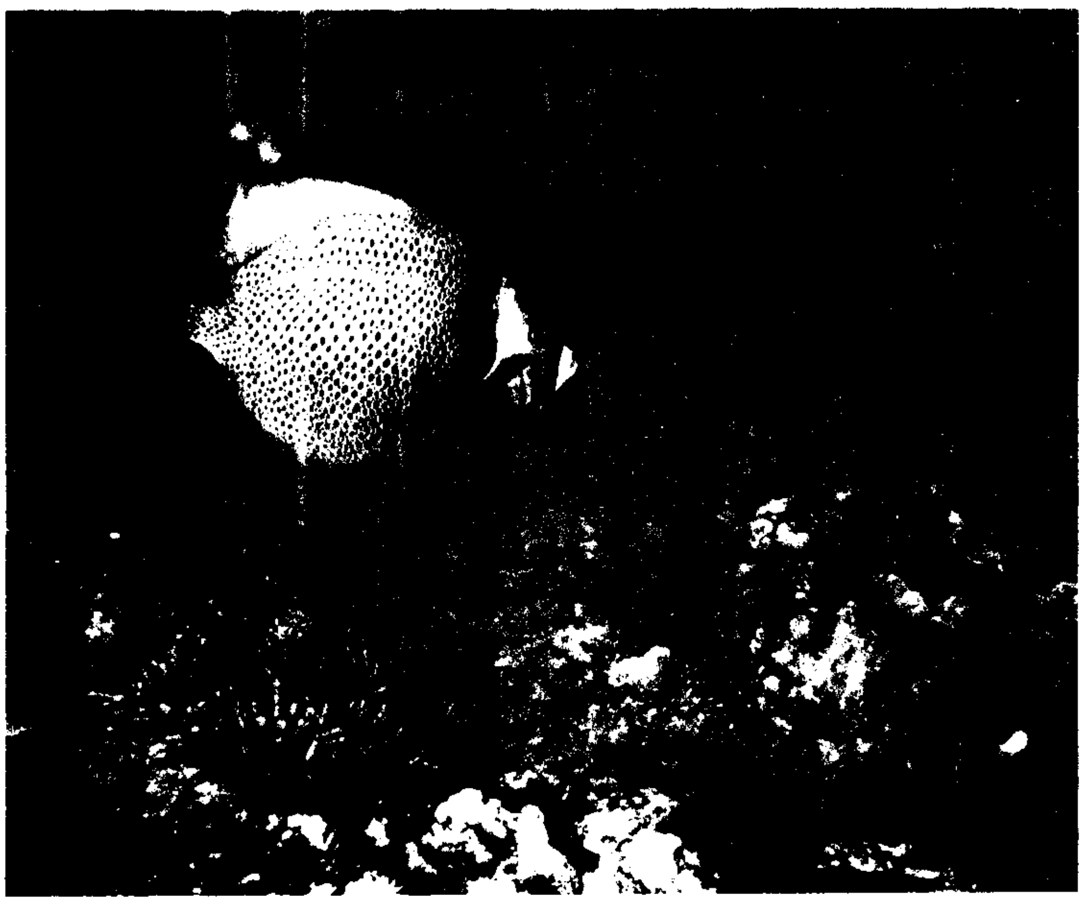
There has been no detectable reef damage due to sedimentation or turbidity during the construction period. Several factors contributed to the lack of turbidity or sedimentation damage to the entire reef system:

1) The location of the limits of the borrow area was no closer than 400 feet to the nearest reef and typically found 700 feet from the reef.

2) Currents oriented predominantly in the north-south direction carried sediment west of, not over, the reef.

3) Water depths in the borrow area and over the reef ranged from 40 to 65 feet, somewhat deeper than in other beach restoration projects in southeast Florida. Deeper water minimized bottom turbulence due to wave action which allowed suspended sediment to settle out in a relatively short period of time. Also, quiescent weather during the construction period contributed to a fairly calm wave climate, further reducing bottom turbulence.

Although there was additional sedimentation attributable to the ruptured underwater pipeline, the area of the reef which received the majority of the sedimentation, monitoring station no. 2, was not observably damaged. One reason for this was the low topography of the reef which was only several feet above the sandy borrow area. Also, numerous large pockets of sediment existed within the reef in this area. Under natural conditions the sedimentation rate of monitoring station no. 2 was approximately 2.5 times greater than



Appearance of the coral reef adjacent to the damaged reef

Portion of the damaged reef

the rates measured on the remaining monitoring stations. The corals living in this area were species which were apparently more tolerant of sedimentation and were able to survive the increased sedimentation rates due to the ruptured pipeline.

The reef damage which was discovered by diver survey appeared to have been caused by an anchor and anchor cable from the dredge. The reef damaged area occurred directly seaward of the last working position of the dredge and was discovered within a few days of its occurrence.

In subsequent observations of the damaged reef it was noted that algae was beginning to grow in areas which were scraped. Sections of broken sponge which had littered the area were less evident, but the absence of large sponges in the damaged area was obvious in comparison to the adjacent undamaged reef. Numerous gorgonians were pushed over and lying on the reef but continued to survive, in most cases retaining some attachment to the reef.

As of this writing, investigations of the damaged reef still continue. Answers will be sought as to the degree of sessile invertebrate repopulation which can be expected and as to whether the partially damaged coral heads will survive.

The daily reporting system utilized by the dredge contractor to provide dredge locations and turbidity measurements proved inadequate. Lag times between receptions of reports by the engineers and questionable dredge positioning accuracy made effective use of report results difficult. Quality control reports were typically submitted to the engineers prior to partial payment requests from the dredge contractor. Daily reports were received as much as one month after they had been completed. In the case of the reef damage, quality control reports made no note of anchors having been placed in the vicinity of the reef damage.

## RECOMMENDATIONS

The following are recommendations which would provide additional safeguards against the possibility of reef damage occurring during beach restoration projects:

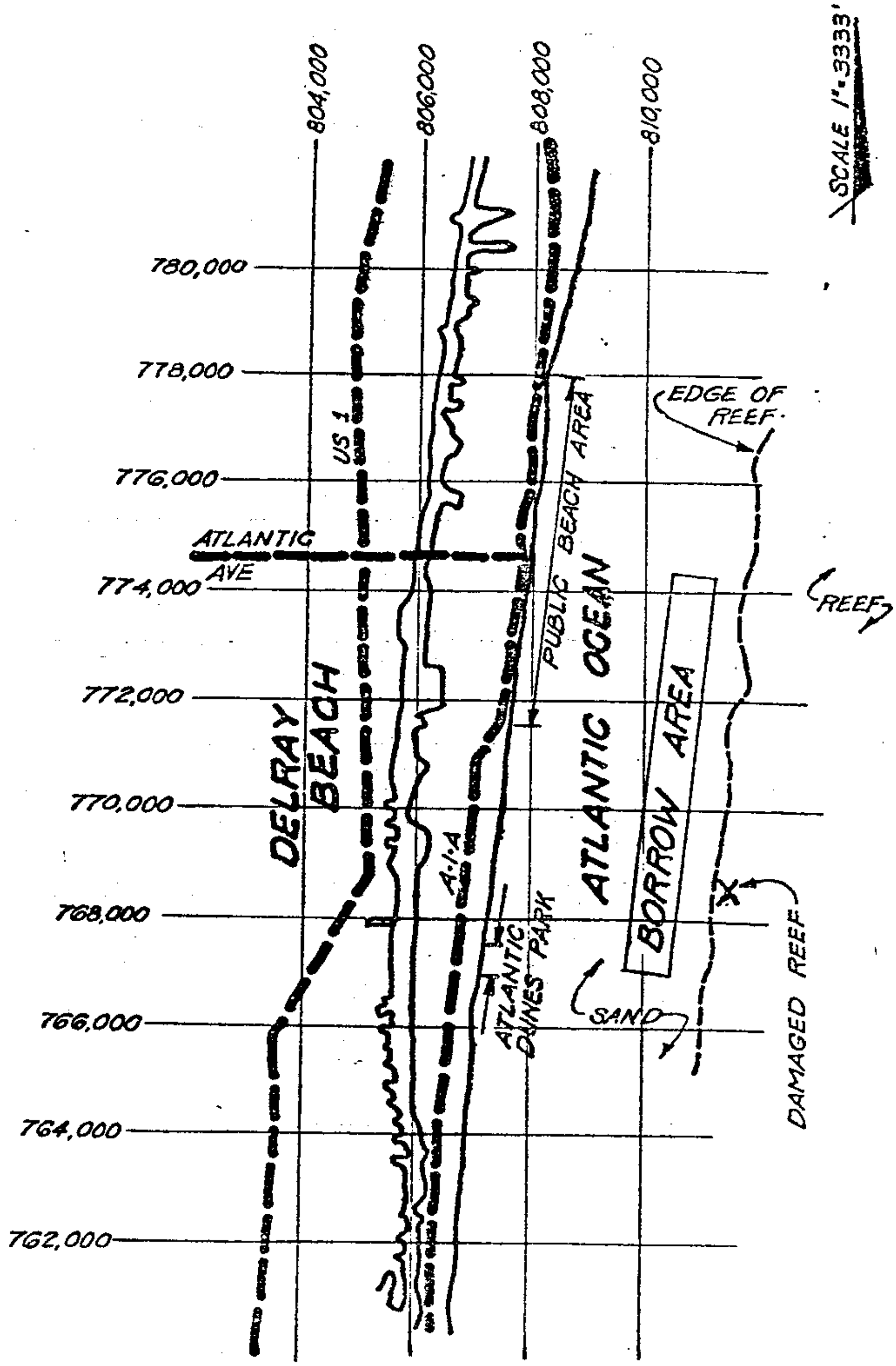
1) The monitoring of water quality by turbidity measurements should be incorporated into a total program to be the responsibility of the engineers overseeing the restoration project. There is a certain amount of lag-time between the sampling and measurement of water quality and reports to the engineer. If turbidity is high, sedimentation rates on the reef may be unacceptably high dur-

ing this time-lag resulting in reef damage. If turbidity rates are found unacceptable for State of Florida Class III water quality standards in the proximity of live reef, the engineer should halt dredging operations until the situation is corrected.

2) Relocation of the dredge in the borrow area or the movement of anchors should be monitored by the engineers. This will insure that the dredge remains within the limits of the borrow area and that anchors are not dropped on coral reefs.

3) A general reef survey should be a requirement of the State of Florida prior to issuance of construction permits for beach restoration. Potential problem areas could be identified in the planning phase of the beach restoration project and adjustments made in the borrow area. In this manner, project delays during construction due to concern over sedimentation damage to nearby reef would be avoided.

4) Every effort should be made to insure that the construction period occurs in the summer months. The ocean is normally much calmer in the summer months allowing for rapid settlement of suspended sediment.

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| ARTHUR V. STROCK & ASSOCIATES, INC.<br>DELRAY BEACH | DRAWING NUMBER: 4818.07-10-001A | |
| | DATE: JUNE 78 | BY: CRIS |
| | COMM. Nº 4818.07 | |

PLATE NO. 1

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# SHORELINE STABILIZATION

# AND ITS

# IMPACT ON THE RECEIVING WATERS

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## ABSTRACT

The United States of America has 58,000 miles of shorelines, including seashores, estuaries, rivers, lakes and springs.

Oceanshores, the transitional zone between dunes and the submerged photic zone, play an important biologic role both to the submerged and the dune areas.

Estuarine marshes and other intermittent land-water interfaces act as an exchange medium between the uplands and the submerged seagrass beds.

Since the transitional zone and estuarine shores have a substantial impact on the receiving waters, stabilization methods play a great role in their well-being.

Waterfront stabilization using natural vegetation is an effective and economical way to combat erosion and at the same time, impose the least amount of detrimental effect on the receiving waters.

SHORELINE STABILIZATION

AND ITS

IMPACT ON THE RECEIVING WATERS

The United States of America has 58,000 miles of coastlines, 15,000 of which are erosion-prone and troubled, with 2,700 in critical condition.[1] These shorelines include miles of rivers, waterways and other shorefront areas, and the target of 53 per cent of the total population density of this country.[2]

The State of Florida has an approximate 1,300 miles of oceanfront. Here, we have 30,000 freshwater lakes, approximately 1,700 streams, and 20 major freshwater springs.[2]

There are no estimates of the miles of artifically created waterfront canals, but with 34 coastal counties, one might guess at the numbers.

Today, I would like to focus on the subject of waterfront areas, what they are, how important they are, and, possibly, how to go about stabilizing them with using natural methods.

I would like to discuss, in general, two types of shorelines with erosion problems. First, the ocean shores, with the rise and fall of tides, storm tides, and hurricanes; and, next, the estuarine shores with wind-driven tides and subject to seasonal inundation with periodic effects of lunar tides.

The Atlantic Ocean shores have a series of dunes to serve as their natural defense system. Depending on the degree and the intensity of a storm, the destruction or breaching of this system leads to various degrees of storm damage and erosion.

The erosion barrier function of the dune system, however, is only one of many functions of the dune line. This area, an immediate neighbor of the intertidal zone, has a close relationship with the land-water interface, which is a complex of habitats forming a productive and fascinating area.

I would like to, briefly, discuss the general components of the beachfront, forming this system.

The ocean nearshore areas within the photic zone have a complex of communities which relate to the deeper areas of the sea floor on one side, and the upland shores on the other. The Atlantic Ocean nearshore areas, with the influences of the Gulf Stream, have a complex of sloughs and ridges, reefs, serpulid worm formed rocks, and bottom vegetation, supporting a complex habitat of marine life.

Utilization, regeneration, and recycling of nutrients are among the most important functions of this zone of dynamic reefs and nearshore life cycles.

The continual cycle of binding and releasing of minerals and nutrients and the exchange of the byproducts with the "next door neighbor" zone organisms, continues in the nearshore areas. This process takes place in the seaweed and seagrass beds on the reefs, and eventually within the turbulent wave action areas where waves break on the shoreline and link this nutrient regime to the intertidal zone.

Each of these zones helps harbor and feed different life stages of many species of fish, shrimp and other sea life, all of biological and eventually economic importance.

Nearshore non-vegetated sloughs, where shrimp are caught, have recently been found to be used by sea turtles for hibernation. With temperatures at a constant several degrees above seawater, these sloughs apparently provide a stable area for the wintering sea turtles.

The intertidal zone supports a different kind of community whose existance hinges on the periodic inundation by the rise and fall of tides. This area, with the community complex of little crabs, coquina clams, washed ashore small fish, and many more organisms, in turn feed, and are food for shorebirds, and small shoreline mammals of the shoreline area. These intertidal zone inhabitants also have a unique relationship with the upland dunes and its animal-vegetation communities.

The submerged seaweeds through the passage of seasons, have their turnover and wash ashore. If one would take time to examine a long, intermittent ribbon of seaweed, one would find on the Atlantic coast, predominantly seaweeds <u>Sargassum</u>, <u>Gracilaria</u>, <u>hyperea</u>, fresh or decaying, all rolled together, covered with bryozoans, weighed down with minute molluscs and crustaceans, mixed with sand and often covering the length of the shoreline. Each succeeding tide forms another line of this vegetation and associated orgamisms. The highest tide lines drive the vegetation up into the sea oats and panicum grass complex beginning at the base of the dunes. This natural action provides organic nutrients to the dune habitat.

Many people mistakenly believe the decaying seaweeds to be offensive, dirty and not befitting a "clean" beach. In some areas, at much expense, these weeds have been removed and carried to the city dump. Such a practice seems to be a waste of public works money. This removal of vegetation further deprives the dunes of naturally available free nutrients.

Natural systems endure and have evolved through coexistance to the present time. Just as we take clean air and clean water for granted, we manage not to notice a stable, intact dune system as nature's defense mechanism. What goes unnoticed by man is in reality, a very efficient, complex, and conservative method to allow life on all possible levels to continue and promote itself.

Man, the newcomer, is an invading species and more often than not, works to promote man, mostly in ignorance of the natural system within which he lives. We are fortunate creatures to have the brain and the technology, and need to develop an awareness of other technologically sound systems in nature within which, in order to survive, we must operate.

I would like to return my discussion to the dunes and focus on their plant life.

Dune plants may appear, conspicuous and green, or may be scattered and not seem evident.[3] In either case, they have a root system under the top sand layer which holds dirt and sand, traps moisture, and can fix nutrients, enabling it to support a variety of shoreline organisms.

Where growth is green and evident, dune line vegetation offers habitat and produces seed food and fruit for birds, small reptiles, crabs, and a variety of other organisms. In turn, the birds and crabs, through their living and nesting provide nutrients to the dune vegetation.

All natural dune vegetation is salt tolerant, and through the trial and error method of time is most resistant to the destructive forces of salt, wind, dessication and invading organisms coexisting with it. In short, a natural plant system on the dunes is a winning system. Through the passage of time, the fittest of these plants have survived. We would learn an important lesson if we mimic nature's system in dealing with natural problems. There is a reason for sea oats, panicum grass and railroad vines to grow in the foredunes. This area is most apt to have salt spray, tidal influence and be sand blasted. The above vegetation types, with firm roots, can withstand high winds and not break. In this way they can provide stability in the interim zone between high tide and the next community of vegetation of the seagrapes, palmetto complex with taller and firmer but more brittle trunks.

Thus, the shoreline, with the submerged and emergent zone form a stable biological habitat. The degree of stability of this habitat and its ability to handle storms, determines the amount of natural protection man may expect, if man plans to live close to the ocean.

Although no biologist claims to ward off hurricane effects with the growth of vegetation on the dune systems, it has been demonstrated over and over again that storm effects can be minimized if healthy dunes and natural dune weeds exist to protect the uplands.

The Brevard County Dune Revegetation program was created on the basis of the above assumption. In Brevard, a group of biologists set out and vegetated a manmade dune. Several months after the vegetation, a storm came along and washed out much of the beach and was at the front steps of several nearby homes and condominiums. The new dune line and vegetation, however, held fast.[4] This finding enabled the County to create a program to eventually rebuild the dunes, close all the dune gaps, and vegetate wherever vegetation was needed. It also brought us head on with the problem of ocean access, where we had to create crossovers for pedestrians. With substantial State aid, we are now in the process of creating a crossover at every county-owned footpath, right-of-way, and street end. These access areas range in width from 6 feet to 200 feet. In some areas, a ramp and a set of stairs were all that was necessary. In other areas, small boardwalks with handrails were constructed. Not all of these crossovers have parking provisions and none have restrooms or other park-type comforts. These walkways are just what they were supposed to be, an access to the ocean and are used heavily by the neighboring residents and visitors.

Lately, we have noticed that the walkways also serve as places for teenage social gatherings. They also serve as the gathering place for fishermen and families who can be seen sitting on folding chairs in the evenings, enjoying the sunset. Most of all, however, the raised wooden access areas protect and promote healthy dunes, without cuts or gaps.

The Dune Revegetation program has received much publicity. The most important consequence of this publicity has been the awareness created in the minds of the county residents living on the ocean. We have groups of condominium residents who have built up their own dunes, harvested and planted their own sea oats, creating green areas where there had been none before. We also have oceanfront homeowners who have considered the duneline as part of their own yard, and have planted, fertilized and watered the dune vegetation.

In order to maintain and meet the county needs, Brevard County began a Dune Vegetation Nursery where the staff experimented with different methods of growing dune vegetation. Some fascinating and very explicit methods have been developed by the county staff and the revegetation crew including facts such as when to harvest, how many to put in each pot, how long to grow, and how deep to plant plants for best results on the beach and under natural conditions. There is so much progress in this program that an update of our 1976 Dune Revegetation Report is now in process.

I would like to change the focus of this talk and address a different type of waterfront: the inland waters.

The State of Florida has 4,308 square miles of inland waters. These waters include estuarine areas, lagoons, aquatic preserves and shellfish harvesting areas. They also include lakes, streams and springs.[5]

As in oceanfront areas, inland waterfront is a most desirable location for development. I would like to discuss the inland waters, especially estuarine areas, including the inshore salt water systems.

The State of Florida enjoys a very extensive tourist industry, much of which is based on the water resources of the State.

Another important industry of the State of Florida is its commercial fishing products. In 1975, the approximate dockside value of the State of Florida's fishing industry, including shellfish, shrimp, crab, and fish catches, was 73.7 million dollars.[6]

For their survival, shellfish, shrimp, crabs, and around 80 per cent of the fish caught in Florida waters depend on the brackish to fresh water areas, constituting inland waters. The upland, consequently, bordering on these waters, have a life or death-type effect upon them and their resources. What we build, how we build, and where we build can influence and dictate the survival of the very resources that drew us here in the beginning.

There has been extensive research performed to measure and assess the value of marshes and wetlands. Fresh or salt, these important biological "food factories" have been studied for their value as nursery grounds, their capabilities in water purification, their capacity as water reservoirs, and many other functions beneficial both to their neighboring upland, and their neighboring lakes, rivers or estuaries.

When one thinks of marshes, vast areas of green come to mind, with birds feeding and tide pools reflecting the sky. Over the years and with increased growth, much of this picture has changed. Through dredging and filling, the size of much of our natural marshes has been reduced. Waterfront development has brought many back yards to the edge of the river or estuary. By dredging part of the former marsh, enough fill material is generated to cover and raise the rest of the marsh for development. The deeper dredged areas are thus turned into navigable canals, creating fingers of water reaching inland. In many parts of Florida, the house foundations meet the minimal flood insurance requirements by a few inches.

I would not care to go into the politics or economics of this type of waterfront housing, but I would like to focus on the newly created problems of this type of waterfront development and some possible solutions to their erosion problems, with minimal detrimental impact on the receiving waters.

As in the oceanfront, and as in a natural marsh and river system, one could visualize a mini zone of upland - intermittent and submerged areas adjacent to waterfront development.

Just as in the oceanfront, nature has a strict and conservative budget of nutrient uptake and release which ties in the upland, the marsh system and the submerged areas. Briefly, upland rains bring in moisture, topsoil nutrients, and minerals to the marshes, where the marsh vegetation would take up and store these components in its living tissue. Vegetation and their root system here helps form a spongy, muddy soup, serving as a nursery ground for much of the eventual seafood we consume. The seasonal and slow release of the components from the marsh to the submerged areas in turn promotes underwater meadows, very rich in seaweeds and seagrasses. These primary producers, in turn, process the upland handouts and generate their own food and release system.

An estuarine area, harboring this submerged vegetation also supports secondary producers such as amphipods and isopods, and eventually tertiary life: fish. An eatuary, reaching from the 36± parts per thousand salinities of the ocean to the fresh waters of the upland river, is responsible for the eventual production of some 80 per cent of all of our offshore fish, and 100 per cent of the shellfish, crabs and shrimp.

Recently, in a joint venture with NASA, Brevard County completed mapping the submerged grassbeds of the county.[7] Findings indicate that Brevard County has approximately 78,600 acres of seagrass beds. These grassbeds are of vast importance to the economy of the county since, directly or indirectly, they are responsible for the basis of a substantial commercial fishing industry. In 1975, the wholesale income of the Brevard County fishing products was approximately 3.4 million dollars. Add to this figure the sports fishing benefits, the sale of gas, boats and other water-oriented equipment, and one would realize the importance of maintaining the integrity of these inside waters.

An economic analysis of the cost of seagrass restoration conducted at the University of Miami estimates an approximate price of $8,000 to seed one acre of submerged land.[8]

How we handle the waterfront has a direct impact on the above resources. Every waterfront industry, every drainage ditch, every waterfront homeowner exerts an impact on the receiving waters. The methods used to stabilize waterfront areas can play an impressive role in the type of impact affecting the water system. A choice exists in the manner of stabilizing waterfront, a choice not always evident to many people. Waterfront inhabitants need to be educated just as the oceanfront residents in Brevard County were educated in the course of the revegetation program.

A healthy stand of <u>spartina</u>, followed by mangroves and followed by a narrow zone of natural upland vegetation, if given a chance will combat erosion in a much more effective way. In erosion-prone areas, coquina rocks or similar material, and <u>spartina</u>, function more effectively than vertical seawalls. Seawalls are a case of overkill in many waterfront areas of the State of Florida. Sometimes seawalls, when not needed, seem to resemble a viral infection. When one is built on a natural shoreline, others follow, at times, through necessity, more than through choice. Seawalls create corners which cause erosion on the neighboring properties. If one could discourage the first seawall from being built, there may well be no need for any at all.

Any natural method to slow down or trap the upland exotic chemicals and nutrients will aid the receiving waters by eliminating assimilation workloads. A Central and Southern Flood Control District study indicated substantial phosphorus and nitrogen removal from upland runoff when this runoff was allowed to pass and filter through a vegetation zone. Of course, the slope, intensity and types of vegetation play a role in the above results.

Many plants, such as mangroves, have a three-fold function for the zone at the edge of water. Mangroves can combat erosion, uptake and release nutrients, and provide an important habitat for submerged organisms.

Department of Natural Resources and the Sea Grant program have numerous publications dealing with the planting of mangroves.[8]

I see a real need for first, defining areas where erosion problems could be solved by planting of natural vegetation, and, next, a program to educate the engineer, architect, builder and finally, the homeowner in his responsibility to his land and his water.

Brevard County has started to grow red and black mangroves in the nursery for transplant purposes. The causeway waterfront area bordering our rivers pose as a good candidate for such a transplant effort.

Another advantage of a natural shoreline is the gradual slope of the land leading into the water. Homeowners with small children should find an advantage in the sloping shoreline, versus a drop-off shoreline created by seawalls.

I would, personally, rather see the accomplishment of better waterfront stabilization methods handled through public education and awareness than through regulatory agencies. Given a choice, and an assurance of the same degree of protection, I believe people would tend to landscape with natural methods in mind. I believe it is the job of a regulatory body to make information available to whoever needs it, publicize that information, and thus provide the waterfront landowner with a choice.

Many natural systems have existed long before we arrived. Our awareness of these systems may play a major role in our survival on this planet.

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# POLITICAL PROBLEMS OF
# EROSION CONTROL

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Long Island Regional Planning Board

## ABSTRACT

The science and technology of shoreline erosion control is fairly well established. Engineering solutions are available for the majority of situations. Financing, even when costly, is often manageable. Implementation of planned projects, however, often falters due to public opposition that counterposes environmentalists vs. engineers; public agencies vs. private interests, and shoreline property owners against one another. In short, it is the political aspect of erosion control that is the deciding factor - even in cases that directly affect property and human safety. This paper examines two examples of current controversy on Long Island. The first is of long-standing debate involving the partially completed groin field at Westhampton Beach - a project that had its genesis in the 1938 hurricane that devastated the south shore of the Island. The second is a new twist to an old theme. It deals with an attempt by the National Park Service to secure Congressional amendments affecting the Fire Island National Seashore to allow for the establishment of a dune district and enable the Service to acquire storm damaged properties within exempted communities. Examinations of the issues and tactics in such disputes may offer useful insight for erosion control professionals.

## Introduction

Various shoreline management problems have resulted from man's use of the shoreline and adjacent land. The natural erosion of the shore has become a problem where permanent structures, buildings or roads are threatened with destruction, either because of long-term shoreline changes, or the short-term effects of hurricanes and "northeasters". Sandmining, channel dredging, stabilized inlets, and shore protection structures have created situations where the natural rate of erosion affecting both beaches and marshes has been increased.

People's memories are also short. They fail to remember, take into consideration, or perhaps are not informed of the devastating shoreline destruction - beaches were literally swept clean of all human development - caused by the September 21, 1938 and August 31, 1954 hurricanes.(1) Loss of life is also a potential hazard; 45 people were killed or listed as missing on the south shore of Long Island as a result of the 1938 hurricane. Extensive development of Long Island's shorelines has occurred without due consideration for the dynamics of shoreline topography. The result of this disregard has been increased shoreline damage on an annual basis.

Shoreline damage caused by wave and tidal action has resulted in the construction of shore protection devices and the placement of beach fill. Such projects have been financed by private individuals, beach associations, local municipalities, the State of New York and the Federal government, and have often been constructed on a piecemeal basis without a comprehensive evaluation of their potential effects on large segments of the shore.(2) The practice of constructing groins, seawalls, and bulkheads, as well as the re-building of beaches by filling with dredged materials is extremely expensive. The U.S. Army Corps of Engineers estimates that the intial cost for beach restoration by sandfill is roughly 157 million dollars for the south shore of Nassau and Suffolk Counties, and 59 million dollars for the shore between Orient and Montauk Points, and about 103 million dollars along Long Island's north shore.(3) Unless care is taken during the design of shore protection devices, they could interfere with the natural equilibrium of coastal processes, and hence may adversely affect nearby shore areas by diminishing their supply of sands; they are also inherently dependent on the dynamics of the littoral zone, and may not perform their intended function. Ideally, future development of Long Island's shorelands should be controlled to lessen the need for coast stabilization measures. Land use planning should be based on an understanding of the processes affecting the configuration of the shoreline, as well as the factors which cause the need for shore protection.

Nevertheless, developments are extant and measures to protect life and property are necessary. Management options can generally be polarized as to structural versus non-structural solutions. Land use controls and deliberate deterioration policies (let nature handle the problem) are obviously more feasible where development has not occurred. Such benign approaches applied to existing communities signal an acceptance for the eventual elimination of buildings by grace of storm or condemnation. The political and policy issues raised by these choices often overshadow the basic concern for shoreline protection.

Conversely, structural solutions are not without controversy. Questions of durability, cost and potential negative impact on downdrift properties must be successfully addressed.

In general, the science and technology of shoreline erosion control is fairly well established. Engineering solutions are available for the majority of situations. Implementation of planned projects, however, often falters due to public opposition. In short, it is the political aspect of erosion control that is the deciding factor.

This paper examines two examples of current controversy on Long Island. The first involves the partially completed groin field at Westhampton Beach. The second deals with proposed Congressional amendments to the Fire Island Seashore Law to create a dune district and provide for the condemnation of storm damaged structures in exempted communities.

The case studies are preceded by a brief discussion of the erosion problems of the south shore, and a description of the myriad array of plans, programs, policies, and regulations pertaining to erosion control for this area.

## The Erosion Pattern

The south shore of Nassau and Suffolk Counties can be divided into two physiographic sections: an eastern headlands section characterized by a narrow beach at the base of a bluff or cliff, and a western barrier complex formed by a series of barrier islands and a barrier beach separated from the mainland coast by lagoons and salt marshes.(4)

The headlands section, which extends 33 miles from Montauk Point westward to Southampton, has suffered severe erosion. It is classified as a glacial deposition coast. The headlands are characterized by truncated hills of varying height and steepness fronted by a narrow beach of gravels and coarse sand.

The barrier complex section stretches approximately 73 miles from Southampton to the Nassau County/Queens boundary. This section of the Nassau-Suffolk coast has been shaped primarily by marine deposition; it is classified as a barrier coast by Shepard.(5) At the present time, five artificially maintained tidal inlets -- Shinnecock, Moriches, Fire Island, Jones and East Rockaway -- break the continuity of this reach. The four barrier islands separated by the inlets — Long Beach, Jones Beach, Fire Island, Westhampton Beach -- and the barrier beach at Southampton are near the northern end of the nearly continuous chain of 281 barrier islands and beaches of 100 or more acres each along the Atlantic and Gulf coasts.(6) These long, narrow strips of sand vary in width from less than 0.1 mile to over 1 mile in localized areas and are continually being remolded by waves, wind and currents. The ocean beach in this section varies in width from a few feet in the eastern portion to over 500 ft. in localized areas; the average width is between 100 and 200 ft. Behind the shores of these barriers, a series of irregular sand dunes rises to 30 ft. in height. They display steep wind-and wave-eroded slopes on the seaward side and gentle slopes often stabilized by beach grass on the landward side. The barriers are separated from the mainland by interconnected tidal lagoons: Shinnecock Bay, Moriches Bay, and Great South Bay. West of Fire Island Inlet, the tidal lagoons are nearly filled with marshy islands and tidal deltas. The barriers, subject to drastic alteration as a result of storm events and net westward movement as a result of longshore transport, are extremely unstable. The position and number of south shore tidal inlets have changed frequently within the historic past. Catastrophic storms have cut new inlets through the barrier islands. Some of these inlets have filled naturally due to the rapid movement of large volumes of littoral sediments from the east to west along the shore; others have been maintained through channel dredging and jetty construction. The westward elongation of Democrat Point at Fire Island Inlet provides a striking manifestation of the dynamic character of the barrier.

The longshore transport pattern along the south shore is strongly unidirectional - from east to west. This is due to the exposure of the south shore to waves generated by winds from the south and east. Net transport direction to the east occurs only in the area immediately to the west of Fire Island Inlet where it appears to be a result of tidal currents and wave refraction.(4) The rates of longshore transport are also more impressive - 300,000 yds. at Shinnecock Inlet, 350,000 yds. at Moriches Inlet, 600,000 yds. at Fire Island Inlet, and 550,000 yds. at Jones Inlet. The impact of longshore transport on inlet migration and spit formation is dramatically shown by a comparison of historical surveys of Fire Island Inlet. The present location of the inlet is 4.6 miles to the west of the position it occupied in 1825.(7)

Changes in the position of a shoreline can be grouped according to their time scale. Short-term beach changes (measured in hours or days) result from normal tide and wave action or the occurence of storm events. Intermediate changes (measured in months) result from the normal seasonal alterations in shoreline configurations represented in summer and winter beach profiles. These seasonal changes are very apparent along the Island's south shore. Long-term changes in the position of the shoreline that occur over a number of years or decades are of primary concern in the development of planning recommendations. Such changes reflect the net effects of the intermediate and short-term processes. Surveys on long-term trends in the position of the high water shoreline have been made for the south shore.(4)

Shoreline trend data has been summarized in this paper by the use of a plot showing net erosion/accretion rates versus shoreline distance for selected locations. Such plots are useful in making general comparisons between different shoreline areas. More detailed analysis, with particular attention to the evaluation of causal factors, is required for evaluating trends on a local basis. A quick glance at the plot reveals areas that have accreted (appear as peaks) or eroded (appear as troughs) during the historical period referenced. Water distances, e.g., at inlets, are not shown to scale on the plot.

The south shore has numerous areas of accretion and erosion as shown in Figure 1. The rates of both accretion and erosion are significant. This is due to the changing form of the barrier islands over time and the influence of tidal inlets on erosion/deposition patterns; rates at inlet areas are not shown in the plot.

For most of the south shore, rates are shown for two periods of record: 1838-1933 and 1933-1956. For the earlier period, rates of erosion generally vary between 2-4 ft./yr. The influence of tidal inlets is reflected in the erosion rates of 10 ft./yr. or greater to the east of Gilgo Beach. Three prominent areas of accretion are shown. The accretion at the Davis Park area and the area to the west of Gilgo Beach may be the result of shoreline straightening and inlet filling. The accretion at the Napeague Beach area is due to the filling of a gap in the Ronkonkoma moraine by littoral drift.

The rates shown for the latter period, 1933-1956, are greater in magnitude and more variable over a given shoreline distance. This is probably due to rate calculation based on a shorter period of record, the occurrence of two catastrophic hurricanes (21 September 1938 and 31 August 1954), and man-induced erosion. The man-induced erosion was caused by the stabilization of Moriches and Shinnecock Inlets. The stabilized inlets trapped significant quantities of littoral drift, resulting in the starvation of beaches downdrift on Fire Island and Westhampton Beach. Erosion rates to the west of both inlets were typically 10 ft./yr. or greater during this period. During the earlier period (1838-1933), there were no tidal inlets open east of Fire Island Inlet.

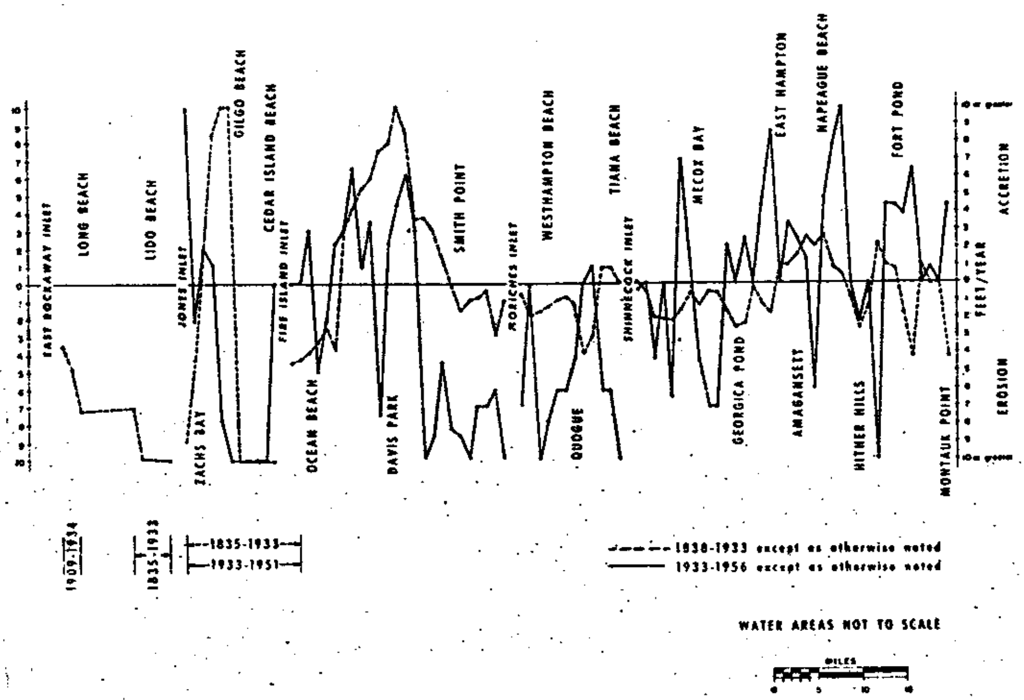


Figure 1 Erosion and Accretion Rates, South Shore of Long Island (based on profile data contained in Taney, 1961)

Recent observations of shoaling within Shinnecock Inlet and erosion rates on nearby downdrift beaches indicate that more littoral drift is supplied to the west as the inlet shoals grow and the efficiency of natural sand by-passing increases. This reduces the erosion rate. Dredging in the inlet to remove the shoals can be expected to reduce natural sand by-passing and increase sand entrapment. Estimates of the amount of littoral drift trapped by inlets each year along the south shore are 150,000 yds. - Shinnecock Inlet, 250,000 yds. - Moriches Inlet, 400,000 yds. - Fire Island Inlet, and 450,000 yeds. - Jones Inlet.(8) This points to the importance of inlet conditions as a factor in determining erosion/accretion of south shore beaches. Where sand by-passing accompanies the dredging and stabilization of inlets, utilization of downdrift beaches as a source of sand for longshore transport can be reduced, thus minimizing man-induced erosion.

In recent years beach stabilization, bluff erosion, and property development along Nassa-Suffolk shores have become controversial issues, generating social, economic, legal and political differences. A sense of the irony in the term "development," the widespread expectation that the shoreline will for some reason stand still after it's been built on, the rude awakening for developers, houseowners, and commercial builders when they discover the shoreline is not static - all are part of a shoreline "consciousness-raising" that has been making painful headway. In addition, the potential for storm-induced erosion damage has increased greatly in recent years because of shoreline construction activity in the late 1960's and the 70's. Perhaps this construction activity has been spurred by a false sense of security arising from the absence of major damage producing hurricanes and northeasters impacting the Long Island region during this time period.(9) Indeed, many Long Island residents have had little or no experience with the effect of storm surge and winds resulting from a major hurricane.

The U.S. Army Corps of Engineers appraised coastal shore erosion problems in its National Shoreline Study.(3) Two hundred seventy nine miles of shoreline in the bi-county region have been designated as critically eroding. In these areas, the rate of erosion and character of development justify the use of beach nourishment or the construction of shore protection devices to alleviate the erosion problem. The estimated first cost for shore protection in the form of beach nourishment for the critically eroding shores is over $300 million. This estimate does not include the price of annual beach nourishment for maintenance purposes.

Although Nassau-Suffolk total shoreline mileage is only about half a percent of the total national shoreline mileage, over 10% of the nation's critically eroding shores are found in the area. All of the south shore is classified as critically eroding.

Nassau-Suffolk has the distinction of having more critically eroding shoreline, where erosion is likely to endanger life or public safety, than any coastal state.

Damages from shore erosion include the loss of beaches used for public and private recreation, the continuing loss of waterfront land, and substantial damage to highways, residences, commercial development, and other waterfront structures. The dollar magnitude of these damages is substantial, especially where shoreline areas have been subject to intense use and development. For the south shore of Long Island, the National Shoreline Study stated that shoreline regression results in the loss of from one-half acre to one acre of unprotected beach per mile of shore. Dollar losses due to land erosion amount to $7,000 - $50,000 per mile of shore per year. The total land losses for the 120 mile shoreline exceed $1 million annually. When combined with estimates of structural damage, increased highway maintenance, etc., total annual damages along the south shore are estimated at about $9 million (about $85,000 per mile of shore). Estimates of erosion costs from land loss, repair and maintenance of shore protection devices, and shore cleanup for New York's Long Island Sound shoreline have been estimated at $4.4 million annually.(2)

The high cost of shore protection is not the only problem facing the shore home or business owner, the park superintendent, and the government official. When structures such as groins or jetties are built, the configuration of the shoreline is changed. This altered shoreline still remains subject to natural forces; winds, waves, tides and runoff establish new conditions of shoreline equilibrium. In all cases, this change has not been to the benefit of man. Unwanted erosion or accretion may result, especially in areas adjacent to the sites of the structures. Such is often the case when shore protection structures, which are inherently dependent on the dynamics of the littoral zone to perform their intended function, are built without enough knowledge of the littoral processes affecting the shore. There are numerous examples in the literature cited in this report that illustrate the beneficial and adverse effects of shore protection both in terms of magnitude and length of shoreline affected.

Extant Solutions

A plethora of plans, programs, projects, and regulations have been put forth by every level of government to the extent that the overlapping and often conflicting proposals constitute a problem by themselves. The U.S. Army Corps of Engineers has seven projects in varying stages of completion, and an additional study. These projects include shoal and channel dredging, dike and jetty constructions and extensions, groin construction, vegetation placements, and sand by-passing installations. The policies of the National Park Service pertaining to erosion control within the Fire Island National Seashore reflect the desire to preserve the serenity and natural beauty of the barrier beach, while providing for lower levels of usage than accommodated at other shoreline parks under other jurisdictions. Thus, the Seashore policy is based on a desire to minimize interference with natural shore processes, and, in some instances, is diametrically opposed to Corps authorized project recommendations for the same beach.

The Federal government makes a further input into the somewhat confused situation by the administration of the National Flood Insurance Act (P.L. 90-488) under the aegis of HUD's Federal Insurance Administration.

This program provides flood insurance protection to previously uninsured property owners in flood prone areas. Flood-related erosion protection was added to the National Flood Insurance Program by the Flood Disaster Protection Act of 1973 (P.L. 93-234). Through the Flood Insurance Program, the Federal government seeks to reduce flood disaster losses through flood plain management measures, which encourage or require property owners to locate outside flood hazard or flood-related erosion prone areas, or to elevate or flood-proof their homes and businesses to reduce flood or flood-related erosion damage. Structural or non-structural methods can be employed in floodplain management. Structural methods include bulkheading, diking, damming, etc. Non-structural methods include the enactment of setback requirements, zoning and subdivision controls, the acquisition of open space, etc. Ironically, coastal flood hazard areas are desirable for residential and recreational purposes. Investigations have shown that a large proportion of homeowners occupying coastal flood hazard lands would rebuild their homes in the same location if wiped out by flooding. (10) It is necessary therefore to ask whether federal policy acts as an incentive or disincentive to locate outside flood hazard areas. Presently, owners whose structures are damaged substantially beyond repair by flooding may choose to relocate outside the flood hazard area. In choosing to do so, however, the owner will receive coverage based on the depreciated value of the structure as settlement on the claim. Should the owner choose to rebuild on the same site, the claim will be paid in full up to policy limits. This disincentive would appear to be counterproductive to Congressional intent as expressed in the National Flood Insurance Act of 1968 as amended. This apparent inconsistency can be resolved by requiring the Program to provide full replacement coverage on structures damaged substantially beyond repair by flooding, should those insured decide to relocate outside flood hazard areas.

The State of New York is also active in erosion control by providing supplemental funding and directly by initiating projects to protect state properties. The Department of Environmental Conservation assists shore protection construction by funding up to 70 percent of the local share for authorized federal projects, and up to 70 percent for state projects built at the request of local government, which must contribute the remaining 30 percent. Therefore, on major federal erosion control projects for which the Federal government provides 70 percent of total project costs, the State of New York could contribute up to 21 percent of total project costs. The remaining costs - nine percent - would have to be provided by local government.

The Long Island State Park Commission (LISPC) is responsible for management and maintenance of New York State Parks in Nassau and Suffolk Counties. The LISPC has implemented a terracing and planting project to forestall bluff erosion at Montauk State Park and is investigating the feasibility of using a cut-off ditch to intercept stormwater runoff before it erodes the face of the bluffs at Camp Hero.

Storms have eroded the primary dune line along the Jones Beach barrier island. Parking field #9 has been abandoned for over two years after repeated beach nourishment projects have failed to maintain adequate beach widths. Corps of Engineers sand by-passing and beach nourishment projects have, however, been successful along other sections of the beach. Should new inlets breach either Robert Moses or Jones Beach State Parks, the LISPC would close the inlets artificially in order to maintain access to the parks via highway. As a further protection to the beach, the LISPC prohibits both pedestrian and vehicular traffic over dunes and the destruction of beach grass and natural vegetation.

The Counties exercise regulatory and operational functions that often conflict with both the Corps and the Seashore. For example, Suffolk County park policy differs from that of the Seashore, both in respect to recreational usage and erosion control. The park department pursues active intervention in order to maintain the higher levels of usage characteristic of the county parks. The County Executive, however, is adamently opposed to groins and has successfully blocked the completion of the Westhampton groin project.

Municipalities are also active, particularly in maintaining regulatory controls over the location, density and types of land uses on the barrier beaches. They also initiate and control dune ordinances, and to a lesser extent, conduct restoration programs. Enforcement though is spotty and little correlation exists in the policies and practice of the separate jurisdictions.

The following sections discuss in greater detail the impact of such uncoordinated approaches on Westhampton Beach and the Seashore.

## Groins - To Be or Not

The New England Hurricane of 1938 struck the south shore of Long Island less than 10 miles west of Westhampton Beach at about 2:30 p.m. on the afternoon of 21 September about 3.5 hours before the predicted high tide. Travelling at a forward speed of 60 miles per hour with sustained wind speeds of over 80 miles per hour (an extreme gust of 186 miles per hour was recorded in Massachusetts), this storm produced waves 10 to 12 feet high along the south shore on a storm surge, or increase in the stillwater elevation of the ocean in excess of that caused by normal tides, of 10 feet. In a few hours, the waves and surge of this hurricane leveled sand dunes on south shore beaches up to 30 feet high that had taken a century to build. Eight inlets were cut in the barrier bar in the vicinity of Westhampton Beach (only one inlet - Shinnecock - remains open today). Overwash fans deposited in the bay adjacent to the breaks in the bar nearly filled the Intracoastal Waterway channel. However, impacts other than those relating to geomorphology were of greater concern to the residents of the region. Forty-five people were killed in the storm; many more lives probably would have been lost had the hurricane occurred a few weeks earlier before the end of the summer vacation season. One thousand houses were damaged or destroyed between Fire Island Inlet and Southampton. At Westhampton Beach 24 people lost their lives (seven additional people were reported missing) and 150 homes were destroyed.

What would happen if another '38 hurricane (a 40 year storm) hit the south shore of Long Island today? The loss of life probably would not be as great because of better advance warning of the storm's approach, but because of the extensive residential/resort related growth that has occurred along the shoreline between Fire Island Inlet and Montauk Point during the last generation, physical damages would be tremendous.

State and local beach stabilization efforts at Westhampton Beach after the occurrence of the '38 hurricane were limited to dune rehabilitation through sand fencing and planting American beach grass and the construction of jetties and revetments at Moriches and Shinnecock Inlets. Damage to the barrier and property continued, however, as a result of hurricane Carol in 1954 and the East Coast Atlantic Storm of March 6-8, 1962. As a result of the latter storm, the area was declared a national disaster.

The U.S. Army Corps of Engineers was asked by New York State to study the problem of erosion control along Long Island's Atlantic Ocean shorefront in the mid 1950's. In 1960, the Fire Island Inlet to Montauk Point Beach Erosion Control and Hurricane Protection Project was authorized by Congress. This project provided for: widening the beaches along developed areas between Kismet and Mecox Bay to a minimum width of 100 feet at an elevation of 14 feet above mean sea level; raising the dunes to an elevation of 20 feet above mean sea level from Fire Island Inlet to Hither Hills State Park, at Montauk, and opposite Lake Montauk Harbor; planting grass on the dunes; constructing interior drainage structures at Mecox Bay, Sagaponack Lake, and Georgica Pond; construction of not more than 50 groins, if needed; and Federal participation in the cost of beach nourishment for a period not to exceed ten years from the year of completion of a useful nourishment unit. The estimated total cost of the project was $137,864,000 of which the Federal share is estimated at $91,180,000, and the estimated annual cost for nourishment is $846,000 of which the Federal share was estimated at $70,000 (October 1976 price level). (11)

To date most construction activity of this project has occurred in Reach 2 - Moriches Inlet to Shinnecock Inlet, which includes the Westhampton Beach area. Because this erosion control work involves political, social, economic, engineering and environmental issues, it has become the most controversial coastal protection project in the Long Island region.

With the support of County Executive H. Lee Dennison and the Suffolk County Board of Supervisors at the local level in the 1960's, two segments of work were completed in Reach 2. The first segment - construction of 11 groins at Westhampton Beach - was completed in October 1966 at a cost of $2,334,955. Contrary to original Corps plans, the groins were not constructed in sequence from west to east, starting at Moriches Inlet, nor were the groin compartments filled. The change in construction schedule resulted from several factors, including strong homeowner pressure for immediate relief at the eastern end of the project. Since it was assumed that the entire project would be finished, the change did not seem important at the time. The predictable result - increased erosion downdrift of the groin field and subsequent damage to private and municipal property occurred. Affected property owners pressed public officials for relief.

A second segment, completed in November 1970 at a cost of $3,663,455, involved the construction of four additional groins and the placement of 6,000 feet of dunes and beach fill west of the original 11 groins. Even though these groin compartments were filled, the impacts of inlet stabilization at Moriches and Shinnecock without sand bypassing and the interception of longshore drift in the unfilled groin compartments again caused insufficient natural nourishment of the beach to the west of the four new groins. Again, man-induced erosion downdrift from the extended groin field becomes a serious problem. Support was generated for the construction of an additional six groins to complete original plans for the stabilization of Westhampton Beach and to prevent creation of a new inlet to Moriches Bay.

However, the policy of Suffolk County regarding financial participation in erosion control projects changed dramatically with the election of County Executive John V.N. Klein in 1972. Mr. Klein's posture was one of non-interference with natural shoreline processes, and hence, he has consistently opposed the construction of additional groins at Westhampton Beach. The 18-member Suffolk County Legislature, which replaced the Board of Supervisors in 1970, has often been at loggerheads with Mr. Klein over County participation in erosion control projects. Heikoff describes in detail the intergovernmental relations and technical considerations involved with this project and the construction of the 15 groins at Westhampton Beach.(12) Many technical considerations were ignored in arriving at policy decisions to reduce project costs. The ultimate cause of the man-induced erosion problem is, according to Heikoff, failure to complete the Corps project as initially designed.

Today, an extremely serious erosion problem persists to the west of the existing groin field. Extensive damage to development and a breach in the barrier occurred here as a result of the severe 1978 winter weather. The problem is exacerbated by unstable shoreline conditions at Moriches Inlet. Scouring along both bay and ocean shores has narrowed the barrier adjacent to the east jetty to such an extent that the jetty may be outflanked in the near future. An emerging nourishment project financed by Suffolk County may forestall this event for a short period of time.

The Long Island Regional Planning Board has developed strategies for erosion control along the Long Island shoreline as part of its Coastal Zone Management Program. The strategies for the south shore are outlined below(13):

- Accept the natural, long-term shoreline regression that is occurring along the headlands section of the south shore as a phenomenon that is beyond man's present capability for practical, effective control. Emphasize non-structural solutions to coastal erosion problems here.
- Stabilize the south shore inlets (Shinnecock, Moriches, Fire Island, Jones, East Rockaway) at approximately their present locations and implement sand by-passing programs. New, natural inlets that breach the Long Beach, Jones Beach, Fire Island and Westhampton Beach barrier islands and the Southampton barrier beach as a result of severe storms and/or shoreline regression should not be maintained. If longshore transport does not repair a natural breach, steps should be taken to close it artificially.
- Artificial manipulation and public investment designed to stabilize the Atlantic Ocean shoreline along Fire Island and the Southampton barrier beach should be minimized.
- Maintain the general position and configuration of the Atlantic Ocean shoreline along the entire south shore of Nassau County, and along that portion of the Jones Beach barrier island located within Suffolk County. The Atlantic Ocean shoreline along the Westhampton barrier island should also be maintained.

To foster these strategies, the Board recommends that the County and State support (both morally and financially) the authorized federal projects for improvement of Shinnecock and Moriches Inlets, including installation of sand by-passing programs. Most of the Fire Island Inlet to Montauk Point Beach Erosion Control and Hurricane Protection project should not be implemented as authorized, with the exception of a modified nourishment program for the central and western end of the Moriches Inlet to Shinnecock Inlet Reach. To maintain the general shoreline configuration of the Westhampton Beach barrier island, the existing 14 groin compartments should be filled as appropriate, and fill should be added to restore that section of the beach immediately to the west of the existing groin field, which is in jeopardy of inlet breaching. The combination of sand by-passing at Shinnecock Inlet and filling the existing groin field may restore the net rate of longshore transport along the Westhampton Beach barrier island to that which existed prior to stabilization of the beach and Shinnecock Inlet.

The New York District of the Corps has completed preliminary planning for filling the groin field and nourishing the downdrift beach. About 8 million yds. of fill will be needed. The fill will be obtained from offshore borrow sites. Total costs amount to about $20 million of which the County share would be about $1.8 million. The Corps appears to be waiting for State and local initiative on this aspect of the project. Political aspects again arise:

> "The Corps assumes leadership in the coordination of project plans and in obtaining required local cooperation to implement a Congressionally authorized project. Since authorization of the Fire Island Inlet to Montauk Point Project, however, the opinion of Suffolk County has frequently varied between opposition and approval. The project is sufficiently extensive and complex that frequently only one small element of the project is desired by the County at any particular time: for example, the next increment of work at Westhampton Beach. For this reason we have given responsibility for the initiation of construction to local interests. In other words, we will not undertake further construction on the project unless requested by the State and County."(14)

Thus, despite decades of study, imminent potential hurricane destruction, and general agreement that coastal protection must be assured - implementation remains mired in political controversy.

## The Fire Island National Seashore (FINS)

The Long Island Regional Planning Board, in the development of its Coastal Zone Management Plan, has emphasized non-structural approaches in dealing with coastal protection problems, wherever feasible. A number of planning guidelines were developed to assist local governments in the formulation of public policy and decision-making. The guidelines are helpful to planning commissions in their review of subdivision design and in municipal planning, to zoning boards in their formulation and amendment of zoning ordinances and building codes, and to conservation advisory councils in their review of both public and private development projects to assure the maintenance of an aesthetic balance between man and the natural environment. Government agencies in charge of projects which can have significant effects on coastal resources should use the guidelines during the design phase of such activities to lessen possible adverse environmental impacts. Table 1 summarizes the major recommendations.(15)

In particular, coastal construction setback lines were proposed for controlling the location of new development along eroding shoreline areas. Two coastal erosion hazard zones were defined by the setback lines:

a. <u>bluff and coastal dune hazard zone</u> - the area seaward of a line located 100 ft. landward from the top edge of a coastal bluff or headland, or the top of the seawardmost rank of coastal dunes.

b. <u>barrier island and barrier beach primary dune hazard zone</u> - the area seaward of a line located 40 ft. inland from the 14 ft. elevation contour on the landward flank of the primary dune; or where applicable, oceanfront areas where primary dunes are absent or are lower than 14 ft. in elevation, including historic overwash areas.

The latter setback recommendation was considered by the National Park Service (NPS) in the development of the General Management Plan for the Seashore.(8) The philosophy expressed in their plan is compatible with it. Table 2 summarizes the general management policies.

Although the Board's barrier island primary dune hazard zone is more restrictive than the FINS dune district, the power and intent of FINS to condemn and purchase properties (given Congressional appropriations) located within the district more than compensate for the difference and should provide protection of Fire Island primary dunes from adverse structural development.

Another proposed FINS policy currently before the Senate concerns the acquisition of property within the 17 exempted communities following major storm damage. The FINS General Management Plan proposed a legislative amendment to permit the NPS to acquire private lands within exempted communities if major storm activity destroys 90 percent or more of all structures within a community, and damage to each structure is in excess of 50 percent or more of its fair market value. Lands where structures were destroyed would be acquired in fee by the NPS. Structures that were not destroyed would remain in private ownership as inholdings exempt from condemnation. These properties would not be acquired unless

TABLE 1: SUMMARY OF PLANNING GUIDELINES FOR COAST STABILIZATION AND PROTECTION (15)

1. Control development on those lands contained in the *Intermediate Regional Tidal Flood Plain** by use of *flood plain zoning*, land use management concepts and other regulatory tools. Uses other than those requiring shorefront locations and those related to recreation, as well as the expansion of existing uses, should be discouraged. *Non-conforming use* status should be applied to existing development. Necessary future construction on the flood plain should be located in accordance with the establishment of sufficient *set-back lines*, so as to avoid damage from short-term shoreline changes. Such construction on the flood plain should include, as a minimum, elevation of first floors of such structures above the Intermediate Regional Tidal Flood Plain level, and floodproofing of utilities and equipment serving such structures. Consult the National Flood Insurance Program as amended by the Flood Disaster Protection Act of 1973 for flood plain insurance eligibility, floodproofing, and land use management requirements.
2. Prohibit construction on *primary dune* lines.
3. Adopt *bluff hazard zoning* in those shoreline areas, especially along the north shore of Long Island, which are backed by eroding bluffs. Discourage construction in the zone 100 feet landward from the top seaward edge of the bluff defined by an abrupt increase in slope.
4. As a general rule, discourage expenditure of public monies for the design and construction of shore protection work and beach nourishment on private lands unless substantial benefit to the public or public lands can be substantiated.
5. Accept the natural, long-term shoreline regression that is occurring along Long Island's north shore as a phenomenon that is beyond man's present capability for practical, effective control. Maintain heavily used beaches and recreation areas and, when the need exists, establish new beach areas by means of sand nourishment techniques in locations where historical records indicate either accretion or low to moderate erosion of the shore. Maintain existing navigation channels connecting major embayments with the Long Island Sound.
6. Emphasize dune stabilization and beach nourishment techniques, compatible with natural processes, as the primary means of minimizing storm breaching of the Long Island south shore barrier islands, and thus protect the environments of the south shore bays from sudden short-term changes.
7. Prohibit dredging of sand from the outer *bar* and from any area between the bar and the beach.
8. Support research designed to develop the required technology for economical transfer of sand from deep water sources to the shore for beach nourishment purposes.
9. Stabilize existing southshore inlets (East Rockaway, Jones, Fire Island, Moriches and Shinnecok) at approximately their current dimensions and locations. Permit drastic changes in the inlet characteristics only when explicitly justified by analysis of consequent changes such modifications will produce in the bays.
10. Advocate the implementation of Federal projects for *sand bypassing systems* at Shinnecock, Moriches and Fire Island Inlets.
11. Prohibit the construction of *groins* and other shore protection devices either by government or private persons unless it can be demonstrated that such structures will not adversely affect adjacent property.

* Those lands covered by a tide having an average frequency of occurrence on the order of once in 100 years, although the tide may occur in any year.

TABLE 2: FIRE ISLAND NATIONAL SEASHORE GENERAL MANAGEMENT POLICIES RELATING TO BEACH EROSION CONTROL AND PRIMARY DUNE PROTECTION(8)

1. Encourage the immediate installation of the authorized sand by-pass systems at Moriches and Shinnecock Inlets.
2. Recommend spoiling sites for material dredged from Shinnecock, Moriches and Fire Island Inlets, and from the Intracoastal Waterway to the Corps of Engineers.
3. Prohibit the artificial opening of new inlets within Fire Island National Seashore boundaries. Should new inlets open naturally, they will be evaluated. If adverse impacts outweigh benefits, new inlets may be closed by the Corps of Engineers.
4. Assess sand nourishment proposals. As a general principle, dune construction and direct beach replenishment will not be undertaken in the large Federal tract east of Watch Hill. However, if research and analysis of environmental impacts show that man's intervention is essential for perpetuating the barrier and its natural resources, such activities may be undertaken.
5. Prohibit the installation of additional groins, bulkheads, revetments and other artificial beach stabilization devices (existing inlet jetties are exempted). Permit snow fences for stabilization purposes in areas where vegetation is sparse, rapid erosion is occurring and where dune buildup is desired.
6. Repair and restore ocean-facing dunes as needed. Planting with native perennial dune stabilizing species to encourage re-vegetation will be initiated throughout the Seashore. Dune blow-outs and other naturally occurring bare sand areas will be repaired and replanted when compelling considerations, such as threat to development, dictate such action.
7. Refrain from disturbing washovers in the natural areas of the Seashore because washovers aid in perpetuating the barrier island system.
8. Establish a dune preservation district extending landward for a distance of 40 ft. from a line representing the primary natural high dune crest as determined from November, 1976 aerial survey maps. Such a district will include the primary dune system, or the primary dune area if no dunes exist. The seaward limit of the district is the mean high water mark. Future use of the dune preservation district will be severely limited. No new structural development or stabilization devices other than snow fences will be permitted. Elevated dune crossings for pedestrian and essential vehicles will be allowed. The approximately 250+ unimproved properties included within the dune district will be acquired, when necessary, to prevent development from occurring. The structures on the other 257 improved properties in the dune district will be permitted to remain indefinitely unless they are damaged by storms in excess of 50 percent of their fair market value.

they too were destroyed by a storm at some future time.

Property owners within the exempted communities vigorously responded to these proposals. More than 1000 letters opposing the amendments were received by Senator Jacob Javits (R.-N.Y.) George Biderman, Chairman of the original Fire Island Seashore Committee, and an affected homeowner, raised the sole voice of support. He contended that the ultimate good must include the maximum expansion of the Seashore. Such altruism is rare indeed. The Long Island Regional Planning Board subsequently added its support for the amendments. The Board indicated that the Senator was unduly sensitive to a letter-writing campaign, especially where the interests of millions of citizens are concerned.

Actually, the situation is a tempest in a teapot. The amendments do not go far enough. Even the 1938 hurricane did not destroy 90 percent of all structures. The basic problem originated with the vacillation on the part of Congress in adopting the 1964 legislation which established the Seashore. They yielded to local pressure and exempted communities within the proposed boundaries of the Seashore. They could have set a specific tenure to cater to the desires of the seasonal property owners - after which the properties would be subject to condemnation.

The outcome of this debate may well set the tone for the future of the Seashore.

## Conclusion

The politics of erosion control is simililar to many public policy debates. Implementation does not occur solely on the basis of technical rationality. Regardless of the severity of the erostion problem, or the technical merits of proposed solutions, implementation involves mediation between diverse groups and individuals who seek to influence land use and environmental decisions. Thus, erosion control must be understood to be funadmentally a political activity. It is political in the following ways: it is a governmental process presumably set up to formulate and execute policy on erosion activities. Administratively, erosion projects are primarily governmental in concept and execution. The interactions between public agencies and private citizens require mediation and compromise - the very essence of politics.

This reality is not necessarily negative. Politics herein, is held to be the conduct of the public business in non-partisan fashion, or perhaps more accurately stated, multi-partisan. However it is viewed, implementation of erosion control will be more successful if it is conducted with the public involved, rather than for the people.

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# NATURE ASSISTED BEACH ENHANCEMENT

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ABSTRACT

NABE (Nature Assisted Beach Enhancement) is proposed as a technique for enhancing a sandy beach by using the forces of nature to bring additional sand ashore. Laboratory tests have shown that under certain conditions additional sand can be brought ashore by allowing the beach to come to an equilibrium state several times following successive berm removals. It is proposed that the additional sand be moved to the dune area and stabilized by vegetation.

## INTRODUCTION

The ever-changing nature of a beach is well known. In "Beaches and Coasts," by King and McKay (1) state "A beach is one of the most variable land forms; it can be there one day and gone the next." Johnson (2) states, "In the first place, it must be borne in mind that the beach is merely a temporary deposit, slowly making its way to deeper water."

Methods employed to date to maintain and enhance beaches include (1) devine supplication, (2) construction of jetties and groins, (3) establishment of construction control lines, and (4) artificial beach nourishment. The latter method is generally accepted as the surest and quickest way of reestablishing a beach once it has disappeared. It would be good if a method could be found to achieve the same objective by a natural beach nourishment technique.

Inman and Bagnold (3) describe the migration of sand grains by bed-load transport and develop an equation for the average migration speed. Yalin (4) provides a rigorous discussion of suspended-load transport. Komar (5) reviews these two methods and concludes that bed-load transport will normally dominate over suspended-load transport.

It has long been recognized that so-called summer (or swell) beach profiles differ from winter (or storm) beach profiles. Extensive laboratory and field studies have been conducted on both sand transport directly to-and-from the beach and along the beach. Tanner (6) has introduced the concept of an equilibrium beach where there is a balance between the forces tending to bring sand to and from a beach.

Figure 1 shows the general features of a beach. Special note should be made of the berm which is defined as the near horizontal portion of the beach formed by the deposition of sediment by the receding waves. The breaker zone is the portion of the nearshore region where the incoming waves become unstable and break.

Pilkey and Field (7) made a thorough study of the onshore transport of sediment from the continental shelf off the south-eastern Atlantic coast of the United States and concluded that beach and estuarine sands "are derived in part from the adjacent continental shelf." King and Williams (8) carried out tank tests under a variety of wave and beach slope conditions and concluded that the transport of sand seaward of the breaker zone was always toward shore. Shoreward of the breaker zone the direction of sediment movement depended on the test conditions.

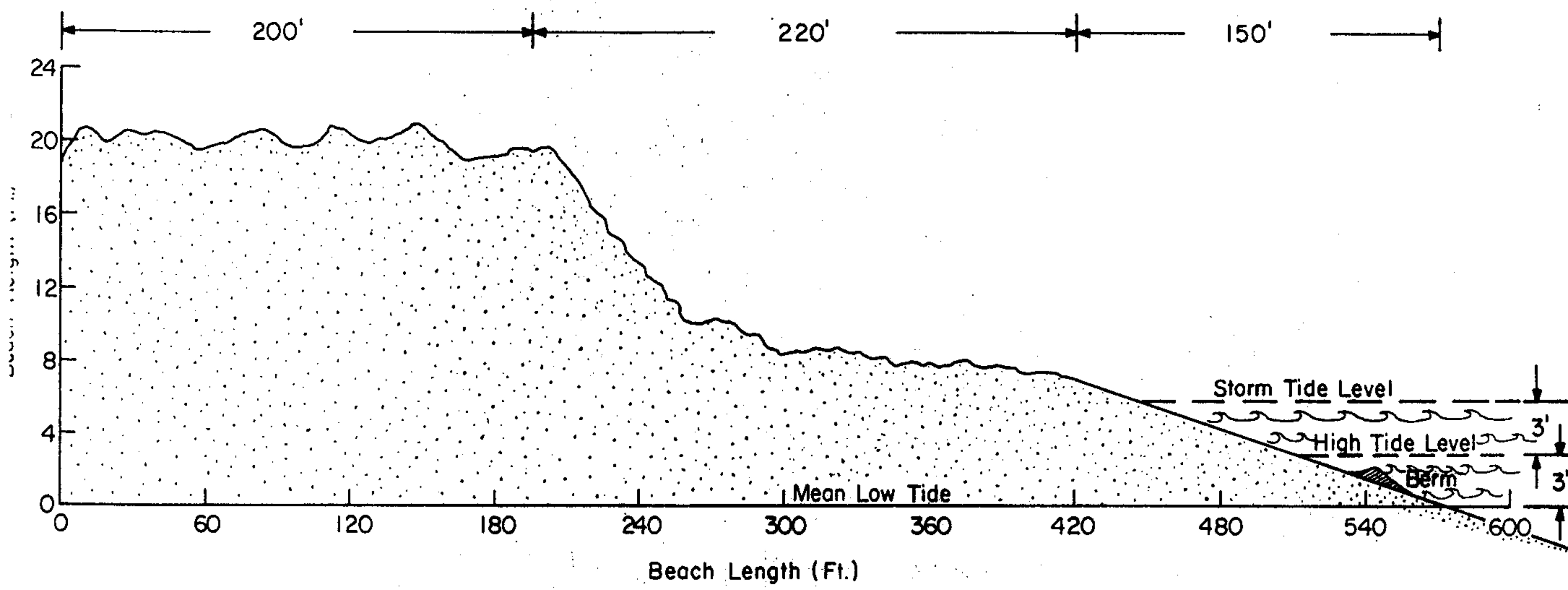

200'
220'
150'
24
20
16
12
8
4
0
0
60
120
180
240
300
360
420
480
540
600
Beach Length (Ft.)
Mean Low Tide
Storm Tide Level
High Tide Level
Berm
3'
3'

Figure 1

A criteria for determining when the net transport of sediment would be toward the shore has been shown to be the ratio of wave height to wave length. The exact relationship depends upon the scale of operation, grain size and other factors. Dean (9) approached the criteria on the basis of sediment settling velocity and found that his method correlated the data of 189 experiments with 89% consistency. Per Bruun and Gunbak (10) discuss the influence of wave period and slope angle to the stability of permeable and impermeable sloping-faced wave-protection structures. The principles obviously apply to sandy beaches which are nature's structures that protect the land from further intrusion by the sea.

In summary of previous work, for sandy beaches like those in Florida, large quantities of sand move to and from the beach area in response to the characteristics of the waves and currents. The transport is opposed by the force of gravity and resistances encountered by the sea bed and beach area. When these forces are in balance, a steady-state or near equilibrium condition results. Under conditions favorable to accretion of sand and when the controlling resistance to accretion is the slope of the beach, it should be possible, in principle, to accumulate more sand on the beach by altering the slope.

## NABE

Nature Assisted Beach Enhancement (NABE) is a proposed means of enhancing or maintaining a beach by using the forces of nature to bring additional sand to the beach. The principle of the technique is quite simple. Under conditions that favor the movement of sand to the beach, the slope of the beach is altered to encourage more sand to accumulate. The additional sand can then be moved to the dune area and appropriate vegetation planted to stabilize it.

Skeptics of the concept are quick to point out that there is only a finite amount of sand in the system and, if one beach area benefits, it must be at the expense of sand supply in another part of the system. Bowen and Inman (11) provide some indirect evidence that this may not be a serious problem. They found that it was not possible to estimate the amount of sand accumulated on a beach by measuring the changes that occurred in the offshore bathymetry because the changes were so small and the area was quite large.

## LABORATORY TESTS

Three series of runs were made to determine (1) whether or not it was possible for us to demonstrate in the laboratory that an equilibrium beach could be obtained, (2) whether or not it was possible to accumulate more sand on the beach by the NABE technique, and (3) the mechanism by which the sand moves from offshore to the berm area. Figure 2 is a photograph of the basin used in the first two series of runs. Figure 3 is a photograph of the basin used in the third series.

Table I shows the values of the test variables for each series of runs.

## APPROACH TO STEADY STATE

At the beginning of the experiment the sand (0.2mm average diameter) was smoothly distributed throughout the basin with a uniform beach slope. As soon as the wave maker was turned on, ripples began propagating seaward and beach berm began to form. The ripples eventually filled the entire basin and the berm grew to full size. A near steady-state condition developed in about eight hours.

The topography between the upper limit of the wave run-up and the breaker-line was characterized by (1) a berm with a smooth surface and a single uniform slope stretching across the basin, (2) a depression or trough at the foot of the berm, (3) a longshore bar situated seaward of the trough, and (4) the breaker-line located a short distance seaward.

As the running time increased various troughs, bars and depression areas formed offshore. These uneven topographical configurations were due to the interaction between incident waves and discrete seaward rip currents. The offshore shelf region still maintained its slope and general features.

The time required for the model to reach steady state obviously depends upon how close the starting conditions resemble the final values. Figure 4 shows the beach profile as a function of time after five hours when the original beach slope was 1:20.

## BERM REMOVAL

In the second series of runs, the beach was allowed to come to a near equilibrium state several times following successive berm removals. Each time the beach reestablished itself when operations were continued. Data concerning the running time and the amount of sand removed are shown in Table II.

The variation in the amount of sand removed was due in part to the difficulty in scraping wet sand to a particular slope.

The 49.3 cubic feet of sand moved to the beach and removed from the basin in 148 hours of running time by one inch waves amounts to over three tons of dry sand per week.

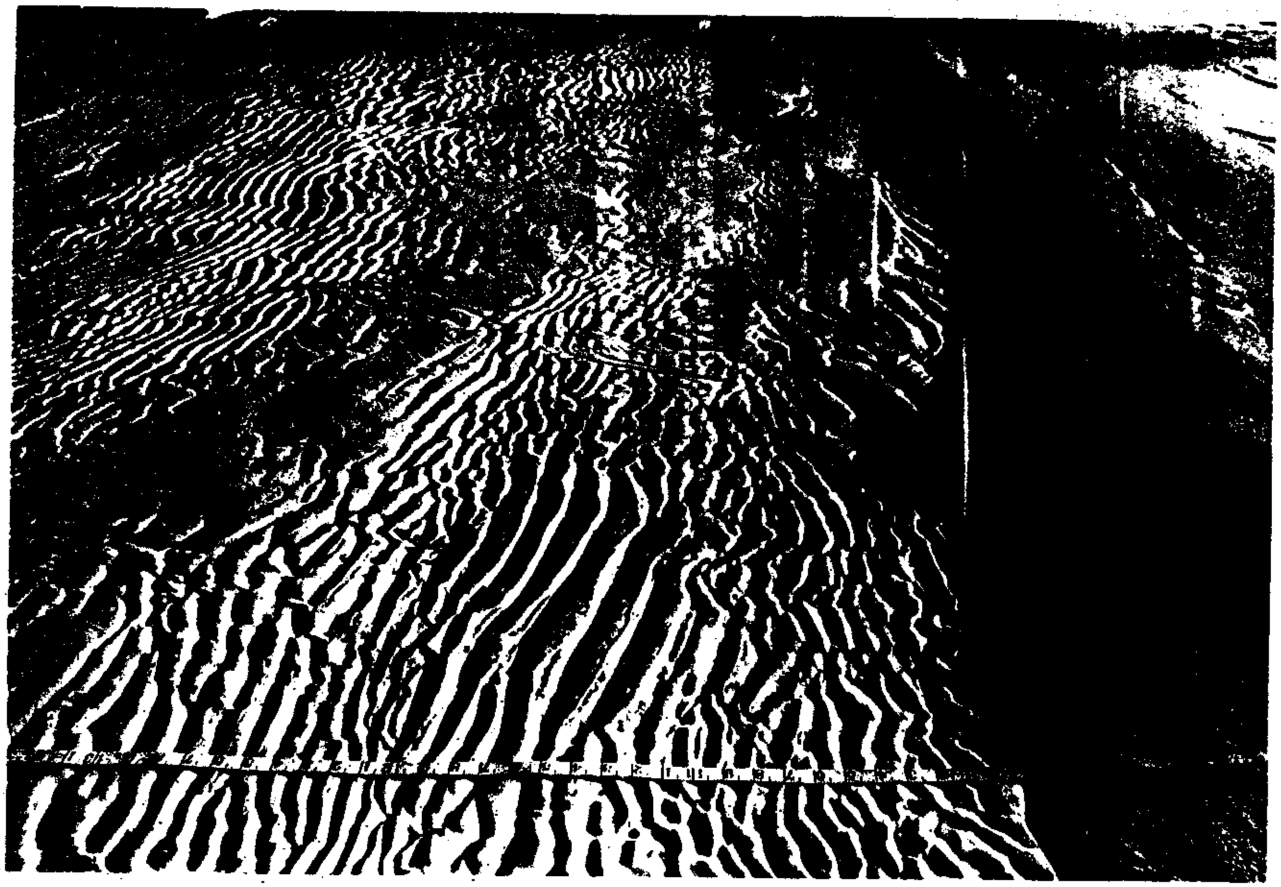


Figure 2.

Figure 3.

TABLE I OPERATING CONDITIONS FOR MODEL RUNS.

| Run Series | 1 | 2 | 3 |
|---|---|---|---|
| $d_o$* | 7" | 9" | 36" |
| $H_o$* | 0.75" | 1" | 2" |
| $L_o$* | 42" | 55" | 110" |
| T | 1.4 sec. | 1.5 sec. | 1.9 sec. |
| $H_b$ | ≈1.5" | ≈2.0" | 2-1/4" |
| Initial Slope | 1 : 20 | 1 : 24 | 1 : 14 |

*Subscript "o" refers to deep water; i.e., near wave paddle

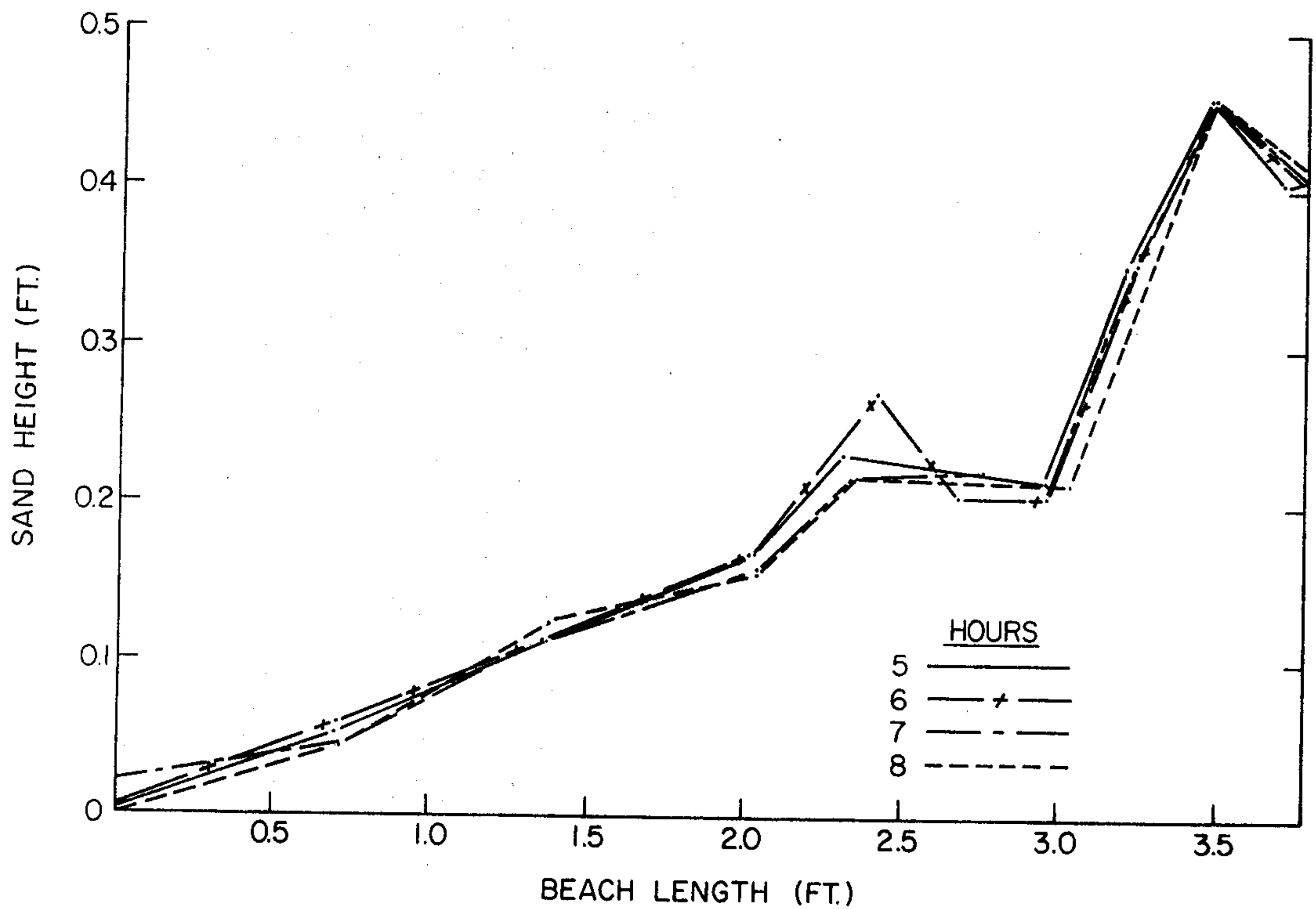
d water depth

$H_o$ wave height

L wave length

T wave period

$H_b$ wave height at break point



SAND HEIGHT (FT.)
0.5
0.4
0.3
0.2
0.1
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
BEACH LENGTH (FT.)
HOURS
5
6
7
8


Figure 4

TABLE II QUANTITY OF SAND REMOVED FROM BERM IN SECOND SERIES OF RUNS.

| Run No. | Running Time (hrs., min.) | | Sand Removed ($ft.^3$) |
|---|---|---|---|
| | Per Run | Total | |
| 1 | 19:30 | 19:30 | 4.7 |
| 2 | 18:20 | 37:50 | 6.6 |
| 3 | 6 | 43:50 | 7.5 |
| 4 | 18:20 | 62:10 | 5.2 |
| 5 | 18:20 | 80:30 | 3.3 |
| 6 | 6 | 86:30 | 2.8 |
| 7 | 18:40 | 105:10 | 4.7 |
| 8 | 18:40 | 123:50 | 6.1 |
| 9 | 18:20 | 142:10 | 3.7 |
| 10 | 6 | 148:10 | 4.7 |
| | | | Total 49.3 |

## SAND MIGRATION

The third series of runs was carried out in a larger wave basin (50' x 70') with a wave maker that permitted larger waves and closer control. The purpose of these runs was to further evaluate the NABE technique and to learn more about the origin of the sand that migrates to the beach area.

After about ten hours of running time, the berm was fully established a few feet shoreward of the breaker zone. Approximately 11 cubic feet of sand were then scraped from the berm and removed from the basin. Two pounds of tracer sand were placed in the middle of the tank at the breaker zone. A similar quantity of blue tracer sand was placed four feet outside of the breaker zone, and green tracer sand was placed near the wave maker, a distance of 40 feet from the berm. In the first half hour the orange and the blue spots were observed to migrate steadily toward the berm while the green spot appeared undisturbed. To our surprise, sand samples of the berm, when viewed under untraviolet light, showed significant numbers of orange and blue sand particles and even a few green particles. Thus, sand was coming to the beach from all over the test basin.

## CONCLUSIONS

1. It is possible in a wave tank to increase the amount of sand on the dry beach by periodically removing a portion of the berm and allowing sand to move from offshore to replace it.

2. After the system has reached steady-state and sand has been removed from the berm, under appropriate conditions, waves cause sand to move rapidly from offshore to reestablish the steady-state condition.

## FUTURE WORK

Laboratory studies now in progress will evaluate the influence of various major variables on the process. One series of runs will study the influence of tidal variations on the transport of sand. Another series will be carried out under conditions where severe beach erosion can be expected.

We would like to conduct a field test during the summer of 1979. We anticipate using a one-mile length of beach as the experimental area, using the next mile as a buffer zone, and using the third mile as a control. As of this date, no decision has been made concerning the selection of a site.

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CAPTIONS

Figure 1. Profile of an Ideal Beach.

Figure 2. Wave Basin used in First Two Series of Runs. Basin was 35.7 ft. wide and 45 ft. long. Paddle was 2 ft. high and 35 ft. wide. Paddle driven by a variable-speed motor.

Figure 3. Wave Basin used in Third Series of Runs. Basin was 50 ft. wide and 70 ft. long. Snake-type wave maker 49 ft. wide.

Figure 4. Rate of Approach to Steady-State in Laboratory Tests.

# REBUILDING THE BEACHES
# OF FLORIDA

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## REBUILDING FLORIDA'S BEACHES


### ABSTRACT

Beach erosion control studies and projects represent only a part of the effort throughout the state to control erosion and the loss of one of Florida's most valuable natural resources, its sandy beaches. Beach erosion control studies are 100 percent Federally funded and are specifically authorized by Congress. Today, the Federal share of construction costs may be as high as 70 percent for public parks and conservation areas, 50 percent for other public shores, and up to 70 percent for hurricane flood protection projects. There are 12 major beach erosion control studies under way and 15 projects authorized for Florida. These beach fill type erosion control projects include a total of 84 miles of the Florida shoreline and not only provide protection from erosion and storm damage but also restore miles of public beach to the state's outdoor recreational resources. In addition to planned beach restoration projects, emergency beach fill projects have been constructed to ameliorate damages to designated "disaster areas" following major storms. Over the past 10 years and at 15 sites around the state, the beach fill material normally obtained from offshore borrow sources has been reduced by the placement of 5.5 million cubic yards of suitable material obtained from adjacent Federal navigation projects during maintenance operations. The Corps of Engineers has taken an active role in environmental protection on beach erosion control projects and is constantly going through an environmentally sensitive evaluation process in all stages of planning and design. During the past 10 years, the Corps of Engineers has placed 20 million cubic yards of sand on Florida's beaches. By next summer, the total will be 30 million, and, to date, no significant long-term environmental damages have been identified. The Corps continually monitors project operations to increase our knowledge and improve methodology for minimizing environmental impacts and have developed the capability to assist in any phase of beach erosion control desired by the state or local governments.

INVOLVEMENT OF THE CORPS OF ENGINEERS IN COASTAL PROBLEMS BEGAN IN 1922 WHEN THE STATE OF NEW JERSEY FORMED AN ENGINEERING ADVISORY BOARD TO STUDY SHORE EROSION. THE CORPS ASSISTED THAT BOARD IN DEVELOPING THE FIRST SUBSTANTIVE REPORT ON SHORE PROCESSES AND BEACH EROSION.

IN 1930, CONGRESS GAVE THE FEDERAL GOVERNMENT SPECIFIC RESPONSIBILITY FOR SHORE PROTECTION BY AUTHORIZING THE CORPS TO STUDY EROSION PROBLEMS AT THE REQUEST OF, AND IN COOPERATION WITH, STATE AND LOCAL GOVERNMENTS AND TO RECOMMEND CORRECTIVE MEASURES. THE STUDY COSTS WERE THEN TO BE EQUALLY SHARED BY FEDERAL AND NONFEDERAL INTERESTS.

THE ROLE OF THE CORPS UNDER THIS AUTHORITY WAS CONFINED ONLY TO THE CONDUCT OF STUDIES UNTIL 1946 WHEN CONGRESSIONAL LEGISLATION EXPANDED THE USE OF FEDERAL FUNDS. UNDER THE NEW LEGISLATION, THE FEDERAL GOVERNMENT COULD CONTRIBUTE UP TO ONE-THIRD OF THE CONSTRUCTION COSTS FOR BEACH EROSION CONTROL PROJECTS FOR THE PROTECTION OF PUBLICLY OWNED SHORES. IN 1956, CONGRESS EXPANDED THE AUTHORITY TO INCLUDE PRIVATELY OWNED SHORES WHERE SUBSTANTIAL PUBLIC BENEFITS WOULD RESULT. FINALLY IN 1962, IT INCREASED THE FEDERAL SHARE OF PROJECT COSTS TO ITS PRESENT LEVEL, WITH ALL STUDY COSTS TO BE BORNE BY THE FEDERAL GOVERNMENT.

TODAY, THE FEDERAL SHARE OF CONSTRUCTION COSTS FOR BEACH EROSION CONTROL PROJECTS MAY BE AS HIGH AS 70 PERCENT FOR PUBLIC PARKS AND CONSERVATION AREAS, AND 50 PERCENT FOR OTHER PUBLIC SHORES. THE

FEDERAL GOVERNMENT WILL BEAR UP TO 70 PERCENT OF THE COSTS OF PROVIDING HURRICANE FLOOD PROTECTION FOR FEDERALLY AUTHORIZED PROJECTS.

EACH BEACH EROSION CONTROL STUDY IS 100 PERCENT FEDERALLY FUNDED, AND IS SPECIFICALLY AUTHORIZED BY CONGRESS. STUDIES AUTHORIZED FOR PENINSULAR FLORIDA, PUERTO RICO, AND THE U. S. VIRGIN ISLANDS ARE ASSIGNED THROUGH THE CHIEF OF ENGINEERS TO THE JACKSONVILLE DISTRICT. STUDIES FOR THE PANHANDLE AREA OF FLORIDA ARE ASSIGNED TO THE MOBILE, ALABAMA DISTRICT.

ONCE A BEACH EROSION CONTROL STUDY IS COMPLETED, THE DISTRICT ENGINEER'S RECOMMENDATIONS AS TO THE FEDERAL PARTICIPATION IN THE PROJECT ITSELF ARE REVIEWED BY THE CHIEF OF ENGINEERS AND THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS PRIOR TO SUBMITTAL TO CONGRESS. FAVORABLE RECOMMENDATIONS GENERALLY RESULT IN AUTHORIZATION OF A FEDERAL PROJECT. FAVORABLE RECOMMENDATIONS RESULT ONLY FOR PUBLICLY OWNED SHORELINE OR SHORES FOR WHICH FEDERAL ASSISTANCE RESULTS IN PUBLIC BENEFITS.

THE MAGNITUDE OF THE EROSION PROBLEMS IN PENINSULAR FLORIDA IS APPARENT FROM THE NUMBER OF FEDERAL PROJECTS AUTHORIZED AND STUDIES UNDERWAY. AS YOU ARE AWARE, THESE PROJECTS AND STUDIES REPRESENT ONLY A PART OF THE EFFORT THROUGHOUT THE STATE TO CONTROL EROSION AND THE LOSS OF ONE OF FLORIDA'S MOST VALUABLE NATURAL RESOURCES, ITS SANDY BEACHES.

THERE ARE 12 MAJOR BEACH EROSION CONTROL STUDIES UNDER WAY AND 15 FEDERAL PROJECTS AUTHORIZED FOR FLORIDA. THESE ARE BEACH FILL TYPE EROSION CONTROL PROJECTS THAT INCLUDE A TOTAL OF 84 MILES OF FLORIDA SHORELINE. TO DATE 27.5 MILES OF THESE PROJECTS HAVE BEEN COMPLETED USING 14 MILLION CUBIC YARDS OF SAND. THESE PROJECTS NOT ONLY PROVIDE PROTECTION FROM EROSION AND STORM DAMAGE BUT ALSO ADD MILES OF PUBLIC BEACH TO THE STATE'S OUTDOOR RECREATIONAL RESOURCES.

IN NORTHEAST FLORIDA THE DUVAL COUNTY BEACH PROJECT WILL PROVIDE 10 MILES OF BEACH FILL IN FRONT OF THE COASTAL COMMUNITIES OF NEPTUNE, ATLANTIC, AND JACKSONVILLE BEACHES.

FOLLOWING HURRICANE "DORA" IN 1964 6 MILES OF ROCK REVETMENT WAS PROVIDED AFTER EXTENSIVE STORM DAMAGE TO THESE COMMUNITIES. HOWEVER, THE REVETMENT WAS A TEMPORARY EMERGENCY MEASURE, AND A MORE PERMANENT PROTECTION IS NEEDED. THE BEACH FILL PROJECT WILL EXTEND ALONG THE 10 MILES OF OCEAN SHORE OF JACKSONVILLE HARBOR ENTRANCE TO THE SOUTH DUVAL COUNTY LINE, REQUIRING 2.3 MILLION CUBIC YARDS OF SAND FOR INITIAL CONSTRUCTION. WORK ON THIS PROJECT WAS INITIATED IN MAY 1978 AND WAS ABOUT 60 PERCENT COMPLETE BY SEPTEMBER 1978. THE REMAINDER OF THE PROJECT IS SCHEDULED TO BE COMPLETED BY THE SPRING OF 1979.

ALONG THE MIDDLE EAST COAST, THE 2 MILE CANAVERAL BEACH PART OF THE BREVARD COUNTY PROJECT WAS COMPLETED IN 1974 USING 2.8 MILLION CUBIC YARDS OF SAND OBTAINED FROM CONSTRUCTION OF THE TRIDENT SUBMARINE BASIN AT CANAVERAL HARBOR.

SOUTH OF CANAVERAL BEACH PROJECTS TOTALING 8.2 MILES HAVE BEEN COMPLETED AT FT. PIERCE AND PALM BEACH AND BROWARD COUNTIES. TOTAL YARDAGE REQUIRED OF THESE PROJECTS TOTALED 4.5 MILLION CUBIC YARDS.

THE LARGEST PROJECT IN FLORIDA, THE DADE COUNTY PROJECT, IS DESIGNED FOR BEACH EROSION CONTROL AND STORM PROTECTION. IN DADE COUNTY, EROSION OF THE OCEAN SHORE HAS BEEN EXTENSIVE WITH MANY SEAWALLS AND STRUCTURES SUBJECT TO DIRECT WAVE ACTION. FOLLOWING A BEACH STUDY COMPLETED IN 1965, CONGRESS AUTHORIZED 10.5 MILES OF SHORE IMPROVEMENT AND HURRICANE PROTECTION FROM OCEANSIDE FLOODING FOR THE 9.3 MILES OF SHORELINE FRONTING THE COMMUNITIES OF MIAMI BEACH, SURFSIDE AND BAL HARBOUR.

THE BEACH ABOVE HIGH TIDE WOULD BE ABOUT 200 FEET WIDE. A LOW DUNE 2.5 FEET HIGHER THAN THE REMAINDER OF THE BEACH FILL WILL BE PROVIDED ALONG THE LANDWARD HALF OF THE BEACH FILL TO PREVENT WAVE OVERTOPPING DURING A STORM. ABOUT 14 MILLION CUBIC YARDS OF INITIAL FILL WILL BE REQUIRED FOR BOTH AREAS. AFTER CONSTRUCTION IS COMPLETE, ADDITIONAL MATERIAL WILL BE PROVIDED AS NEEDED AT 3- TO 5-YEAR INTERVALS TO PROVIDE THE ESTIMATED 200,000 CUBIC YARDS OF SAND NEEDED ANNUALLY TO MAINTAIN PROJECT DIMENSIONS.

THE FILL MATERIAL IS BEING OBTAINED FROM BORROW AREAS APPROXIMATELY 1 TO 2 MILES OFFSHORE FROM THE PROJECT BEACH IN ABOUT 50 FEET OF WATER. BY SEPTEMBER 1978, OVER 3 MILLION CUBIC YARDS HAVE BEEN PLACED ON THE BEACH AND THE PROJECT WAS ABOUT 22 PERCENT COMPLETE.

TO REDUCE FUTURE NOURISHMENT REQUIREMENTS AND FURTHER STABILIZE THE ISLAND SHORELINE, A SYSTEM OF 13 GROINS WAS ALSO PROVIDED AT VIRGINIA KEY PROJECT IN CONNECTION WITH THE BEACH FILL. THAT BEACH WORK WAS COMPLETED IN APRIL 1974. HALF A MILLION CUBIC YARDS OF SAND OBTAINED OFFSHORE OF KEY BISCAYNE WERE REQUIRED FOR THAT PROJECT AND THE NORTH END OF KEY BISCAYNE.

PROJECTS ON THE WEST COAST INCLUDE THE TREASURE ISLAND BEACH PROJECT WHICH WAS INITIALLY COMPLETED IN 1969 WITH SAND OBTAINED OFFSHORE IN THE GULF OF MEXICO. A TOTAL OF 1.4 MILLION CUBIC YARDS OF SAND HAS BEEN PLACED ON TREASURE ISLAND BEACH. TWO GROINS WERE ADDED TO THE PROJECT IN 1976 TO REDUCE EROSION LOSSES FROM THE PROJECT FILL AS WELL AS SHOALING IN BLIND PASS.

THE INITIAL CONSTRUCTION FOR MULLET KEY LOCATED IN SOUTH PINELLAS COUNTY REQUIRED ABOUT 140,000 CUBIC YARDS OF SAND. TO THE SOUTH THE LIDO KEY PROJECT, WHICH REQUIRED 350,000 CUBIC YARDS OF SAND, WAS CONSTRUCTED BY THE CITY OF SARASOTA.

THE 14 MILLION CUBIC YARDS OF SAND PLACED ON FLORIDA'S BEACHES AS OF THIS DATE WILL, WEATHER CONDITIONS PERMITTING, BE INCREASED TO ABOUT 24 MILLION BY THE END OF THE NEXT SUMMER AS PROJECTS IN DADE, DUVAL, BROWARD, PINELLAS, AND BREVARD COUNTIES ARE CONTINUED OR COMPLETED.

IN ADDITION TO PLANNED BEACH RESTORATION PROJECTS, EMERGENCY BEACH FILL PROJECTS WERE CONSTRUCTED AT INDIAN ROCKS BEACH IN 1969 AND 1974 AND AT PANAMA CITY BEACH IN 1976 FOLLOWING DESIGNATION OF THESE AREAS AS "DISASTER AREAS" FOLLOWING MAJOR STORMS. THESE FILLS TOTALED 750,000 CUBIC YARDS.

BEACH REBUILDING UNDER THESE BEACH EROSION CONTROL PROJECTS ARE AUGMENTED BY THE PLACEMENT OF MATERIAL OBTAINED FROM ROUTINE HARBOR MAINTENANCE ON THE ADJACENT BEACHES. WHENEVER POSSIBLE IT HAS ALWAYS BEEN THE POLICY OF THE CORPS OF ENGINEERS TO PLACE SUITABLE MATERIAL FROM MAINTENANCE DREDGING OF INLETS ON NEARBY BEACHES. IN CASES LIKE THIS, BEACH IMPROVEMENT CAN BECOME A NO COST BENEFIT OF MAINTENANCE DREDGING. THIS HAS BEEN ACCOMPLISHED AT 15 SITES AROUND THE STATE WITH 5.5 MILLION CUBIC YARDS OF SAND OBTAINED FROM FEDERAL NAVIGATION PROJECTS PLACED ON FLORIDA'S BEACHES OVER THE PAST 10 YEARS. THIS IS ACCOMPLISHED AS LONG AS THERE ARE NO ADDED COSTS FOR DISPOSAL OF THE MATERIAL. SHOULD ADDITIONAL COSTS RESULT FROM BEACH DISPOSAL, THE ADDITIONAL FUNDS REQUIRED MUST BE OBTAINED FROM A NONFEDERAL SOURCE.

IN DUVAL COUNTY FOR EXAMPLE, IN 1972 ABOUT 1.6 MILLION CUBIC YARDS OF MATERIAL OBTAINED FROM DEEPENING THE JACKSONVILLE HARBOR NAVIGATION PROJECT AND 400,000 CUBIC YARDS FROM MAINTENANCE DREDGING IN 1974 WERE PLACED ON THE BEACH SOUTH OF THE HARBOR ENTRANCE FROM THE MAYPORT NAVAL STATION TO KATHRYN ABBEY HANNA PARK.

THE 1.6 MILLION CUBIC YARDS OF MATERIAL REMOVED IN 1972 WERE PLACED BY A FLOATING PIPELINE DREDGE WORKING IN THE SHELTERED WATERS OF THE ENTRANCE CHANNEL. THE 400,000 CUBIC YARDS WERE PLACED IN 1974 BY THE CORPS DREDGE "GOETHALS," A HOPPER DREDGE EQUIPPED WITH DIRECT PUMPOUT CAPABILITIES. AFTER FILLING ITS HOPPERS IN THE INLET ENTRANCE CHANNEL, THE DREDGE WAS SECURED TO A MOORING BARGE ANCHORED INSIDE THE CHANNEL AT MAYPORT AND NEAR THE SOUTH JETTY. THE BARGE WAS NECESSARY TO PERMIT A FLEXIBLE HOOKUP TO THE DISCHARGE LINE ON THE BEACH. THE DREDGE THEN PUMPED THE MATERIAL TO THE PLACEMENT AREA 8,000 FEET SOUTH OF THE INLET TO KATHRYN ABBEY HANNA PUBLIC PARK.

AT THE PRESENT ONLY FOUR OF THE CORPS' 17 HOPPER DREDGES HAVE DIRECT PUMPOUT FACILITIES, AND ONE OF THESE IS IN THE JACKSONVILLE DISTRICT (DREDGE MCFARLAND). THE HOPPER DREDGES ARE IN CONSTANT DEMAND FOR MAINTAINING THE NUMEROUS DEEPWATER FEDERAL NAVIGATION PROJECTS. THUS, CONVERTED DREDGES ARE NOT ALWAYS READILY AVAILABLE AS NEEDED TO NOURISH PROBLEM BEACHES WHEN SUITABLE MATERIAL IS TO BE REMOVED FROM

INLETS. SINCE CONVERSION AND SUCCESSFUL OPERATION OF THE DREDGES TO DIRECT PUMPOUT CAPABILITY, PRIVATE DREDGING INTERESTS ARE NOW MOBILIZING DREDGES OF THIS TYPE.

OTHER BEACHES THAT HAVE BENEFITED FROM NOURISHMENT MATERIAL PROVIDED DURING DEEPENING OR MAINTENANCE DREDGING OPERATIONS IN NEARBY CHANNELS AND HARBORS IN THE PAST INCLUDE JACKSONVILLE, PONCE DE LEON INLET, CAPE CANAVERAL, FORT PIERCE, PALM BEACH, MIAMI, FORT MYERS, AND SARASOTA. IN THE SUMMER OF 1977 SUCH PROJECTS WERE UNDERTAKEN AT CLEARWATER PASS, MULLET KEY, LONGBOAT PASS, AND NEW PASS. THIS FALL WE WILL BEGIN PLACING ABOUT ONE MILLION CUBIC YARDS OF SAND OBTAINED FROM CONSTRUCTION OF CHANNELS FOR THE NEW NAVY BASE AT KINGS BAY, GEORGIA, ON THE BEACHES AT FORT CLINCH AND FERNANDINA BEACH.

THE SUCCESS OF THE FEDERAL PROGRAM FOR EROSION CONTROL IN FLORIDA INVOLVED RESOLUTION OF BOTH ENGINEERING AND ENVIRONMENTAL PROBLEMS. ONE OF THE PROBLEMS INHIBITING THE CONSTRUCTION OF BEACH FILLS EARLY IN THE PROGRAM WAS LOCATING A SUITABLE SOURCE OF SAND WITHIN ECONOMICAL PUMPING OR HAULING DISTANCE OF THE PROJECT SITE.

IN 1965, THE STUDIES COMPLETED OR UNDERWAY ON THE EAST COAST OF FLORIDA SHOWED THAT IF THE FEDERAL OR LOCAL GOVERNMENTS WERE TO COME TO

GRIPS WITH THEIR EROSION PROBLEMS, A COMPREHENSIVE PROGRAM WAS NEEDED TO LOCATE SAND DEPOSITS OFFSHORE IN THE ATLANTIC OCEAN. ORIGINALLY, AND HISTORICALLY, SAND FOR BEACH FILLS HAD COME FROM BENEATH THE INLAND WATERS OF RIVERS AND ESTUARIES. THESE SOURCES OF SAND WERE LATER ABANDONED AFTER THE ENVIRONMENTAL TRADEOFFS WERE CONSIDERED BY MANY AS TOO EXCESSIVE FOR THE BENEFITS TO BE OBTAINED.

IN 1965, THE CORPS OF ENGINEERS' COASTAL ENGINEERING RESEARCH CENTER INITIATED STUDIES LEADING TO A PROGRAM OF MAPPING SAND DEPOSITS OFFSHORE IN THE ATLANTIC OCEAN FROM MIAMI TO NEW JERSEY THAT WOULD BE SUITABLE FOR BEACH RESTORATION. THE RESULTS OF THAT PROGRAM, KNOWN AS THE INNER CONTINENTAL SHELF SEDIMENT AND STRUCTURE PROGRAM, HAVE FORMED THE BASIS FOR MORE DETAILED GEOLOGIC INVESTIGATIONS SUCH AS THIS THAT HAVE IDENTIFIED SOURCES OF SAND FOR CONSTRUCTION FROM JACKSONVILLE SOUTH TO MIAMI. ONCE THESE STUDIES PROVED THE EXISTENCE OF SUITABLE SAND IN SUFFICIENT QUANTITIES OFFSHORE IN THE ATLANTIC, THE JACKSONVILLE DISTRICT MOVED IN A POSITIVE MANNER TO IDENTIFY SPECIFIC SOURCES OF SAND FOR THE FEDERAL BEACH EROSION CONTROL PROJECTS.

WE HAVE LOCATED SOURCES OF SAND FOR PROJECTS SUCH AS THE DADE AND DUVAL COUNTY PROJECTS OFF THE EAST COAST OF FLORIDA AND HAVE THE PRELIMINARY DATA AND ENGINEERING CAPABILITY TO DEVELOP OTHER SOURCES AS NEEDED.

ALTHOUGH STUDIES ON THE LOWER WEST COAST OF FLORIDA HAVE NOT BEEN AS EXTENSIVE AS THE CERC STUDY, THE DISTRICT HAS ALSO DEVELOPED A KNOWLEDGE AND INVENTORY OF SAND OFFSHORE IN THE GULF OF MEXICO.

NEW METHODS AND EQUIPMENT FOR LOCATING SAND OFFSHORE ARE BEING USED BY THE CORPS, SUCH AS THE JACKUP BARGE WHICH ALLOWS DETAILED SUBSURFACE INVESTIGATIONS OFFSHORE IN MOST WAVE CLIMATES.

IN APPROACHING THE ENVIRONMENTAL CONCERNS OF DREDGING OFFSHORE FOR BEACH FILL MATERIAL AND ALSO ROUTINE MAINTENANCE DREDGING THE CORPS OF ENGINEERS AND OTHERS SOMETIMES USE THE EXPRESSION, "THE CORPS STANDARDS FOR ENVIRONMENTAL PROTECTION AND ENHANCEMENTS." THE CORPS OF ENGINEERS DOES NOT HAVE STANDARDS THAT ARE REGARDED AS A MEASURE OF ADEQUACY, BUT RATHER A YARDSTICK TO MEASURE OUR LEVEL OF EXPERTISE IN THE DEVELOPMENT OF METHODS AND PRACTICES THAT SAFEGUARD OUR NATURAL ENVIRONMENTAL RESOURCES WHILE AT THE SAME TIME PROVIDING THE ENGINEERING AND CONSTRUCTION NECESSARY TO THE CONTINUANCE AND WELL-BEING OF OUR SOCIETY.

IN THAT CONTEXT THE CORPS OF ENGINEERS HAS NO STANDARDS PER SE, BUT INSTEAD FOLLOW A POLICY THAT ENCOMPASSES FOUR GENERAL ENVIRONMENTAL OBJECTIVES. THEY ARE:

1. TO <u>PRESERVE</u> UNIQUE AND IMPORTANT ECOLOGICAL, ESTHETIC, AND CULTURAL VALUES OF OUR NATIONAL HERITAGE;

2. TO <u>CONSERVE</u> AND USE WISELY THE NATURAL RESOURCES OF OUR NATION FOR THE BENEFIT OF PRESENT AND FUTURE GENERATIONS;

3. TO <u>RESTORE</u>, <u>MAINTAIN</u>, AND <u>ENHANCE</u> THE NATURAL AND MANMADE ENVIRONMENT IN TERMS OF PRODUCTIVITY, VARIETY, SPACIOUSNESS, BEAUTY, AND OTHER MEASURES OF QUALITY; AND,

4. TO <u>CREATE</u> NEW OPPORTUNITIES FOR THE AMERICAN PEOPLE TO USE AND ENJOY THEIR ENVIRONMENT.

OUT OF THIS POLICY EVOLVES PRACTICES THAT CONTINUALLY IMPROVE SUPERVISION OF CONSTRUCTION PRACTICES AND ACTIVITIES THAT MINIMIZE ADVERSE ENVIRONMENTAL IMPACTS. QUITE OFTEN NEW PRACTICES ORIGINATING WITH THE CORPS ARE ACCEPTED BY OTHER AGENCIES AND PRIVATE INDUSTRIES AS "STANDARDS."

AS THE CORPS OF ENGINEERS MOVES FORWARD IN THE IMPLEMENTATION OF THE POLICY TO <u>PRESERVE</u>, TO <u>CONSERVE</u>, TO <u>RESTORE</u>, <u>MAINTAIN</u>, OR <u>ENHANCE</u>, AND TO <u>CREATE</u>, NEW LEVELS OF PERFORMANCE ARE CONTINUALLY ESTABLISHED.

TO MOVE ABOVE ACCEPTED LEVELS OF CONTROL FOR ENVIRONMENTAL PROTECTION, THE CORPS OF ENGINEERS CANNOT, AND DOES NOT RELY ON

GUESSWORK, BUT UPON THE INTERDISCIPLINARY EFFORTS OF PROFESSIONAL ENGINEERS AND SCIENTISTS, AND THE SOLICITATION OF ASSISTANCE FROM SUCH PROFESSIONALS OUTSIDE THE CORPS.

THREE AREAS OF BASIC ENVIRONMENTAL CONCERNS CAN BE IDENTIFIED IN ANY BEACH EROSION CONTROL PROJECT. THESE ARE: (1) BORROW SITE LOCATION; (2) DREDGING ACTIVITIES IN THE SELECTED BORROW SITE; AND (3) DISPOSAL ACTIVITIES ALONG THE SHORE.

BORROW SITE LOCATION IS CRITICALLY IMPORTANT FOR A VARIETY OF REASONS. LOCATING CLEAN SAND OF COMPATIBLE SIZE FOR BEACH PLACEMENT IS ESSENTIAL TO BOTH PRESERVING THE ESTHETIC VALUE OF THE BEACH AND MINIMIZING CONSTRUCTION-ASSOCIATED TURBIDITY AND WATER QUALITY DEGRADATION WHICH MIGHT RESULT FROM LENSES OR POCKETS OF SILT OR CLAY WITHIN A BODY OF SAND. ANOTHER VERY IMPORTANT CONSIDERATION IS THE BORROW AREA LOCATION IN RELATIONSHIP TO PRIME FISHING AREAS AND SENSITIVE OR HIGHLY PRODUCTIVE ENVIRONMENTS.

ONCE A SOURCE OF SAND IS LOCATED, DREDGING MUST BE ACCOMPLISHED IN AN ENVIRONMENTALLY COMPATIBLE MANNER. IF THE BORROW AREA IS RELATIVELY CLOSE TO ECOLOGICALLY SENSITIVE AREAS, GREAT CARE MUST BE TAKEN IN CONTROLLING DREDGE LOCATION. IN SOME APPLICATIONS, THE USE OF SPECIAL EQUIPMENT SUCH AS A SUCTION HOPPER DREDGE WITH PUMPOUT CAPABILITY IS DESIRABLE, AS BETTER CONTROL OF TURBIDITY CAN BE ACHIEVED.

UNFORTUNATELY, THIS TYPE OF EQUIPMENT IS EXCEEDINGLY EXPENSIVE WITH FEW COMMERCIAL UNITS AVAILABLE.

DISPOSAL OF SAND ON BEACHES, BY ITS VERY NATURE, MUST PRODUCE SOME TURBIDITY. GENERALLY, EVEN THE CLEANEST OF SUBTIDAL SAND IN FLORIDA HAS SOME SILT ASSOCIATED WITH IT, SOME OF WHICH IS SUSPENDED IN THE WATER DURING CONSTRUCTION.

MANY OF FLORIDA'S BEACHES, ESPECIALLY ON THE EAST COAST, ARE USED EXTENSIVELY BY NESTING SEA TURTLES. NESTING AND BEACH NOURISHMENT ACTIVITIES ARE NOT EXACTLY COMPATIBLE WHEN OCCURRING TOGETHER. NESTING ACTIVITIES OCCUR FROM LATE MAY THROUGH LATE SEPTEMBER, WITH HATCHING CONTINUING THROUGH NOVEMBER.

THE CORPS OF ENGINEERS HAS BEEN WORKING TOWARDS SOLUTIONS FOR THESE CONFLICTS IN STUDIES LEADING TO CONSTRUCTION OF CURRENT BEACH NOURISHMENT PROJECTS. THE DADE COUNTY BEACH EROSION CONTROL PROJECT FOR EXAMPLE HAS PROVIDED SEVERAL CHALLENGING ENVIRONMENTAL PROBLEMS.

BORROW AREA LOCATION WAS LIMITED TO POCKETS OF SAND BETWEEN LONGSHORE LIMESTONE RIDGES WHICH WERE REPORTED TO HAVE EXTENSIVE HARD CORAL COVERAGE. HARD CORALS ARE ESPECIALLY SENSITIVE TO SMOTHERING BY SEDIMENTS WHICH ARE SUSPENDED DURING DREDGING. TO PROTECT THESE REEFS, THE CONTRACTOR SPECIFICATIONS WERE WRITTEN SO AS TO REQUIRE PRECISE

ELECTRONIC LOCATING EQUIPMENT BE USED, WITH THE PERIMETER OF EACH BORROW AREA DELINEATED BY LIGHTED BUOYS, PLACED WELL CLEAR OF THE REEF AREAS. TO MONITOR ANY POTENTIAL DAMAGE TO REEFS, THE CORPS HAS CONTRACTED FOR BIOLOGICAL MONITORING OF SELECTED REEF AREAS ADJACENT TO THE BORROW SITES. INTERESTINGLY, THE BIOLOGICAL CONTRACTOR REPORTED THAT HARD CORALS COLONIZE 1 TO 5 PERCENT OF THE LIMESTONE RIDGES, AND ARE THUS NOT REALLY CORAL "REEFS" BUT INSTEAD SHOULD BE CALLED "HARDGROUNDS." ABSENT ARE SEA GRASSES, MOST REEF FISH, MOST INVERTEBRATES, AND MOST SPECIES OF SPONGES AND REEF CORALS SO COMMON IN THE FLORIDA KEYS.

AN EXAMPLE OF HOW ENVIRONMENTAL CONSTRAINTS CAN HAVE ADVERSE IMPACT, ONE CONCERNED AGENCY EARLY ON IN THESE PROJECTS INSISTED THE DISCHARGE PIPE BE FLOATED OVER THE INNER LONGSHORE REEF TO PREVENT DIRECT MECHANICAL DISTURBANCE BY THE PIPELINE TO REEFS. THE CORPS' EXPERIENCE WITH FLOATING PIPELINES HAS SHOWN THAT IN EXPOSED LOCATIONS LIKE BEACH NOURISHMENT SITES, OCEAN SWELLS CAUSE THE PIPELINE TO MOVE, RESULTING IN INCREASED PROBABILITY OF JOINT LEAKAGE AND RESULTANT INCREASED TURBIDITY.

IN REFERENCE TO SEA TURTLES, WE KNOW THAT IF TIMING CONFLICTS BETWEEN NESTING ACTIVITIES AND BEACH FILL CANNOT BE AVOIDED, A PROGRAM OF DAILY PREDAWN BEACH SURVEYS CAN BE CONDUCTED BY TRAINED PERSONNEL. IF NESTING SITES ARE FOUND, EGGS CAN BE EXCAVATED AND TRANSPLANTED TO

BEACH REACHES WHICH WILL NOT BE NOURISHED. A BENEFICIAL RESULT OF BEACH NOURISHMENT IS OFTEN INCREASED HABITAT FOR NESTING ACTIVITIES. THIS IS PARTICULARLY TRUE FOR BEACHES LIKE THOSE IN NASSAU COUNTY AND PREVIOUSLY IN DUVAL COUNTY WHICH HAVE MOSTLY RUBBLE RIPRAP AT MEAN HIGH WATER WHICH IS NOT A HOSPITABLE NESTING LOCATION.

THE CORPS OF ENGINEERS IS NOT ONLY CONCERNED ABOUT ANY POSSIBLE ARCHEOLOGICAL RESOURCES WHICH MIGHT BE LOST AS A RESULT OF CONSTRUCTION ACTIVITIES BUT ALSO REQUIRED BY FEDERAL LAWS TO PROTECT SUCH RESOURCES. THEREFORE, THE STATE HISTORIC PRESERVATION OFFICER IS CONSULTED PRIOR TO PROJECT IMPLEMENTATION AND A MAGNETOMETER SURVEY IS MADE IF ONE IS RECOMMENDED. MAGNETOMETER SURVEYS HAVE BEEN MADE OF THE OFFSHORE BORROW AREAS ON DADE, DUVAL, AND TAMPA PROJECTS.

THE CORPS OF ENGINEERS HAS TAKEN AN ACTIVE ROLE IN ENVIRONMENTAL PROTECTION ON BEACH EROSION CONTROL PROJECTS AND IS CONSTANTLY GOING THROUGH AN ENVIRONMENTALLY SENSITIVE EVALUATION PROCESS IN ALL STAGES OF PLANNING AND DESIGN. DURING THE PAST 10 YEARS THE CORPS OF ENGINEERS HAS PLACED 20 MILLION CUBIC YARDS OF SAND ON FLORIDA'S BEACHES. BY NEXT SUMMER THE TOTAL WILL BE 30 MILLION, AND TO DATE, NO SIGNIFICANT LONG-TERM ENVIRONMENTAL DAMAGES HAVE BEEN IDENTIFIED.

I WOULD LIKE TO SUMMARIZE BY SAYING THAT THE CORPS IS INVOLVED IN BEACH EROSION PROBLEMS IN FLORIDA; THAT THE CORPS IS CONTINUALLY STUDYING THE PROBLEM AND INCREASING OUR KNOWLEDGE OF THE CAUSES OF THE

EROSION PROBLEMS; ARE CONSTANTLY SEEKING MORE ECONOMICAL SOLUTIONS. THE CORPS CONTINUALLY MONITORS PROJECT OPERATIONS TO INCREASE OUR KNOWLEDGE AND IMPROVE METHODOLOGY FOR MINIMIZING ENVIRONMENTAL IMPACTS AND HAVE DEVELOPED THE CAPABILITY TO ASSIST IN ANY PHASE OF BEACH EROSION CONTROL DESIRED BY THE STATE OR LOCAL GOVERNMENTS.

# TIDAL INLET CONTROL OF BEACH EROSION - DEPOSITION CYCLES

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## ABSTRACT

Erosional and depositional patterns on barrier islands are commonly controlled by the morphology and hydrodynamics of affiliated tidal inlets. Sand shoals deposited seaward of the inlets (ebb-tidal deltas) determine wave-refraction and tidal-current patterns that mold the shape of the islands. Severe erosion can sometimes be related to tidal inlet migration.

Kiawah Island is one of several barrier islands on the South Carolina coast showing this type of tidal inlet influence. The island has been highly modified on either end by the migration of the tidal inlets and their associated ebb-tidal deltas. These tidal-inlet related processes mold the shape of the island into an arcuate "drumstick" pattern, which has a bulbous, updrift end composed primarily of bifurcating beach ridges, a relatively narrow central zone of closely-spaced multiple beach ridges, and a downdrift recurved spit system. Historical studies using maps, charts, and aerial photographs show shoreline progradation on the east end of over 1300 m in the past century and the westward building of the recurved spit system at a rate of 40 m/yr since 1949. The tidal deltas act as giant storage systems that feed sediment to the island.

Understanding of these types of erosional and depositional patterns has been helpful in making recommendations for land development of several barrier islands on the South Carolina coast.

## INTRODUCTION

The main thesis of this paper is that tidal inlets are important elements in barrier island shorelines which, in many instances, exert strong influence on the beach erosion-deposition cycles of the adjacent islands. These conclusions are based mainly on studies of coasts with intermediate tides (1-3.5 m), in particular the coast of South Carolina. South Carolina barrier islands are characteristically short and stunted, being cut by numerous inlets. Inlets are not so important to erosion-deposition trends on barriers with small tides (< 1 m; e.g., Texas coast); therefore, that type of barrier will not be considered in this discussion.

## SOUTH CAROLINA COAST

### Introduction

Studies carried out on the South Carolina coast form one of the primary bases for our conclusions on tidal-inlet influences on beach erosion-deposition cycles. The principal data source is an historical analysis of charts and aerial photographs. Some sequential beach-profile surveys and field mapping projects were also carried out. Several specific areas will be discussed (see Fig. 1 for locations).

## South Carolina Barrier Islands

Between Bull Bay and the Georgia border, a distance of approximately 160 km, a series of barrier islands front the coast of South Carolina. These barrier islands average about 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.

Two types of barrier islands were recognized by Brown (ref. 1), barriers composed of a series of vegetated beach ridges (beach-ridge barriers) and those composed of washover terraces transgressing salt marshes (transgressive barriers). Tidal inlets do not significantly affect the erosion-deposition cycles on transgressive barriers; therefore, they will not be discussed further.

Beach-ridge barriers comprise the majority of the central and southern portion of South Carolina's coast. The morphology of beach-ridge barriers has been discussed elsewhere (ref. 2). Beach-ridge barrier morphology is greatly affected by the presence of tidal inlets. Wave refraction and storm protection provided by the ebb-tidal delta cause accretion on the updrift end of the barrier. Slight changes in inlet configuration and position can cause shoreline orientations up to 6.4 km from the inlet (ref. 3).

Erosional-depositional trends on the beach-ridge barrier islands of South Carolina are complex; however, two general patterns are apparent. Barrier islands longer than approximately 6 km tend to develop a drumstick-like shape (ref. 2). The updrift (east; northeast) ends of the island are either basically erosional or show wide fluctuations between erosion and deposition. The central portions of the barriers are usually either stable or show slow erosional and/or accretional changes. The downdrift (west; southwest) ends usually prograde downdrift through the development of recurved spit systems. Kiawah Island (Fig. 2), Isle of Palms, and Bulls Island are examples of this type.

Barrier islands shorter than approximately 6 km, on the

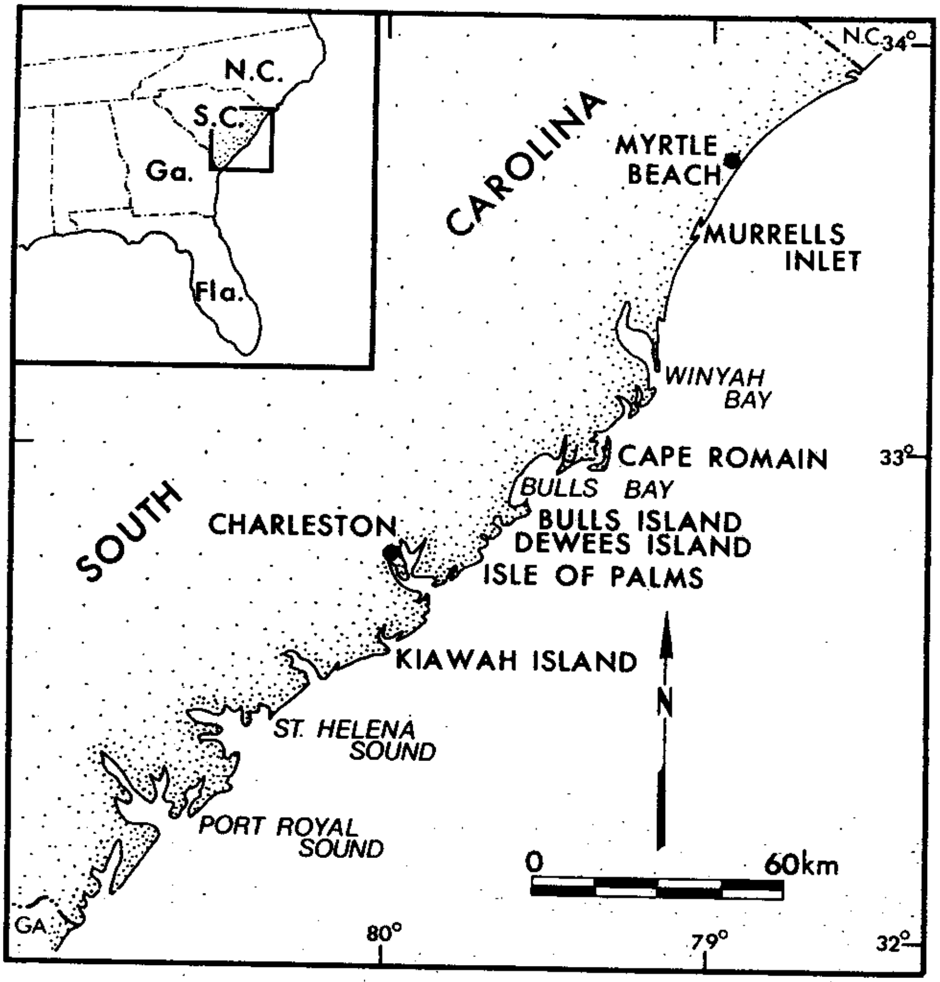


Figure 1. Location map, South Carolina coast.

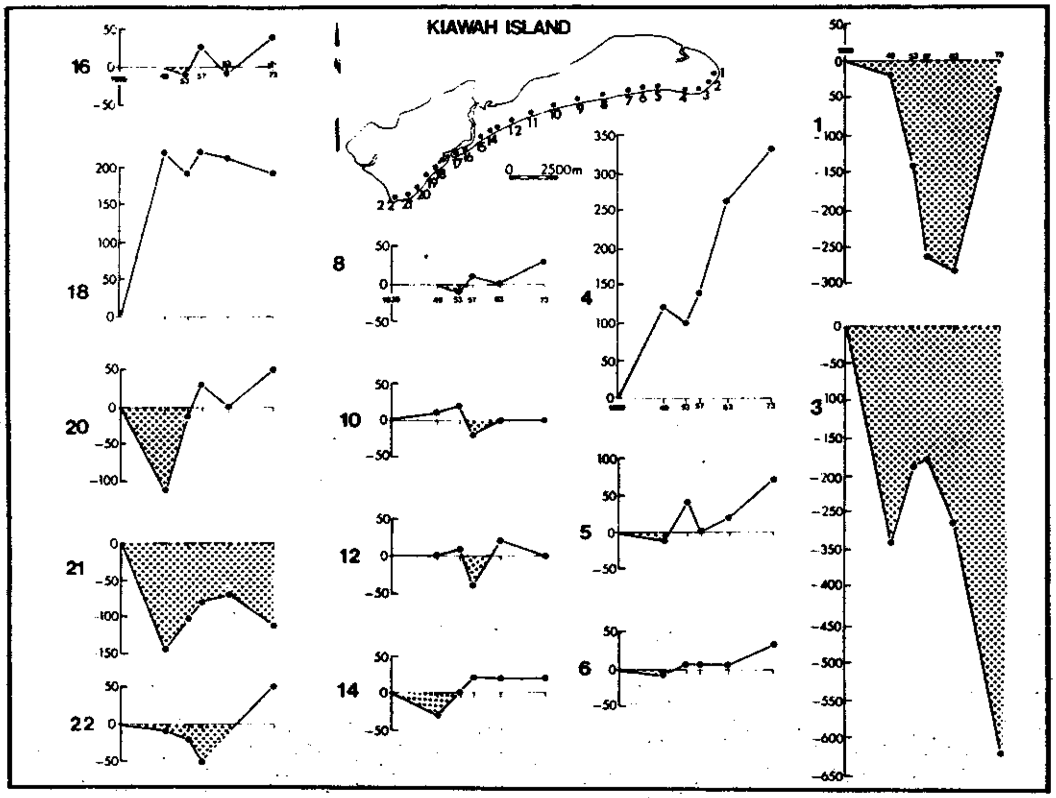


Figure 2. Erosion-deposition graphs for Kiawah Island, South Carolina, based on 6 sets of sequential vertical aerial photographs (after ref. 3). Numbers by the graphs refer to reference points located on the map above the graphs. Erosional areas are shaded. Note the large-scale erosional (graphs 1 and 3) and depositional (graph 4) trends of the east end of Kiawah. These fluctuations are related to changes in Stono Inlet. The midsection of Kiawah Island is stable.

other hand, are under the influence of tidal inlets for their entire length. Therefore, these islands change rapidly in a sporadic fashion, depending upon the position and configuration of the adjacent inlets and their ebb-tidal deltas. Long-term changes at Dewees Island, a short barrier influenced by Capers and Dewees Inlets, are illustrated in Figure 3.

## Arcuate Strand Area

The gentle shoreline crescent of the northern South Carolina coast between the North Carolina border and Winyah Bay was named the arcuate strand by Brown (ref. 1). Inspection of charts dating back to 1879 reveals that the arcuate strand shoreline has been generally stable over the past century. The only exceptions to this trend occur in the vicinity of the few tidal inlets in the area, such as at Murrells Inlet, Little River Inlet and North Inlet. The long-term changes of the coastline between Garden City and Pawley's Inlet are illustrated in Figure 5. Note the long-term stability of this area, which is typical of the rest of the arcuate strand.

## Price Inlet Area

Introduction. - Details of the erosion-deposition trends in the Price Inlet area (Fig. 1) were determined by FitzGerald (ref. 4). An aerial view of the inlet is shown in Figure 6. At Price Inlet, it is evident from the recurved spit structures on the southern half of Bulls Island that the inlet has migrated south 2-3 km. A 1661 map of the Charleston Harbor region indicates that the southern-most position of the inlet was located along the truncated beach ridges of Capers Island, 1 km south of its present location (see Fig. 7).

The present position of Price Inlet was established sometime between 1661 and 1856 when Price Creek breached through the southern spit system of Bulls Island. Unlike the day-to-day activity which builds recurved spits, inlet breaching is usually a catastrophic event associated with storm surge and wave attack (ref. 5).

The processes involved in causing recent shoreline changes at Price Inlet have been determined from sequential vertical aerial photographs (1941-1973) and three years of field observations (ref. 4; summarized in Fig. 7). Constructional processes differ slightly on either side of the inlet; whereas, erosional events appear to be caused by the same factor on both sides.

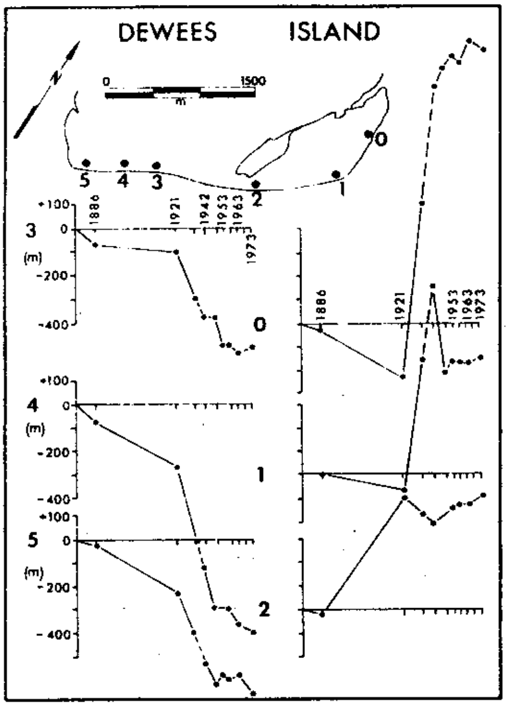


Figure 3. Erosion-deposition trends at Dewees Island, South Carolina. This short barrier island has been highly influenced by changes in the adjacent Dewees and Capers tidal inlets. An aerial view of the island is given in Fig. 4.

Figure 4. Low-tide view of Dewees Island, South Carolina. Compare with erosion-deposition map in Figure 3.

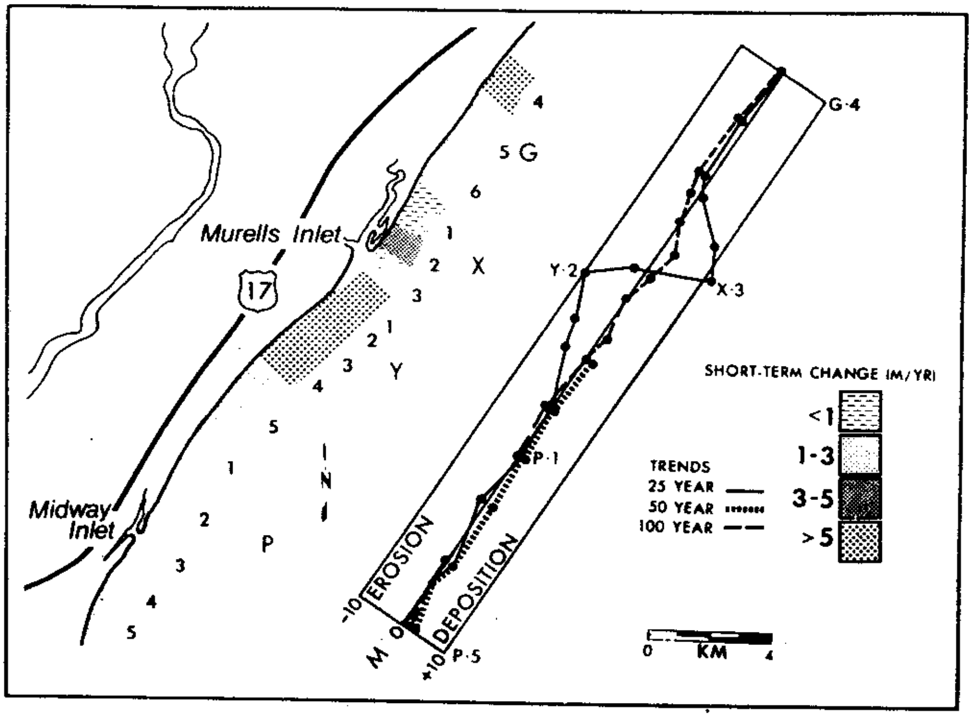


Figure 5. Erosion-deposition trends illustrating the general stability of the arcuate strand area. The graph shows yearly erosion rates (in meters) based on 25, 50 and 100 years of data. The shaded patterns along the beach give an indication of the short-term variability that has occurred along this section of coastline since 1940. Note that despite an overall lack of change, on a long-term basis, significant short-term variations (shaded areas) have occurred since 1940, in some instances averaging over 5 m per year. The effect of tidal inlet migration on shoreline change can be seen by comparing stations X-2 through Y-3 with the rest of the points on the graph.

Figure 6. Low-tide view of Price Inlet, South Carolina. Compare with erosional-depositional trends in vicinity of inlet illustrated in Figure 7.

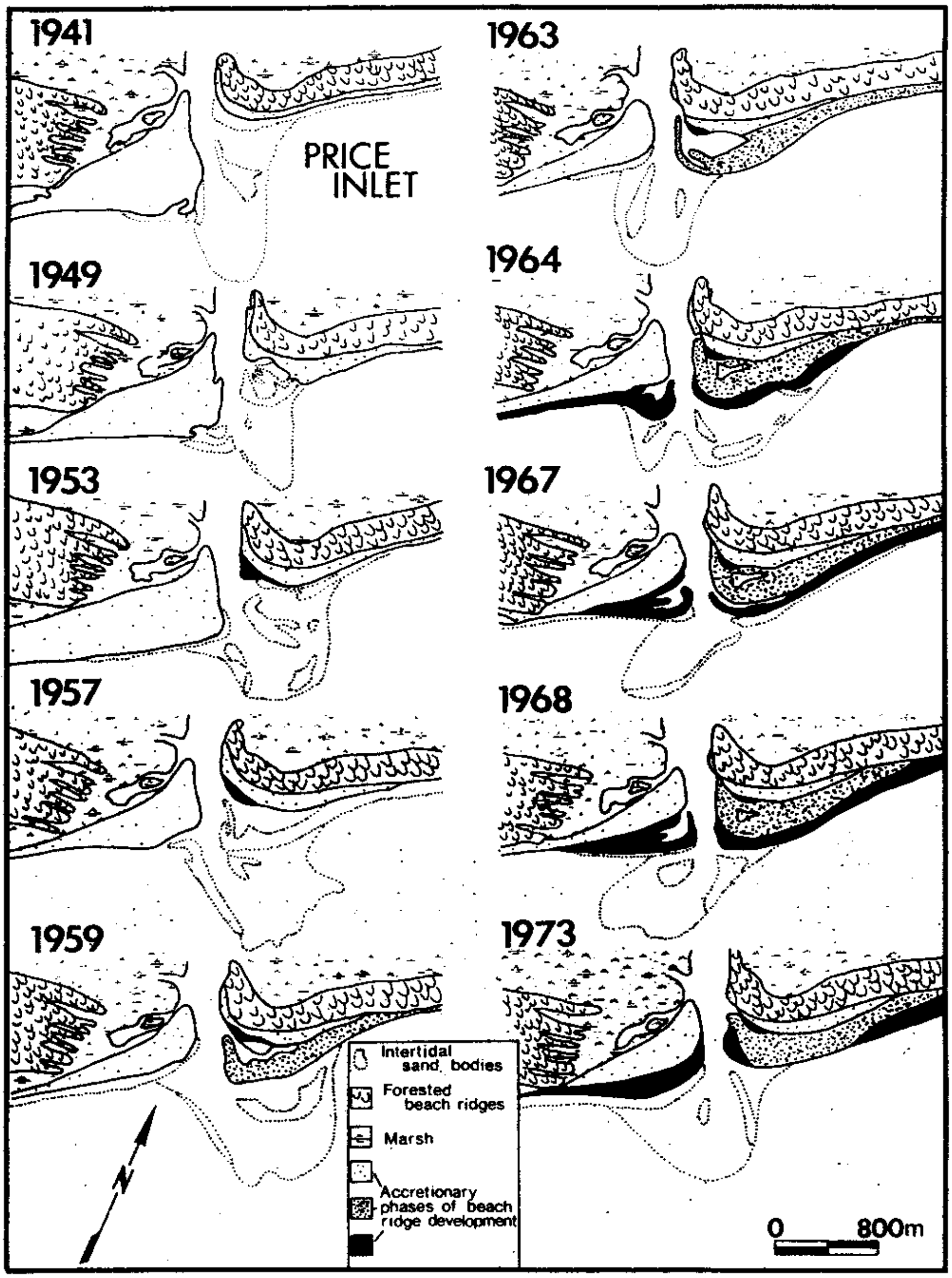


Figure 7. Price Inlet shoreline changes from 1941 to 1973 traced from vertical aerial photographs. On the southern side of the inlet, accretion has occurred in the form of bar migration and a sediment transport reversal. Accretion on the northern side of the inlet is due to bar migration and spit growth. Erosion on either side of the inlet occurs when the ebb-tidal delta is asymmetric to one side of the inlet, leaving the other side exposed to storm waves (From ref. 4; Fig. 11).

Constructional processes. - On the northern side of the inlet, shoreline progradation occurs from landward bar migration and spit accretion. Swash bars form in the distal portion of the ebb delta, migrate landward and attach to a linear shoal on the north side of the main ebb channel (channel-margin linear bar). At the same time, a spit builds out from Bulls Island and connects to the bar complex. This whole bar system migrates landward and welds completely or partially to the beach. In the case of incomplete bar welding, a salt water pond is formed landward of the bar complex, which is subsequently filled by washovers and aeolian sands.

On the southern side of the inlet, shoreline accretion occurs by means of landward bar migration and to a lesser extent by a sediment transport reversal. As in the northern portion of the ebb delta, a swash bar - channel-margin linear bar complex forms on the southern portion of the ebb delta, migrates landward and welds or partially welds to the beach. The major process responsible for bar migration is wave swash.

Normally, along this section of coastline, the net longshore transport direction is toward the south (ref. 6). But due to wave refraction around the ebb delta, a local sediment transport reversal occurs just south of the delta, resulting in a northerly transport of sediment. This causes a reintroduction of sand to the inlet and the ebb delta complex and possible accretion of the southern shoreline adjacent to the inlet. The most important effect of the transport reversal is that sand is trapped on the ebb delta complex and prevented from being transported further down the island to the downdrift beach. Over the past three years, the shoreline of Capers Island, which is located south of the inlet, has retreated 10-30 m while the ebb-tidal delta has substantially increased in volume.

Erosional processes. - Periods of erosion, which have occurred at both sides of the inlet, are thought to be caused by the location and geometry of the ebb delta. When the ebb delta is very asymmetric, overlapping one side of the inlet shoreline preferentially, the other side of the inlet is left unprotected from storm waves, and there is consequent erosion. The Price Inlet ebb delta was very asymmetric to the north between 1953 and 1959, resulting in 400 m of shoreline retreat at the south side of the inlet (see Fig. 7).

Kiawah Island Area

Introduction. - The geomorphology and shoreline changes of the Kiawah Island (Fig. 1) area have been under study by our research group for several years (ref. 7). One of the major findings of the work is that tidal inlets have been all-important in determining the erosional-depositional history of the area.

Historical changes - central barrier. - The central portion of Kiawah Island has shown the least change of any part of the island (Fig. 8). All data available for recorded history indicate that the shoreline has been gradually prograding. Between 1867 and 1973, the west-central shoreline prograded 200 m. Over this same period of time, the east-central shoreline advanced more than 600 m (Fig. 8).

Kiawah River Inlet. - Since 1661, Kiawah River Inlet has migrated along a 4 km stretch of coast on southwest Kiawah and southern Seabrook Islands (Fig. 9). The rate of migration between 1949-1973 was approximately 40 m/yr. A perfectly formed recurved spit developed updrift of the inlet. As the inlet migrates, the ebb-tidal delta migrates with it. The process of refraction of the dominant northeasterly waves around the ebb-tidal delta brings about accretion on the downdrift (southwest) side of the inlet in the manner shown in Figure 10. Recent studies by FitzGerald (ref. 4) and Hubbard (ref. 8) indicate that the process of beach growth downdrift of inlets may be more complicated than this. They document inlet bypassing of packets of sand as a result of shifting positions of the main channel of the inlet and landward migration of large swash bars as important beach-welding processes.

Updrift end of barrier. - The eastern, or updrift, end of Kiawah Island has undergone many changes in the past 300 years. In 1661, a large waterway incised the northeastern portion of the island. Between 1661 and 1854, the waterway filled in with sediment, leaving only a small tidal inlet. Beginning in the late 1880's and continuing at a rapid rate until the 1920's, the eastern shoreline underwent rapid progradation. This accretional trend continued at a slower rate until the late 1930's, adding a total of 1,036 m of shoreline in the form of a triangular foreland. Starting in the late 1930's, the southeast flank of this foreland began to erode with contemporaneous accretion taking place along the southwest flank. Since 1939, this trend has continued at an average rate of 30 m per year, resulting in approximately 120 m of westward migration and general straightening of this part of the shoreline. A future consequence of this migration probably will be the partial erosion of the present day accretional shoreline along eastern Kiawah Island. The current erosion of the southeast flank of the triangular foreland is evidenced by marsh clays cropping out on the beach face, the presence of small trees and bushes in the intertidal zone, and the truncation of post-Civil War beach ridges.

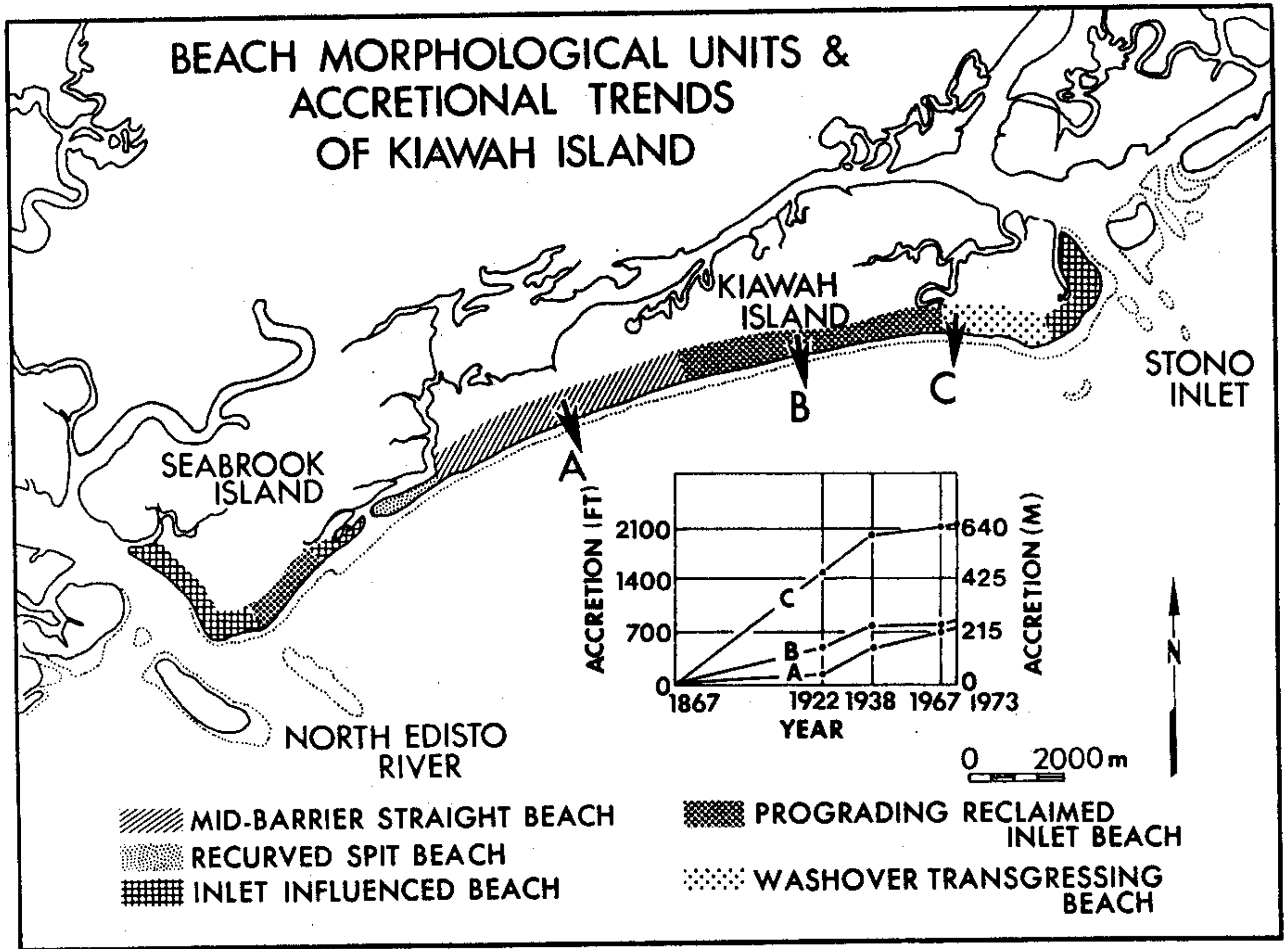


Figure 8. Accretional trends for central Kiawah Island, based on combination of data from historical charts and aerial photographs. The morphological units of the shoreline are also given (From ref. 7; Fig. 3).

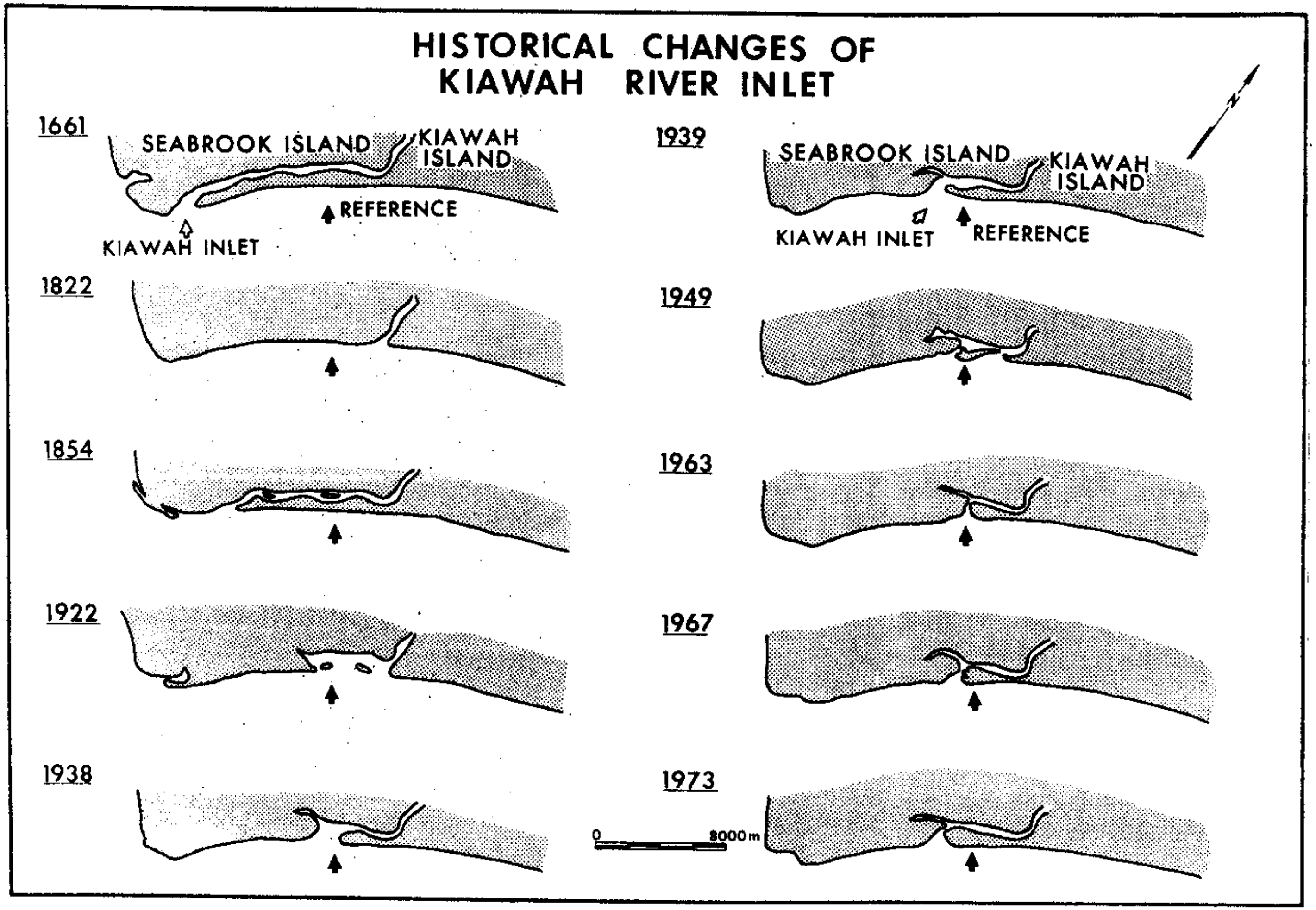


Figure 9. Historical changes of Kiawah River inlet between 1661 and 1973, based on a combination of historical charts and aerial photographs. These data show three periods of breaching of the spit: 1822, 1922 and 1949.

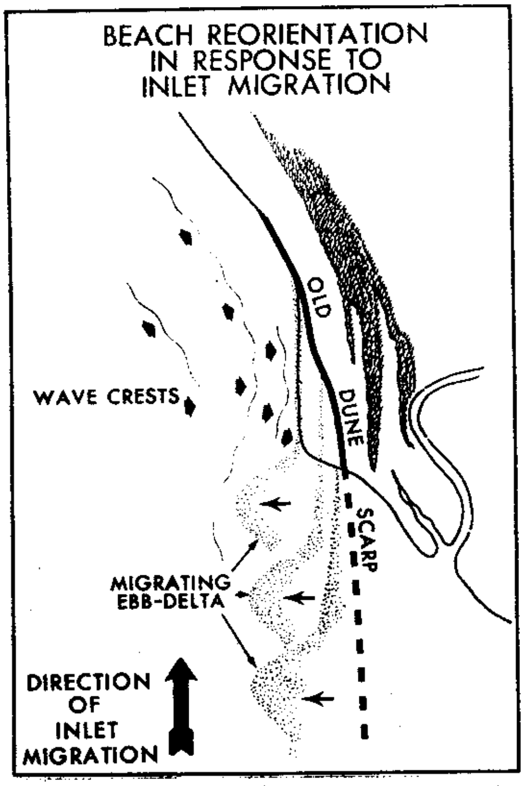


Figure 10. Illustration of how an ebb-tidal delta, with its associated wave-refraction pattern, influences beach progradation downdrift of an inlet. Based on observations at Kiawah River Inlet, S. C.

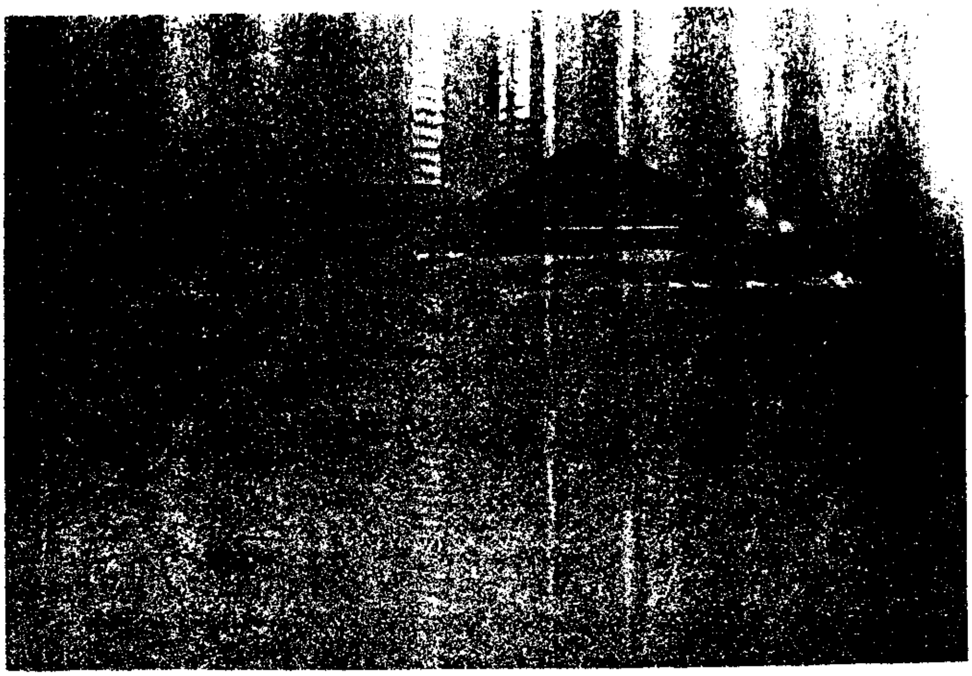

Figure 11. Eroding dune scarp on the western end of Seabrook Island (station KWI, Fig. 12). This scarp retreated 7 m during a single high tide. Photograph taken at low tide on 12 October 1974.

Synopsis of recent changes. - Stephen et al. (ref. 3) completed an inventory of shoreline erosional-depositional trends in Charleston County which included 22 stations on Kiawah Island. The results of this study are shown in Figure 2. At the 22 sites, erosional and depositional rates were measured for 6 sets of aerial photographs dating between 1939 and 1973. These more precise and closely-spaced data indicate that the general trends recognized on the older maps and charts continued into the 1970's. For example, a comparison of station 3 (Fig. 2), where the shoreline retreated 520 m between 1939 and 1973, with station 4, which is located only 1220 m to the west and has accreted 365 m, shows that the east end of the island continued to be extremely unstable. The middle part of the island, on the other hand, remained essentially stable. Note that at stations 10 and 12, the net erosion/deposition was zero.

Beach profiles. - A series of beach profiles, measured at two-week to one-month intervals for one year between June 1974 and June 1975, showed erosion-deposition patterns similar to those observed on the charts and aerial photographs. The greatest changes were observed in the vicinity of inlets (Figs. 11 and 12), whereas the middle portion of the barrier showed little change.

Influence of tidal inlets. - The erosional and depositional history of Kiawah Island is closely related to changes in the morphology and processes associated with its neighboring tidal inlets, those of the Stono, Edisto, and Kiawah Rivers. The Stono and Edisto inlets are characterized by large, well-developed ebb-tidal deltas. Using the method of Dean and Walton (ref. 9), the volumes of sand in the two ebb-tidal deltas were calculated and compared with the estimated total volume of sand in the Kiawah-Seabrook barrier, with the following results:

| | | |
|---|---|---|
| Stono ebb-tidal delta | = | $69 \times 10^6$ $m^3$ |
| Edisto ebb-tidal delta | = | $128 \times 10^6$ $m^3$ |
| Total | | $197 \times 10^6$ $m^3$ |
| Kiawah-Seabrook barrier island complex | = | $252 \times 10^6$ $m^3$ |
| Difference | | $55 \times 10^6$ $m^3$ |

Thus, the sand volume of the two adjacent ebb-tidal deltas is 78% of the sand volume of the barrier island complex itself.

Waves approaching the adjacent beaches of Kiawah Island are strongly influenced by these huge masses of sand. Wave refraction has undoubtedly played an important role in shaping the complex morphology of the eastern end of Kiawah. The ebb-tidal deltas are

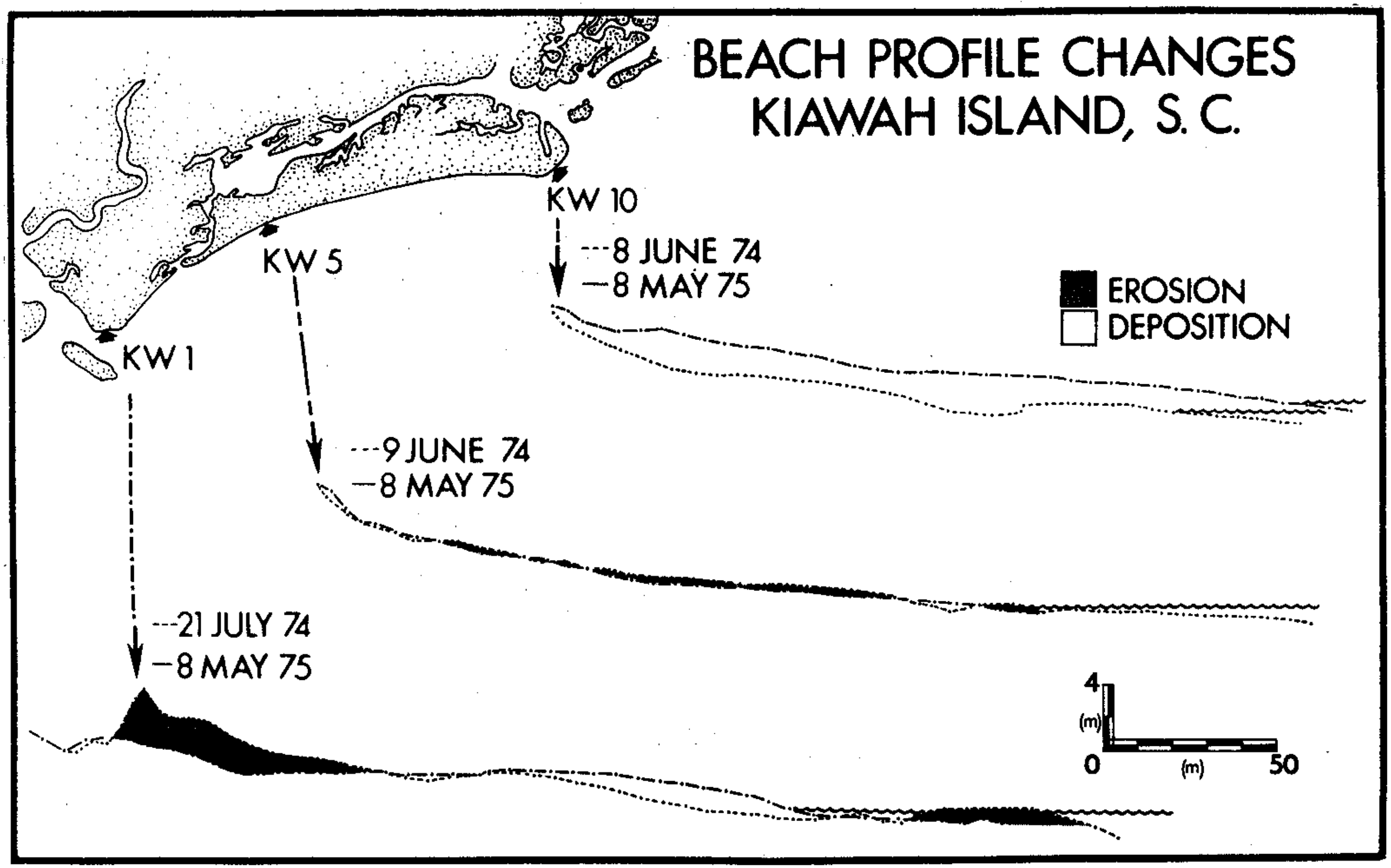


Figure 12. Beach profile changes at 3 stations, KW-1, KW-5, and KW-10 between June-July 1974 and May 1975. Station KW-1, located near the tidal inlet on Seabrook Island showed the most erosion of any station (over 100 m of landward retreat of the high tide line). Station KW-10, which is located on the 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.

also important storage areas for sand.

## BARRIER ISLAND DRUMSTICK MODEL

Many barrier islands in areas of moderate tides (mesotidal; tidal range = 1-3.5 m) have a drumstick shape, with the fat part of the drumstick being located on the updrift side of the barrier. Drumstick-shaped mesotidal barrier islands from Alaska, the Netherlands, South Carolina, and Georgia are outlined in Figure 13B. Several barrier islands in South Carolina have pronounced drumstick shapes, especially Bulls Island, Kiawah Island (ref. 7), and Sullivan's Island (ref. 10). The formation of the drumstick is synonymous with the development of downdrift offsets (ref. 10; see Fig. 13A).

Both the drumstick shape of mesotidal barriers and the downdrift offsets at inlets are at least in part related to wave refraction around the ebb-tidal deltas, as is illustrated in Fig. 13A. Waves approaching the shoreline obliquely are refracted in such a way that a zone of sediment transport reversal occurs on the downdrift side of the inlet (as noted above for Price Inlet, S. C.).

## CONCLUSIONS

Using the South Carolina coast as a model, it is clear that tidal inlets play a major role in beach erosion-deposition cycles on barrier islands. Erosion-deposition trends along the beach-ridge barrier shorelines are highly variable. Islands longer than 6 km develop a characteristic drumstick shape. The central portions of these islands, which are usually stable or slightly accretional, can generally be developed without fear of property loss except during the most severe storms. The updrift and downdrift ends of the islands, on the other hand, are extremely unstable and should not be developed. There are several areas of severe erosion and property loss of the South Carolina coast at the present time. Many of them are located in the vicinity of tidal inlets on the ends of beach-ridge barriers. Beach-ridge barriers less than 6 km are unstable for their entire length and, for the most part, should be avoided as development sites.

The ebb-tidal deltas of the major inlets, which may contain almost as much sand as the barrier island complex itself, exert a profound effect upon the erosional and depositional history of the barrier islands. Offshore sand shoals associated with these tidal deltas create distinctive wave-refraction patterns which determine where wave energy is focused on the island. The locus of concentration of wave energy will change depending upon chang-

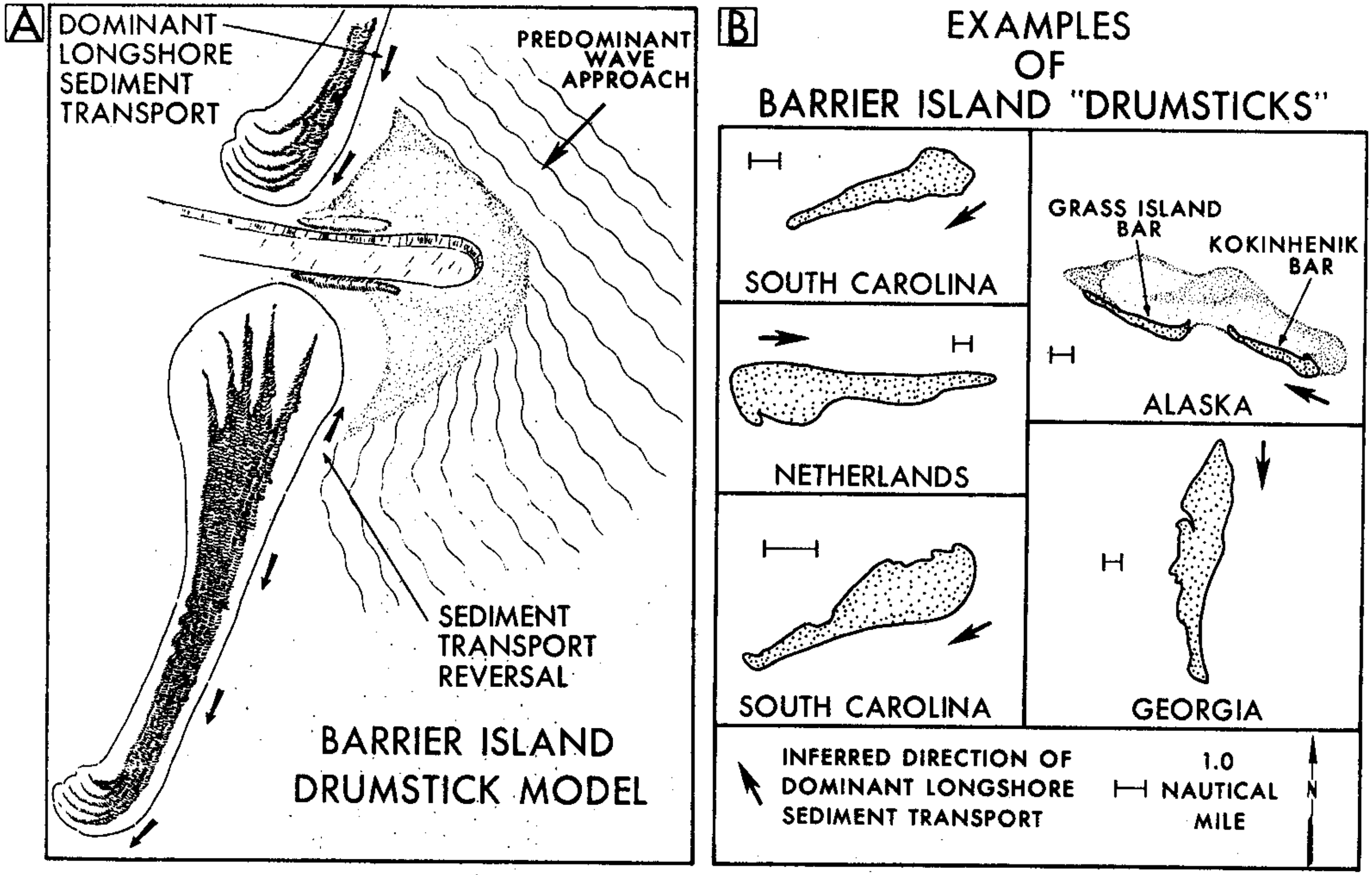


Figure 13. A. Barrier island drumstick model. Note important role played by the ebb-tidal delta.

B. Examples of barrier island drumsticks from South Carolina, Georgia, the Netherlands, and Alaska.

ing configuration of these offshore shoals, which are very delicately adjusted to changes in the position and characteristics of the inlet itself. These tidal deltas also act as large reservoirs of sediment that may be made available to the island under certain natural conditions.

## ACKNOWLEDGEMENTS

This work was supported by the National Oceanic and Atmospheric Administration, Sea Grant Program, project number 04-6-158-44096. Additional funds were provided by the University of South Carolina, Geology Department and Environmental Research Center, Inc., Columbia, S. C. Photographs were obtained from the Eastern Aerial Photographic Laboratory, U.S. Agricultural Stabilization and Conservation Service, and the National Archive, to whom we extend our gratitude for their valuable cooperation. Thanks are also extended to the U.S. Waterways Experiment Station in Vicksburg, Mississippi for permission to photocopy chart data pertinent to this study. Many members of the Coastal Research Division of the University of South Carolina have contributed to the compilation of these data, especially Michael F. Stephen, John H. Barwis, Leita J. Hulmes, Dag Nummedal, Stephen J. Wilson, and Frank Lesesne.

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# BEACH EROSION - LONG AND SHORT TERM IMPLICATIONS (with special emphasis on the State of Florida)

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## Introduction

Beach erosion and its consequent property damage appears to be here to stay as noted in the recent National Shoreline Study authorized by Congress in 1968 and conducted by the U.S. Army Corps of Engineers[1]. In Florida along, over 200 miles of ocean and gulf front property were found to be in a critical state of erosion meaning imminent danger to upland structures and property, while another 1500 miles were suffering less severe erosion.

It is imperative that our nation take a close look at what is occurring on our shorelines such that we do not make the same mistakes as those of our less experienced predecessors who developed our coastline rapidly without thought to the perils which lay ahead.

This paper provides a review of the erosion problem with special emphasis on the State of Florida where beaches support a multimillion dollar tourist industry as well as provide a means of recreation for the populace of that state.

## Causes

The causes of beach erosion (or what we at least perceive as beach erosion) are relatively simple to describe heuristically, but often very hard to document conclusively. A major cause of beach erosion along all our open coast shorelines is that of sea level rise. Presently we are in a warming age and polar ice caps are melting leading to a rising sea level on the order of 1.2 to 9.2 mm per year on the Atlantic and Gulf Coasts with an average rise of 3.3 mm per year[2].

The effect of rising sea level on our coast is twofold: first, the rising sea level causes a direct encroachment on the shoreline leading to an "apparent" shoreline recession which is larger on milder slopes (See Figure 1); and second, a volume of sand from the upper beach profile will slough off to maintain an equilibrium bottom profile offshore. This hypothesis was first discussed by Bruun[3] who developed a quantitative relationship for the rate of shoreline retreat in terms of the rate of sea level rise which, for Florida, amounts to about 1 to 3 feet of beach recession per year. As many areas of the coast appear to be relatively stable (i.e. much less that 1 foot erosion per year in the short term), it is reasonable to postulate that either the hypothesis is wrong or that a trend of shoreline erosion in response to rising sea level is not gradual but rather takes place during more severe wave activity such as occurs during hurricanes or extra-tropical storms. In areas of normally low wave energy, rapid response to high wave events does occur and lends credulity to the above theory. Severe erosion occurs on our shorelines during storms and complete recovery of the lost sand is never made to the beaches. An example of what can happen during a hurricane is shown in Figure 2 from the work of Hayes[4]. This figure documents the potential for a large storm (Hurricane Carla) to transport tremendous quantities of material offshore out of the zone of all but extreme wave activity where it will not be returned to the beaches. In this storm over 100 feet of dune system on a Texas barrier island was virtually destroyed and a sand layer varying in thickness from 1 to 9 cm was deposited offshore to depths of 120 feet by a combination of hurricane waves and currents. Figure 3 presents the results of a more recent study of the beach erosion occurring during Hurricane Eloise which made landfall just west of Panama City, Florida in September 1975[5]. The dune erosion profile shown is the result of a composite profile taken over a twenty mile stretch of beach from Panama City Beach to Destin, Florida. Over 75 feet of large 15-20 foot primary dune system was virtually destroyed by this storm. It will take years before the dune system will be rebuilt naturally from the sand deposited offshore during this storm, and from experience gained after other hurricanes, the beach-dune system will never recover to its prior state.

Sea level rise coupled with severe wave events is not the only reason for our erosion problem though. Another major contribution to erosion is our inlet systems and their corresponding navigation channels either natural or artificially cut through the littoral zone. In the sandy beach littoral zone of Florida alone there are 57 inlets. Fourteen of these inlets have Federally authorized navigation projects with authorized navigation projects with authorized channel depths extending to the ocean or gulf of over 20 feet. There are at least 14 more navigation projects with authorized channel depths of 10 feet or more. For comparative purposes, natural controlling depths on the outer bars of "unimproved" inlets are on the order of 6-8 feet. Many of our Federal navigation projects are not natural channels but have been cut directly through the corresponding barrier island such as St. Lucie Inlet on the lower east coast of Florida. The effects of this inlet will be mentioned later. When a channel is either cut through a barrier island or dredged below the natural existing depths, the flow of water through the channel to the bay (or lagoon) on flood tide and to the ocean (or gulf) on ebb tide is increased leading to an increased capability of the channel to flush sand to its inner bay system or outer shoal system. The channel also acts as a barrier to littoral sand moving along the coast which eventually works its way into the channel and then migrates to either the inner or outer shoals of the inlet. The sand in the interior of the bay systems cannot work its way back out as there is no wave activity to agitate the sediments into suspension such that the water can carry it out. Thus, the bay shoals of these inlet systems act as net sinks to the beach sand system. Volumes of material residing in the inner and outer shoal systems have been shown to be substantial[6]. An example of the amount of sand stored in Florida's outer shoal systems is shown in Table 1. In Florida, considering present erosion rates, it has been estimated that over 200 years worth of sand resides in the outer shoals of these inlets[6]. Figure 5 shows an example of inner shoal sand trapping for St. Lucie Inlet which was cut in 1892 through the barrier island. As noted by the solid line in Figure 4, the total sand deposited in the inlet over the years 1892 to 1930 amounts to over 9 million cubic yards of sand.

It appears from the trend shown in this figure that inlets shoal rapidly in their early years and eventually reach an equilibrium inner shoal area[7]. The trend for outer bar shoals of inlets is not so apparent. Figure 5 shows a relationship proposed by Walton[8,9] between the volume of sand stored in the outer shoal of an inlet and the size of the inlet as determined by its cross sectional throat area (which is related in turn to the volume of water flowing through the inlet). Three curves are given expressing various severity of wave activity at the inlet. The following sand storage equations postulated by regression analysis by Walton[8,9] are given for the three wave conditions:

$$\forall = 33.1\ A^{1.28} \quad \text{heavily exposed inlets}$$

$$\forall = 40.7\ A^{1.28} \quad \text{moderately exposed inlets}$$

TABLE I

VOLUMES OF MATERIAL PRESENT IN OUTER INLET SHOALS OF FLORIDA INLETS[6]

| Inlet | (cubic yards) | Year of Survey |
| --- | --- | --- |
| St. Mary's River Entrance | 136.0 X $10^6$ | 1954 - 1955 |
| Nassau Sound | 53.2 X $10^6$ | 1953 - 1954 |
| St. John's River Entrance | 90.2 X $10^6$ | 1954, 1958 - 1959 |
| St. Augustine Inlet | 106.0 X $10^6$ | 1954, 1957 |
| Ponce de Leon Inlet | 19.0 X $10^6$ | 1924 |
| Jupiter Inlet | 0.97 X $10^6$ | 1967 |
| Baker's Haulover | 0.29 X $10^6$ | 1928 |
| Pensacola Harbor Entrance | 49.1 X $10^6$ | 1940 |
| Destin (East) Pass | 4.90 X $10^6$ | 1941, 1947 |
| St. Andrews Bay Entrance Channel | 1.60 X $10^6$ | 1941 |
| Indian Pass | 2.39 X $10^6$ | 1942 - 1943 |
| West Pass | 51.5 X $10^6$ | 1943 |
| East Pass (Dog Island) | 15.9 X $10^6$ | 1935 |
| Clearwater Pass | 3.00 X $10^6$ | 1950 |
| John's Pass | 6.30 X $10^6$ | 1952 |
| Blind Pass | 0.43 X $10^6$ | 1952 |
| Pass-A-Grille | 23.5 X $10^6$ | 1952 |
| Longboat Pass | 7.78 X $10^6$ | 1954 |
| New Pass (Lido Key) | 6.60 X $10^6$ | 1954 |
| Big Sarasota Pass | 18.68 X $10^6$ | 1954 |
| Midnight Pass | 0.63 X $10^6$ | 1954 |
| Venice Inlet | 0.89 X $10^6$ | 1954 |
| Gasparilla Pass | 6.90 X $10^6$ | 1956 |
| Boca Grande Pass | 175.00 X $10^6$ | 1956 |
| Captive Pass | 12.34 X $10^6$ | 1956 |
| Redfish Pass | 4.29 X $10^6$ | 1956 |
| Big Carlos Pass | 5.19 X $10^6$ | 1960 - 1961 |
| New Pass (Lover's Key) | 0.54 X $10^6$ | 1965 |
| Wiggins Pass | 0.88 X $10^6$ | ? ? ? |
| Gordon Pass | 1.43 X $10^6$ | 1946 |
| Big Marco Pass | 25.00 X $10^6$ | 1930 |
| | Total = 827 X $10^6$ | |

$$\forall = 45.7\ A^{1.28} \text{ mildly exposed inlets}$$

where $\forall$ = volume of sand stored in the outer bar in cubic yards, and A = cross sectional area of the inlet in feet squared. As seen in the above equations, the more severe the wave activity on the outer bar, the smaller its storage capacity is; i.e. wave activity limits the size of the outer shoal area by driving shoal material back to the beaches. The size of the inlet is the main controlling factor though as larger inlets store more sand. Thus deepening an inlet and consequent enlargement of an inlet's tidal prism may well cause additional shoaling on the outer bar if bar storage equilibrium has not been reached. The sand necessary to make up this additional storage volume must come from adjacent beaches.

Additional evidence exists to incriminate channel deepening of our ports for part of the erosion problem in Florida. Figures 6a and 6b are mass balance curves for two Florida Inlets where dredging records have been maintained. The curves show the cumulative maintenance dredging which has taken place from the earliest date indicated and represents the volume of sandy beach material that has moved into the channel from adjacent shorelines.

The slopes of the curves represent the annually averaged channel maintenance necessary to keep the channels at project depth. As can be noted in the Figures, increased depths in the channels cause considerable increased maintenance and the relationship leans toward an exponential type maintenance increase with channel depth rather than a linear type relationship.

Prior to 1965 much of the sand in Florida's deeper navigation channels was barged offshore and dumped in water too deep for the sand to return to shore naturally. In Florida this practice is no longer continued although in many states valuable beach sand continues to be dumped in deep water offshore.

Figure 7 is a view of the erosion situation along Florida's coast in 1963, but is similar to the erosion situation today. The large black spikes where the critical shoreline recession exists are at locations of inlets thus confirming our expectations that inlets cause erosion to adjacent beaches. Of course, it is also well known that in areas of a predominant net sand transport along the beaches, improvements such as jetties at inlets can cut off the natural flow of sand and thereby starve downdrift beaches of sand. In Florida on practically every south side of an inlet (downdrift side), erosion is excessively high. It is not uncommon in Florida to have large stretches of shoreline adjacent to inlets undergoing recession at rates upwards of 10 feet per year.

Another cause of "apparent" erosion to our shorelines is that of barrier overwash. Many of our low barrier islands are very susceptible to wave action occurring over the barrier island during period of high tides with a consequent driving of sand into the bay systems as overwash fans. Very little is known as to the quantities of sand moved into lagoonal systems during overwash events[10].

## Implications

In the developed areas of our coast, the consequences of the erosion problem can be of major importance. As an example, Hurricane Eloise which made its landfall just west of Panama City Beach in September 1975 caused over 80 million dollars damage to an 18.5 mile reach of coastline, much of it due to the undermining of structures by wave action[11].

Much of this damage could have been prevented by proper construction techniques, a good building code, and possibly a setback line controlling building placement along the coast prior to its development[12]. Much of our nation's coast has already been developed though, thus it becomes imperative that we concentrate our efforts on learning to cope with erosion in the most suitable and economical way possible.

Presently, the most economical way to deal with beach erosion is believed to be beach nourishment in which large quantities of suitable beach sediment are dredged (typically from offshore) and placed on the beaches. To date, though, many beach nourishment projects have not performed as well as expected[13]. Table 2 is a listing of some nourishment projects which have been placed along the lower southeast coast of the United States.

Other means of protecting beaches consists of structures such as offshore breakwaters, groin fields, rock revetment, and seawalls. Many of these structures can have adverse effects on shorelines if not used properly. As their cost is considerable (i.e. rock revetment is on the order of $200 per front foot of protection), they are often not considered in as favorable a light as is beach nourishment. As energy costs rise,though, the cost of pumping sand from offshore onto beaches may again become excessive and permit erosion prevention coastal structures to be viewed in a more favorable light.

Perhaps we may have to be more ingenious in our approaches to coastal engineering problems and promote either low energy systematic solutions to sand bypassing problems as conceptualized in Figures 8 and 9 or dual purpose coastal protection/energy creation structures as envisioned in Figures 10 through 12.

TABLE 2

| Location of Nourishment Project | Date of Fill Placement | Volume of Fill ($yd^3$) | Length of Shoreline Filled | Loss Rate (yd/year) | Reference |
|---|---|---|---|---|---|
| Carolina Beach, N.C. | April 1965<br>March 1967 | 2.632.000<br>360,000 | 3 miles | 600,000<br>180,000 | 14,15 |
| Hunting Island, S.C. | December 1968<br>May 1971 | 750,000<br>750,000 | 3 miles | 370,000<br>360,000 | 16,17 |
| Cape Canaveral, Fla. | May 1975 | 2,300,000 | 2 miles | 270,000 | 18 |
| Virginia Key/ Key Biscayne, Fla. | July 1969 | 370,000 | 3 miles | 60,000 | 19 |
| Treasure Island, Fla. | July 1969 | 763,000 | 1.7 miles | 100,000 | 20,21 |
| Harrison County, Mississippi | November 1951 | 7,000,000 | 20 miles | 100,000 | 22,23 |

## Summary

In all, the picture is not a pleasing one. Erosion is with us to stay due to our rising sea level and our needs for improved navigation in our coastal zone. We are still at a stage in which our best alternatives for mitigating shoreline damage are not known completely and subsequent investigations must not only involve theoretical evaluations but also sound engineering judgment.

## Acknowledgments

This work was supported, in part, by the Office of Sea Grant, Marine Advisory Program. The author would also like to thank the following agencies for their generous assistance and access to information:

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Wilmington District, U.S. Army Corps of Engineers, Wilmington, North Carolina

Charleston District, U.S. Army Corps of Engineers, Charleston, South Carolina

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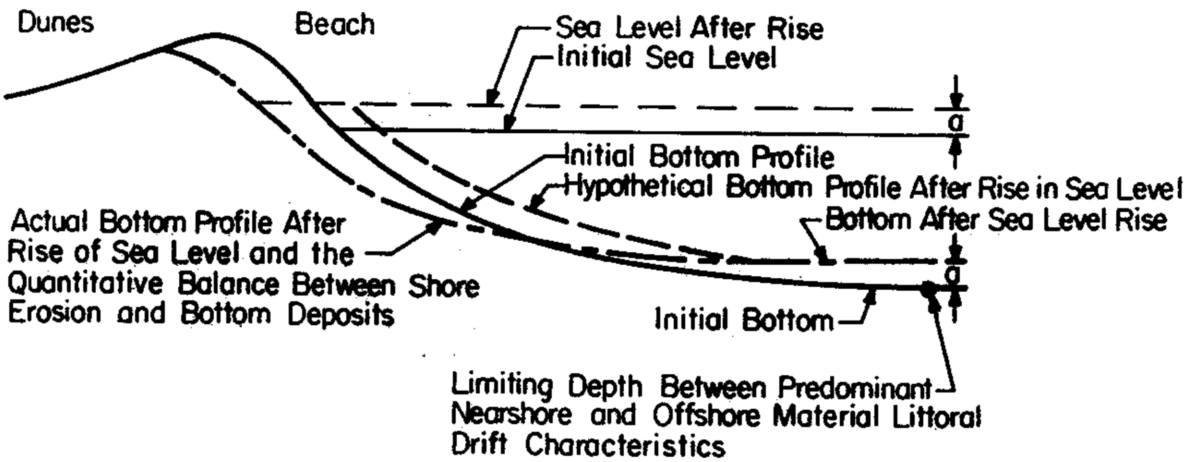



FIGURE 1. BRUUN'S CONCEPT OF BEACH PROFILE RESPONSE TO SEA LEVEL RISE (FROM BRUUN, P.[3])

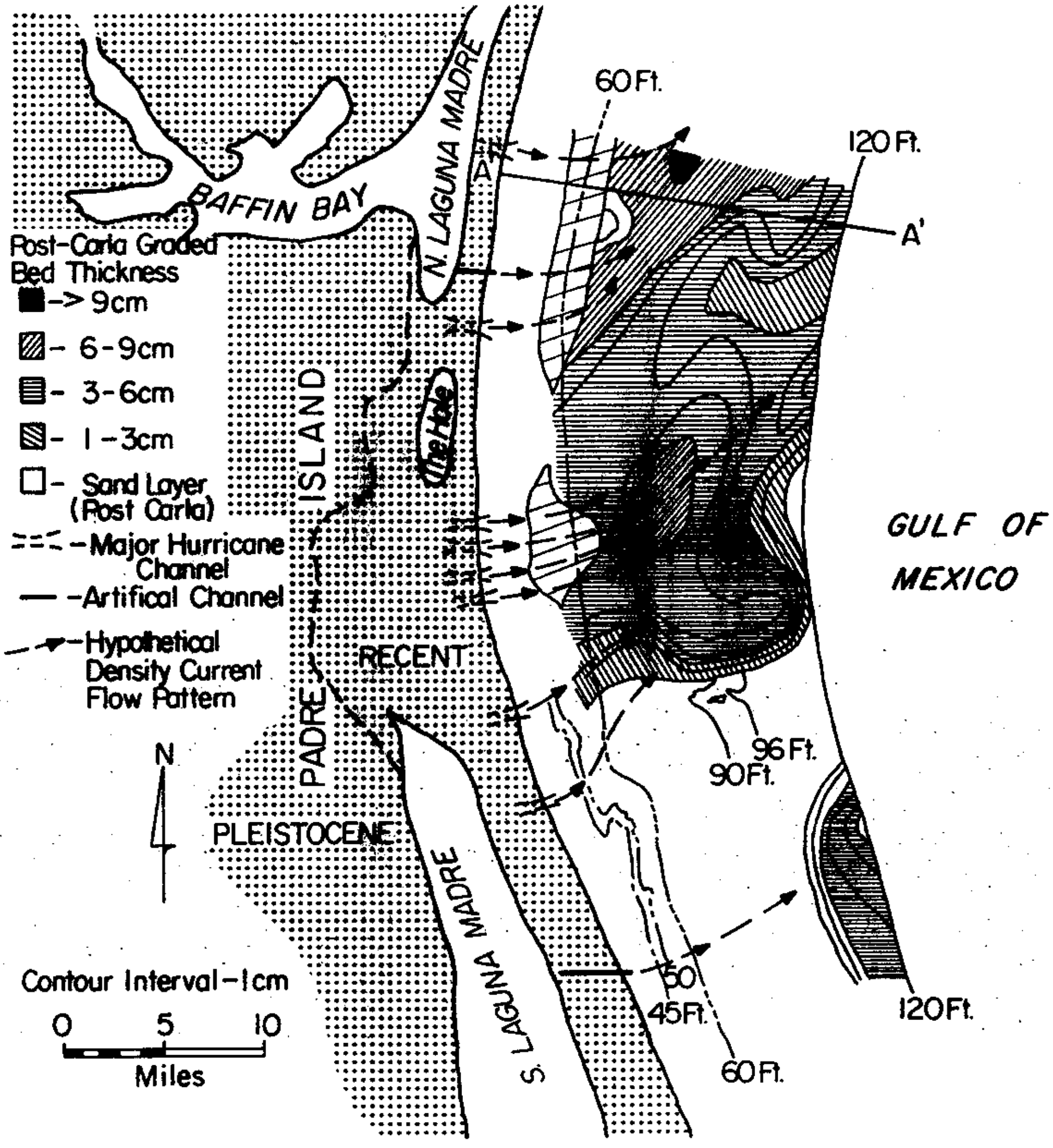



FIGURE 2. SEDIMENTS DEPOSITED OFF CENTRAL PADRE ISLAND DURING AND AFTER HURRICANE CARLA ON A MUD BOTTOM (FROM HAYES[4])

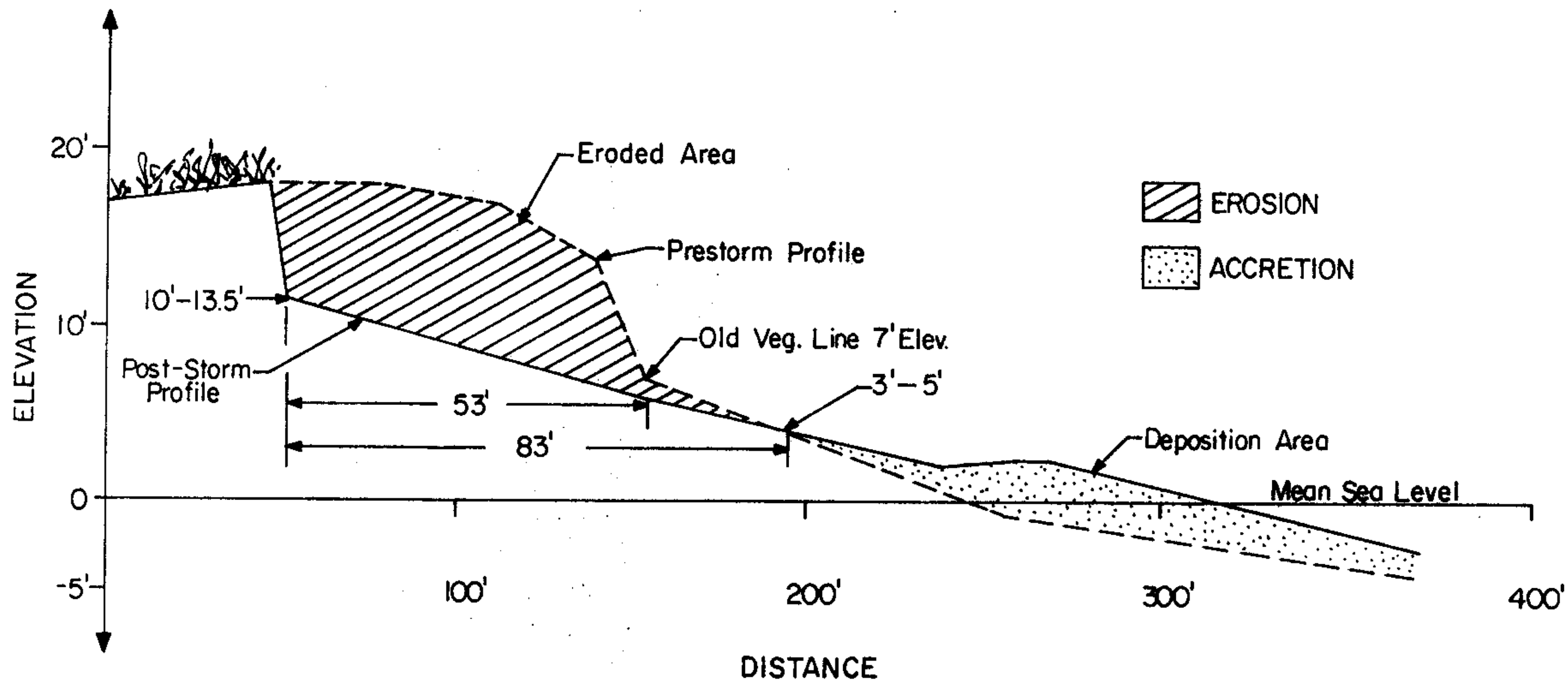



FIGURE 3. GENERAL BEACH - DUNE PROFILE BEFORE AND AFTER HURRICANE ELOISE BETWEEN PANAMA CITY AND DESTIN, FLORIDA (FROM CHIU AND PURPURA[5])

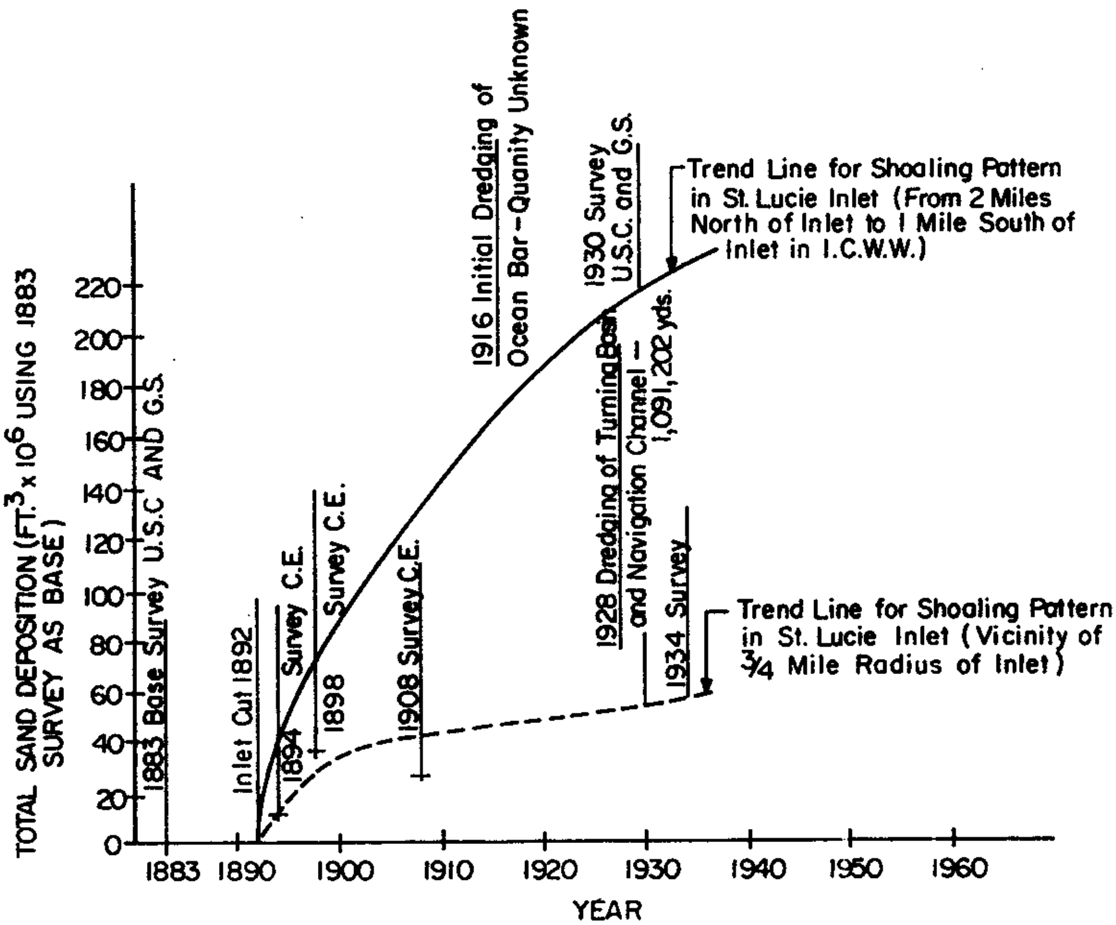



FIGURE 4. DEPOSITION OF SAND IN THE INTERIOR OF ST. LUCIE INLET (FROM DEAN AND WALTON [7])

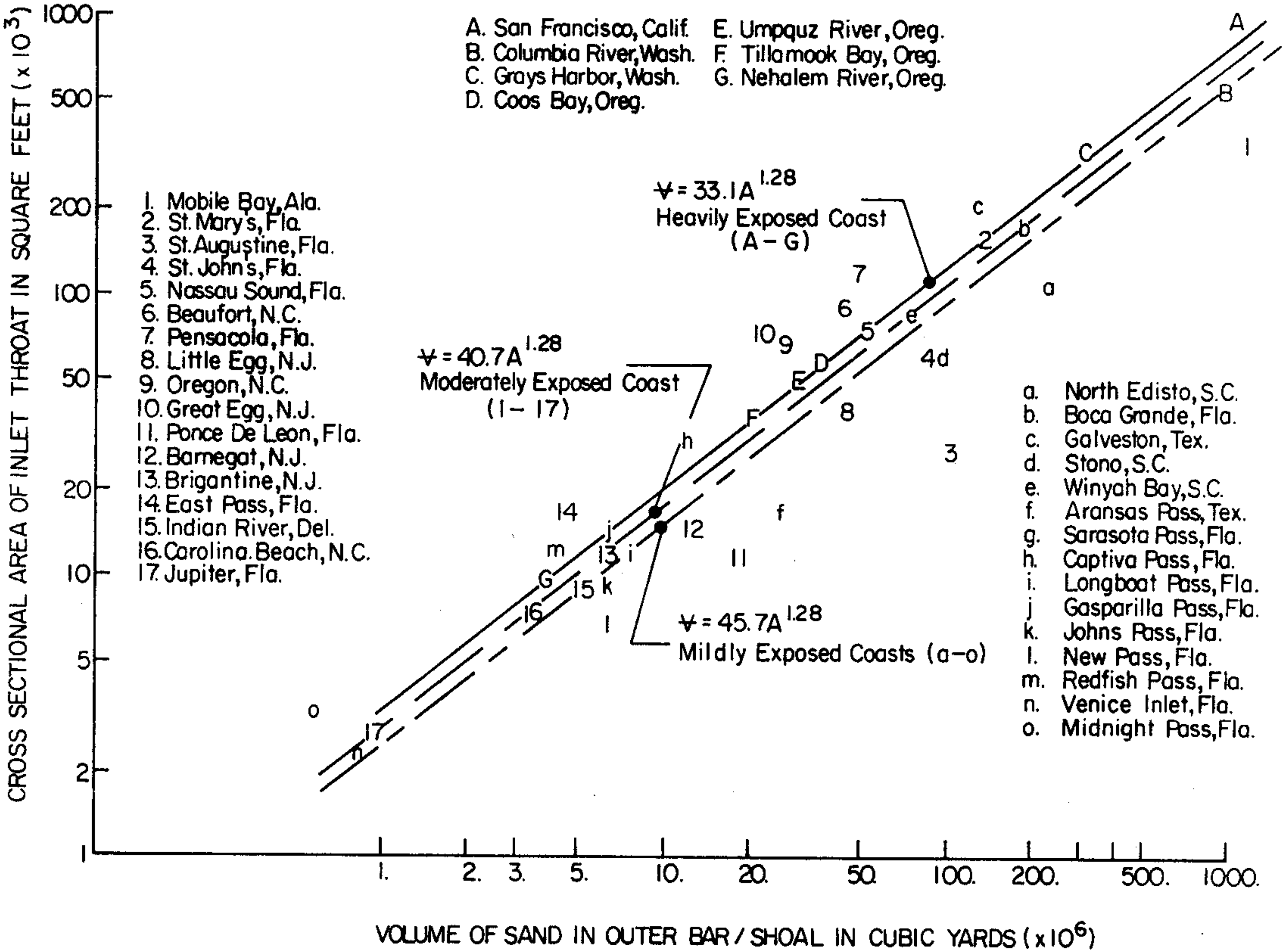



FIGURE 5. RELATIONSHIPS BETWEEN OUTER BAR STORAGE AND CROSS SECTIONAL AREA OF INLETS (FROM WALTON[8,9])

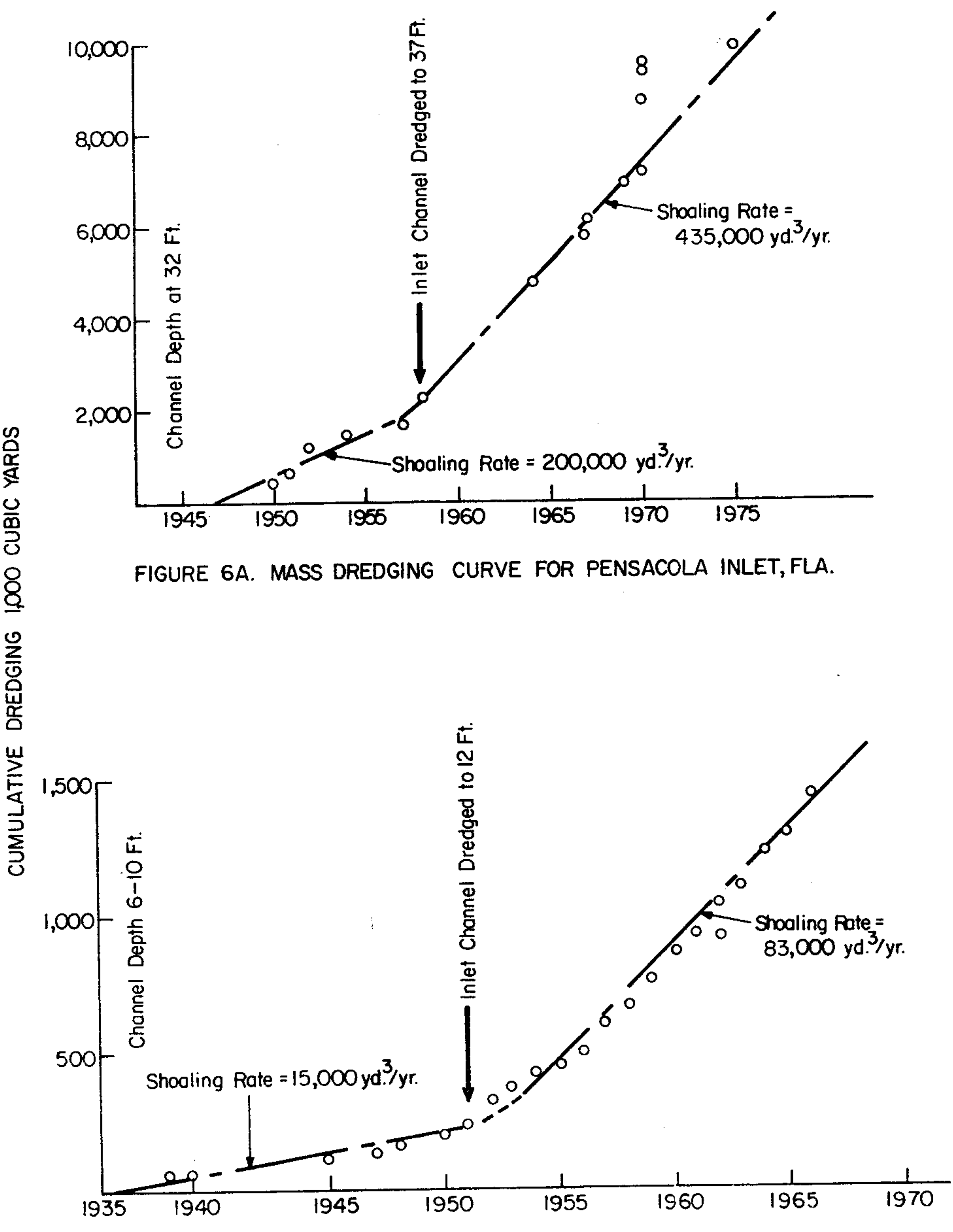



FIGURE 6A. MASS DREDGING CURVE FOR PENSACOLA INLET, FLA.



FIGURE 6B. MASS DREDGING CURVE FOR EAST PASS, FLA.

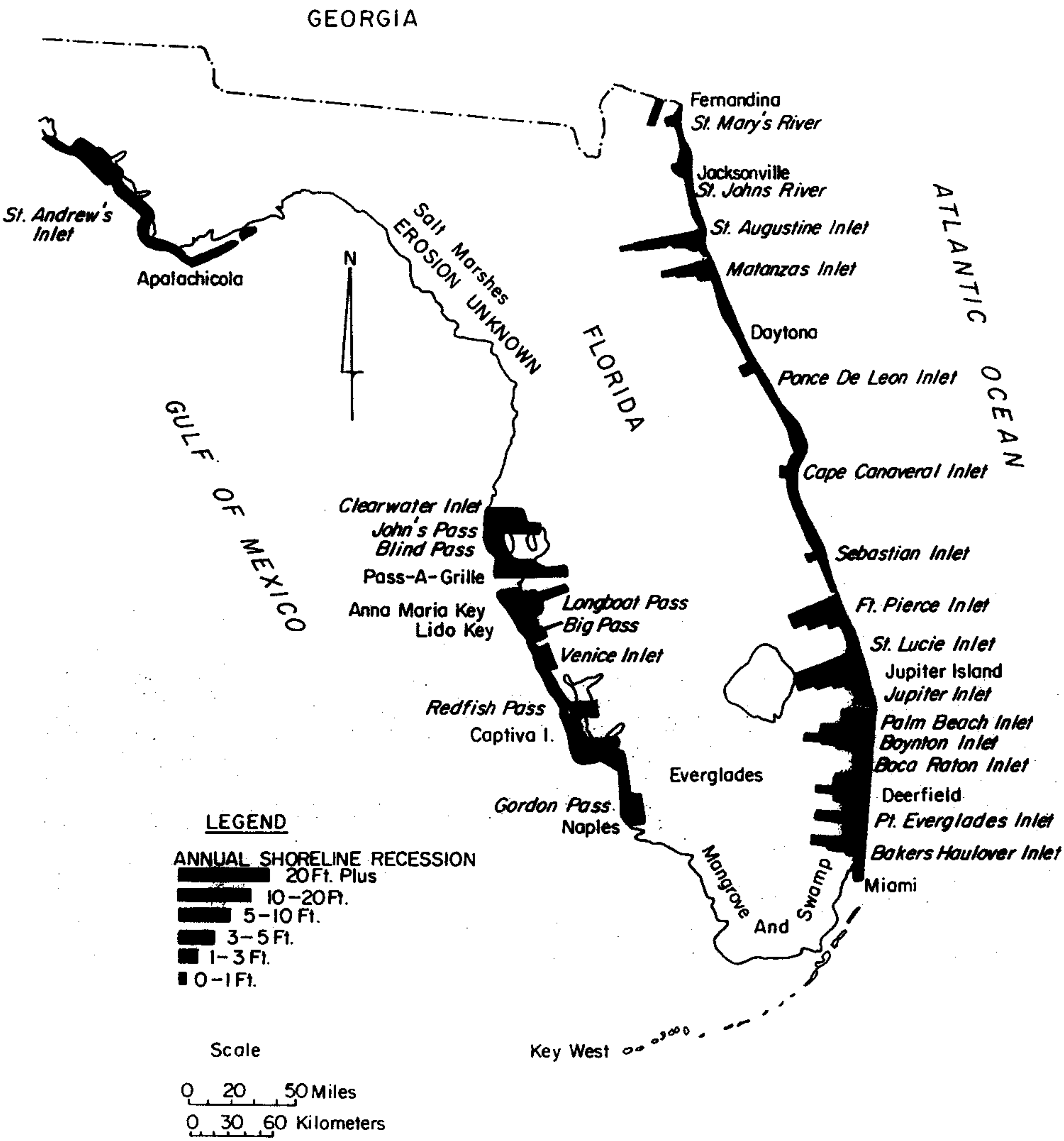
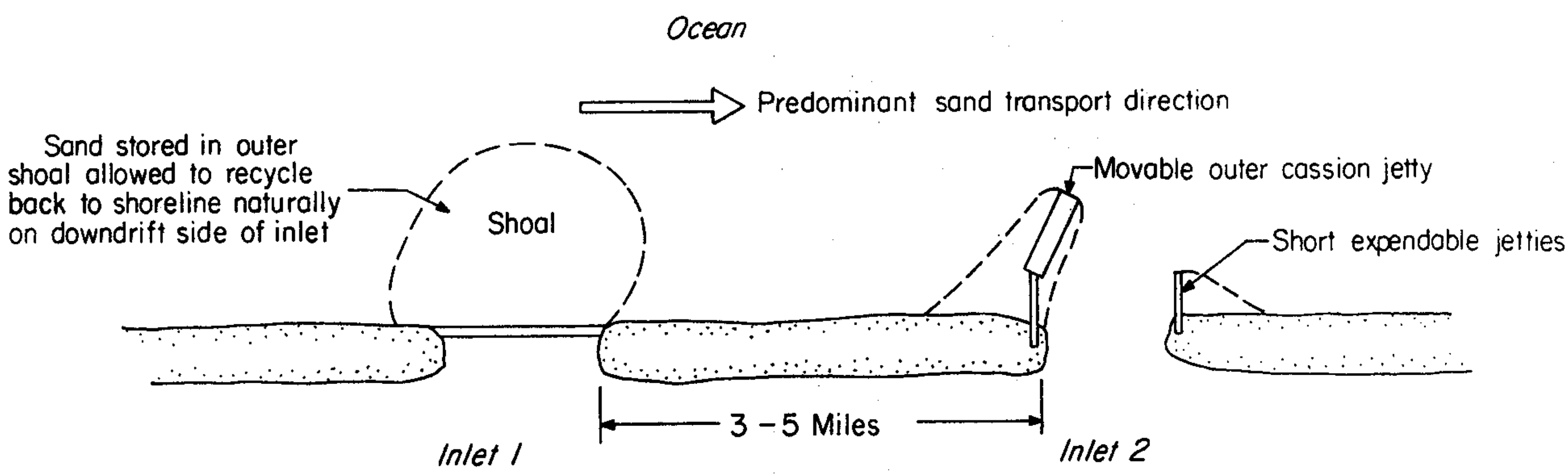



FIGURE 7. EROSION SITUATION IN FLORIDA, 1963

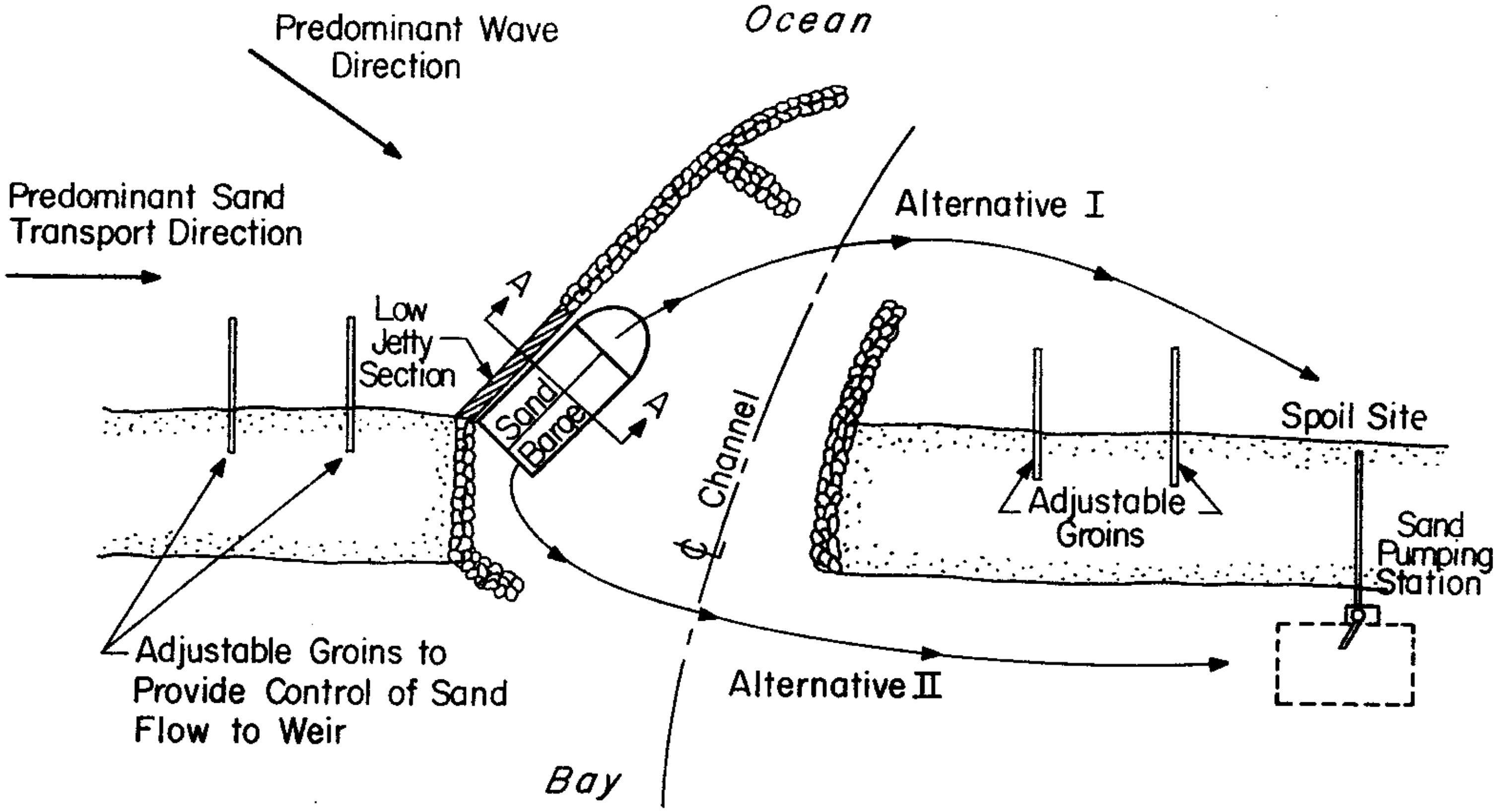



(a) Inlet 2 is opened and Inlet I is closed to allow sand in outer bar to cycle back to shoreline to downdrift side of Inlet I.

(b) After x number of years when Inlet 2 becomes hydraulically inefficient, Inlet I is opened and Inlet 2 is closed to allow sand in outer shoal to migrate back to shore downdrift of dual inlet system.

(c) Repeat process.

FIGURE 8. DUAL NAVIGATION CHANNEL APPROACH TO SAND BYPASSING OPERATION




Alternative I – Barge is floated and moved (sailed) to beach dumping site; sand is dumped

Alternative II – Barge is floated and moved (sailed) to sand pumping station; sand is pumped to beach spoil site

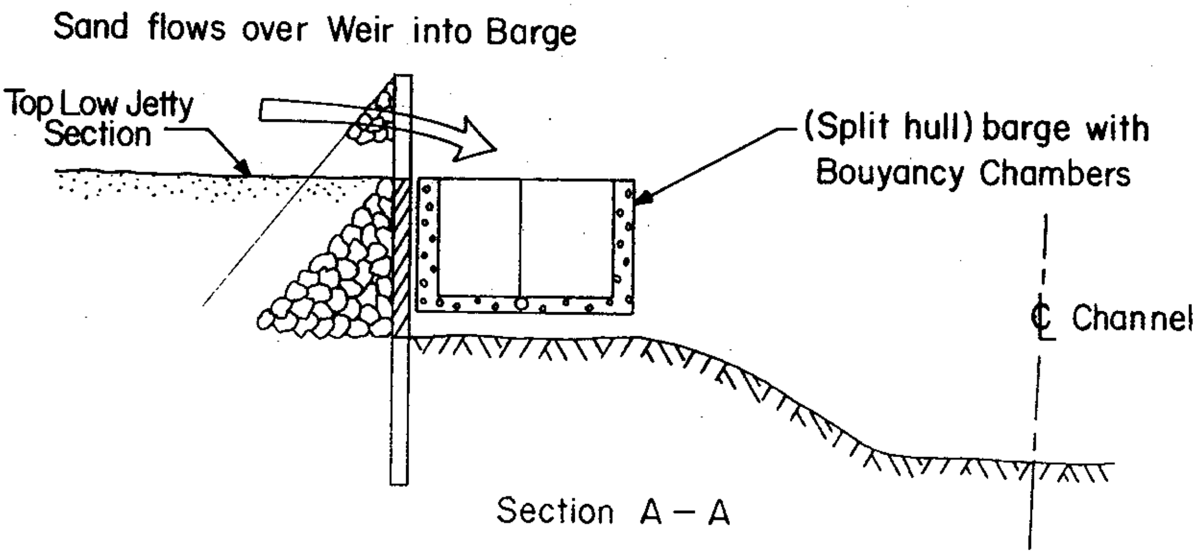



FIGURE 9. SCHEMATIC WEIR JETTY – HOPPER BARGE SAND BYPASSING SYSTEM

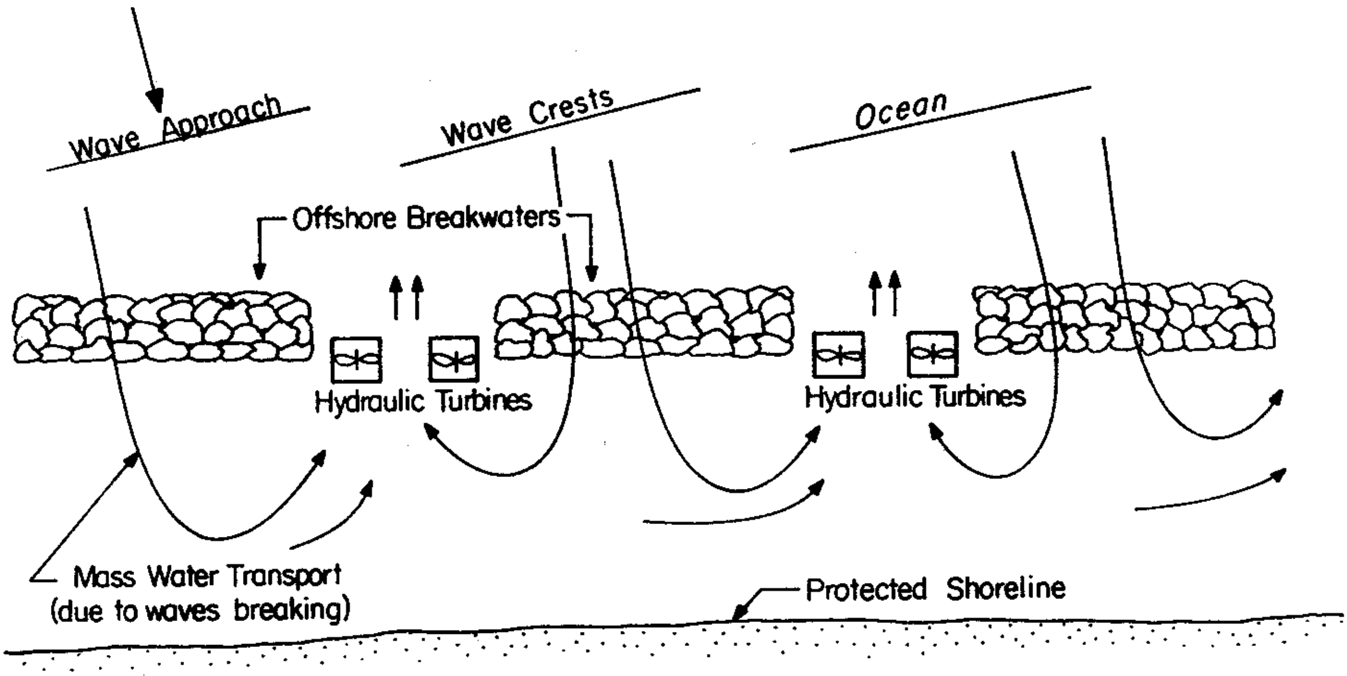



FIGURE 10A. SCHEMATIC 1. COAST PROTECTION — ENERGY EXTRACTION

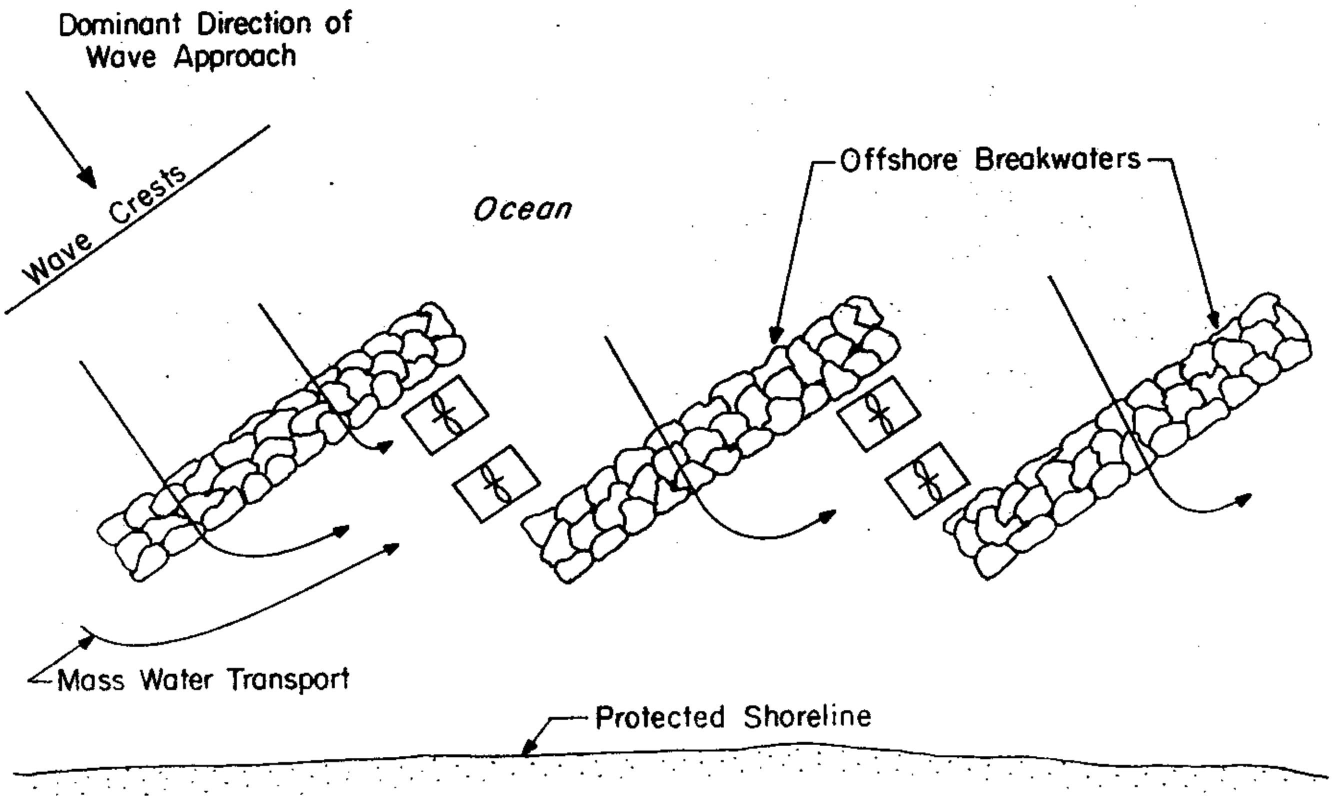



FIGURE 10B. SCHEMATIC 2. COAST PROTECTION — ENERGY EXTRACTION

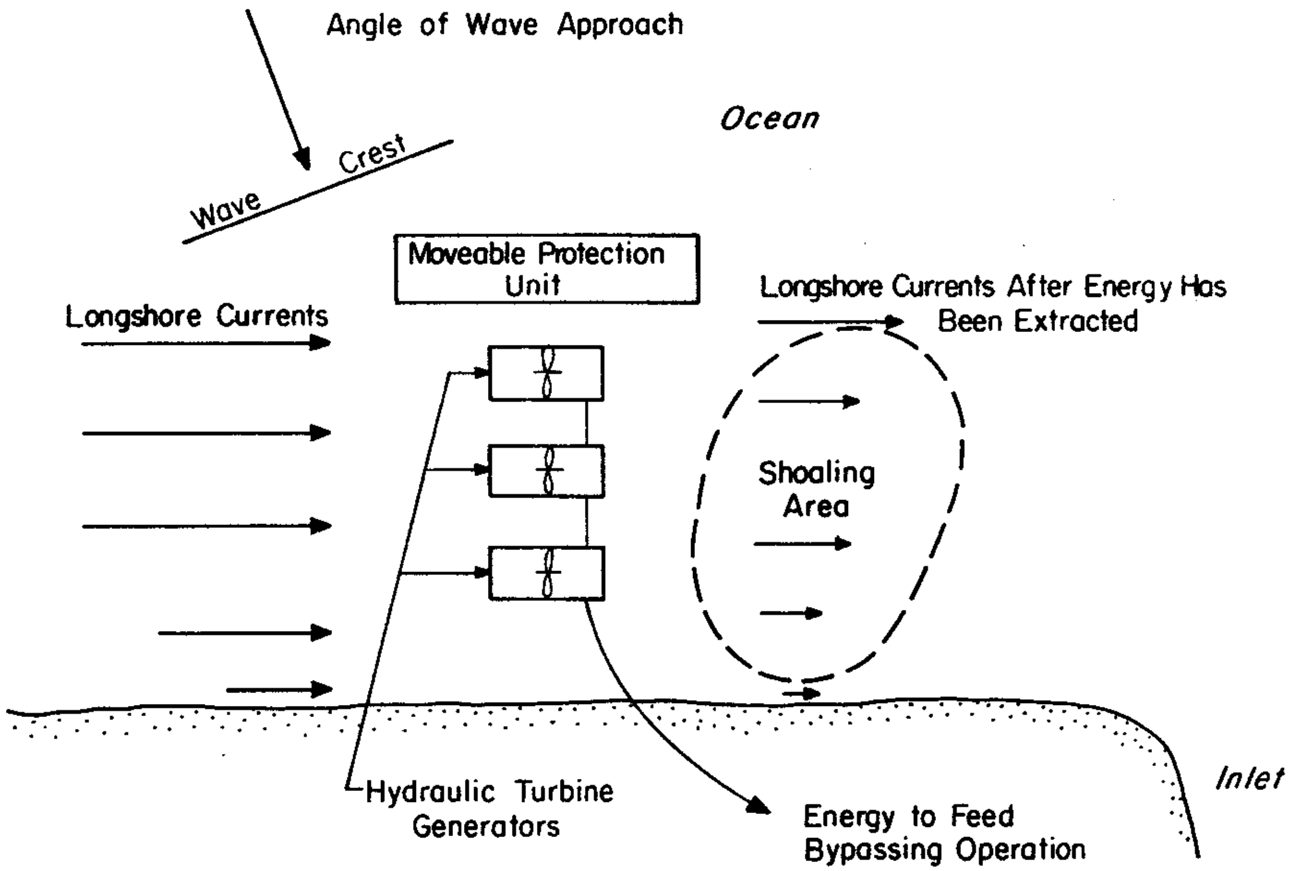



FIGURE 11. SCHEMATIC 2 — LONGSHORE CURRENT ENERGY EXTRACTION

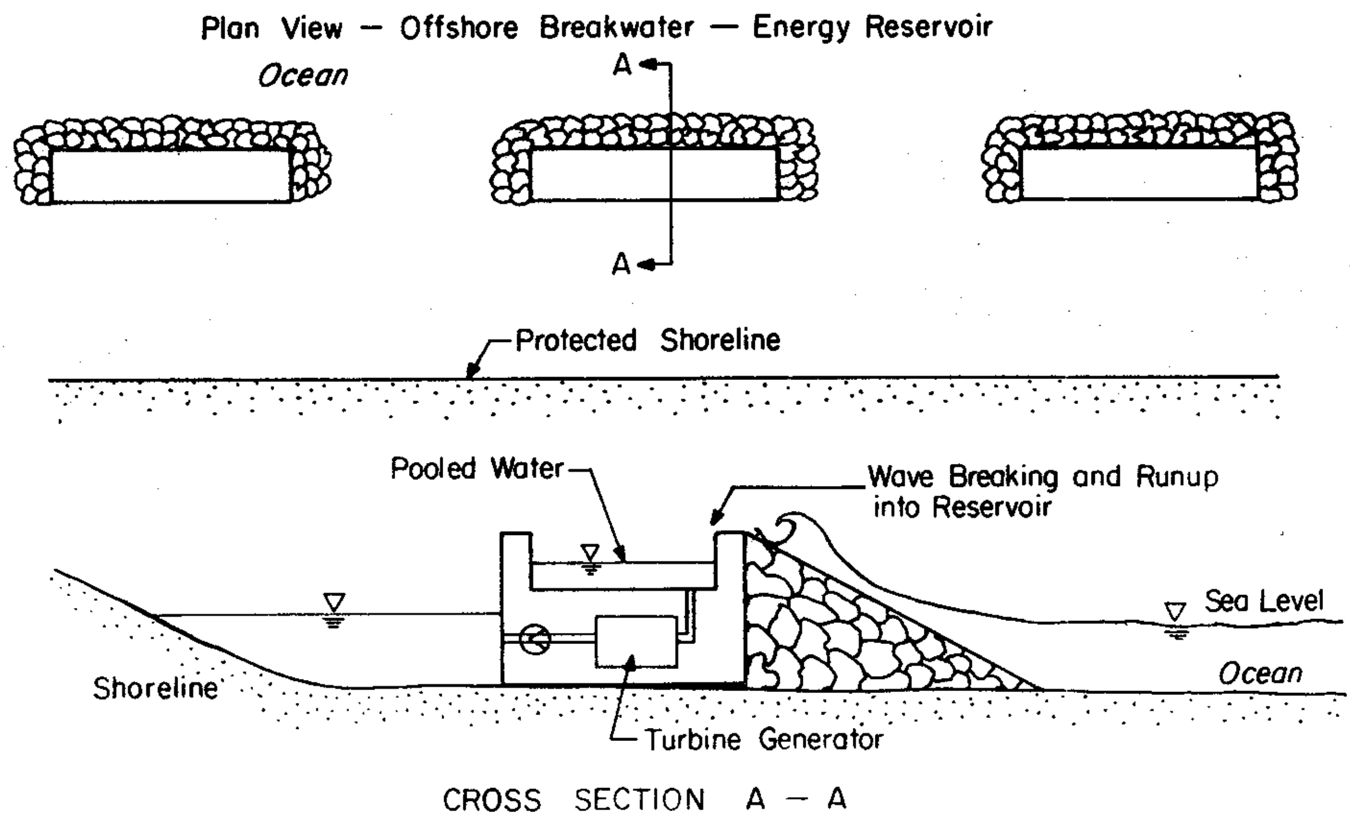



FIGURE 12. SCHEMATIC 3 — COAST PROTECTION — ENERGY CREATION

# ADDENDUM

The following two articles were prepared for the joint Florida Sea Grant/Coastal Plains Center/Florida Shore and Beach Conference held in Gainesville, Florida in May 1978. As no proceedings of the conference were printed it was decided to reproduce these papers here.

# THE COASTAL PLAINS

# MARINE CENTER

Colonel Beverly C. Snow, Jr.
Executive Director
Coastal Plains Center for Marine Development Services
Wilmington, N.C.

## THE COASTAL PLAINS MARINE CENTER

Colonel Beverly C. Snow, Jr.
Executive Director

The Coastal Plains Marine Center was created in 1969 by the Coastal Plains Regional Commission to promote the accelerated economic development of the Coastal Plains Region in ways that will not degrade the quality of its environment by providing free continuing technical assistance to the public agencies, academic institutions, and private enterprises engaged in managing, exploring, and developing the coastal and marine resources of North Carolina, South Carolina, and Georgia.

In 1975 the Commission boundaries, and areas served by the Center, were expanded to include eastern Virginia and northern and western Florida. The Center accomplishes its overall purpose by transferring information and by coordinating the sharing of expertise across State lines. It strives to achieve the following functional objectives:

1. To stimulate, coordinate, and financially support information exchange projects.

2. To extend the technical staff capabilities of the Commission and its member States.

3. To bring marine agencies and organizations together to facilitate communication and cooperation, and to get them working together on a Regional basis.

4. To respond to requests for technical assistance, information, or publications.

5. To identify needs for coastal and marine resource information and conduct an active information dissemination program to meet those needs.

6. To strengthen and coordinate coastal and marine research and development through information exchange.

The Center achieves these goals and objectives through various program activities, including its Cooperative Projects Program, supplementary staff work, its annual Conference on Marine Resources, responding to requests, performing advisory and consulting services, and compiling and distributing various publications.

In 1973 the Center initiated a Cooperative Projects Program which has been highly successful. Projects in this program are joint efforts by the Center and State coastal and marine-related agencies, and benefit not only the States, but more importantly have potential Regional economic impact. The Center contributes coordination, advisory and consulting services, and financial support. The States do the detailed planning, make the necessary arrangements, and furnish the required personnel, equipment, and materials. In other words, stimulated and assisted by the Center, the States work together, sharing their available talent with each other. These projects include small meetings, workshops, and demonstrations related to problems, new techniques, or other interests common to the States. Examples of such projects include the Shark Conference, which was held near Orlando in November of 1975; the Seminar on Beaches vs. Hurricanes, which was held here in Gainesville in March of 1976; and of course this meeting. The projects to be undertaken are determined by a group composed of Center and State representatives, considering Regional needs and availability of funds.

In another program activity, the Center professional staff has extended in various ways the technical staff capabilities of the Commission and of its member States, which do not always have all of the expertise they need. They turn to the Center for assistance in these instances. For example, the Commission's Environmental Affairs Advisory Committee asked the Center to undertake a project involving assistance in submitting State applications to the NOAA Office of Coastal Zone Management for estuarine sanctuary grants under the Federal Coastal Zone Management Act of 1972. The procedures for submitting these applications require a list of protected sites, either within the estuarine sanctuary program or within other Federal, State, or private programs which are located in the same regional or biogeographical classification, the Carolinian classification, extending from Cape Hatteras to Cape Kennedy, being applicable in this case. To meet this need, the Center compiled a map indicating protected sites in this area and including information on these sites. This is an example of a case in which each of the States would have had to do this work individually for themselves, resulting in unnecessary duplication of effort and expense.

In addition to the smaller meetings in the Cooperative Projects category, the Center annually sponsors, plans, and conducts a much larger Conference on Marine Resources. The detailed planning and conduct of this Conference, as well as the compilation, publication, and distribution of the report, is handled entirely by the Center. The purpose of the Conference is to serve as a means through which Federal, State, and local government administrators, scientific researchers, and representatives from private industry, as well as private citizens, can address some of the major coastal and marine issues facing the Coastal Plains Region. Information is exchanged among leaders in marine fields both inside and outside the Region, and efforts are coordinated toward the solution of common problems. To give an idea of the broad scope of problems addressed at these Conferences, the subjects involved at the last Conference, which was held in Jacksonville last December, were: Raising the Level of Coastal Awareness; Coastal Hazards and Natural Disasters; Groundwater Problems in the Coastal Zone; Coastal Resources Data Systems; and Extension of Fisheries Jurisdiction to 200 Miles.

The Center responds to requests for assistance, information, or publications. This activity is one of the most important, as it directly affects filling the stated needs of the five States for coastal and marine resources information. While requests are received and honored from all sources, those from individuals and organizations involved in managing and using the coastal and marine resources of the Region, and particularly from State agencies and industries which influence economic betterment in coastal and marine areas, are most pertinent to the Center's overall purpose.

Another Center activity which affects filling the needs of the five States for coastal and marine resources information involves advisory and consulting services wherein the recipients of these services are unaware of the avilability of information they need. In this case these needs are identified by the Center, which conducts an active information dissemination program to keep users of Center services abreast of recent coastal and marine developments both within the Region and outside it. Information collected by the Center is reviewed and analyzed to determine those individuals and organizations within the Region who would benefit the most from it. This information is extracted, summarized, and distributed accordingly without any prior initiative by or obligation on the part of these recipients.

A final Center activitiy which should be mentioned is the Center's publications program. The Marine Newsletter is an 8-page bimonthly publication, whose circulation has recently increased above 7,000 and which continues to be well-received. It reports recent developments of value to the complete spectrum of coastal and marine interests in the five States. The Conference on Marine Resources was discussed earlier. While the Conference in itself serves as a means of information exchange, further benefits are produced by the Center in the compilation, publication, and distribution of the Report. These further benefits are derived through capturing the information and results in written form for dissemination to a much broader audience. Still another Center publication is the annual Summary of Marine Activities of the Coastal Plains Region, which includes information about coastal and marine organizations in the five States and their current interests and projects in order to enable contacts to be made. This publication informs researchers of what is being done in their particular fields of interest and where it is being done, so as to facilitate communication across State lines, prevent duplication of effort, and coordinate coastal and marine research and development programs.

In summary, the Center provides free continuing technical assistance to those who manage, explore, and develop the coastal and marine resources of Florida, Georgia, South Carolina, North Carolina, and Virginia; and transfers information and coordinates the sharing of expertise across State lines. This is a job which is not being done by anyone else. The Center stimulates, coordinates, and financially supports information exchange projects such as those included in its Cooperative Projects Program. It extends the technical staff capabilities of the Commission and its member States. Through such means as its annual Conference on Marine Resources it brings coastal and marine agencies and organizations together to facilitate communication and cooperation, and to get them working together on a Regional basis. In order to fill the stated needs for coastal and marine resource information, the Center responds to requests for technical assistance, information, and publications. In order to fill the unstated needs for such information, the Center identifies these needs and conducts an active dissemination program to meet them, involving advisory and consulting services. Sometimes this information is specialized and of interest to only a limited number of individuals or organizations. Sometimes this information is of interest to a broad spectrum of coastal and marine interests and is disseminated through Center publications such as the Newsletter, conference reports, and summaries of coastal and marine activities.

Further information regarding the Center and its services can be obtained by writing to the Coastal Plains Marine Center, 1518 Harbour Drive, Wilmington, N. C. 28401, or telephone 919/791-6432.

# BEACH NOURISHMENT

# IN VIRGINIA

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# BEACH NOURISHMENT IN VIRGINIA

by

Curtis W. Baskette, Jr.
(presented at 1977 seminar)

Virginia Beach is a resort city which is heavily dependent upon its coastal beaches as the economic base of the community. Correspondingly, it is quite sensitive to the problems of shoreline erosion. Over the last twenty years the Norfolk District of the Corps of the Engineers has been involved in a number of programs directed toward controlling the erosion process at Virginia Beach and to provide protection to the significant developments along its shores. After many years of artificial nourishment, several conclusions can be made relative to the effectiveness of this erosion control technique.

## Beach Nourishment Programs

In 1954 a beach restoration program was undertaken at Virginia Beach whereby over 1.4 million cubic yards of sand were placed along 3.3 miles of shoreline for both recreational and structural protection purposes. A beach berm generally 100 feet wide at elevation +7.0 feet above mean sea level was constructed. The nourishment material was derived from a small estuarine area south of the city by hydraulic dredging techniques. Following the restoration program, local and state agencies continued to nourish the beach by pumping dredge material to several locations at the south end of the beach, allowing the natural littoral forces to carry and distribute the sand to the north.

In 1962, the original Corps project was modified to provide for Federal participation in the cost of continuously nourishing the project beaches for a 25-year period. Local and state interests would again be responsible for developing and accomplishing the actual nourishment activities. Beach and hydrographic surveys were also taken on a regular basis so as to determine the response of the beach to the nourishment program. Initial cost sharing was 1/3 Federal and 2/3 non-Federal, but was soon changed to a 50-50 basis. Terms of the agreement were based on the cost of placing suitable (material of grain size greater that 0.01 mm), and new source (material which would not have reached the project beaches naturally) material.

The role of the Federal Government is generally from a cost sharing and advisory standpoint, with the actual nourishment activities being accomplished by local interests.

## Methods and Sources of Nourishment

When the initial beach restoration work began in 1952, the nourishment material was obtained from the small tidal estuary inside Rudee Inlet. At that time Rudee Inlet was no more than a small creek emptying into the Atlantic Ocean. It was frequently opened and closed, depending on the magnitude of longshore transport or occurrences of storms. Between 1952 and 1954, over 1.4 million cubic yards of material were removed from the estuary by a large hydraulic dredge which dug its way from the ocean across the narrow shoreline into the interior waters. This materal was pumped and distributed along the northern shoreline to build a uniform beach about 100 feet wide at elevation 5.4 feet above mean sea level.

Following the initial restoration work the project beaches were periodically nourished by the Virginia Beach Erosion Commission, a state agency formed for that specific purpose. Again, the nourishment material was obtained from within the estuaries of Rudee Inlet by a small, commission-owned hydraulic dredge. However, nourishment during this period was accomplished through a different technique, a feeder beach concept. By this method material was continuously pumped to discharge locations at the southern end of the project, allowing the natural northward moving longshore currents to sort and distribute the material. An electric booster station was constructed about 1/2 mile north of the inlet to enable direct nourishment to the northern project beaches, if necessary.

After the northeaster of 1962 devastated the resort city and stripped the beaches down to the underlying organic strata, a restoration effort involving the placement of 315,000 cubic yards of sand was undertaken. Material was obtained from the Lake Rudee area and also pumped or trucked from other areas to the interior of the resort strip (estuaries, dunes, commercial borrow pits, etc.).

From 1962 to present, the Corps of Engineers has been involved in the continual nourishment of the resort beaches. The Erosion Commission has continued to perform the nourishment function, with cost participation by the Corps. Up until 1974, the nourishment program was accomplished employing the feeder-beach concept, with the nourishment material being derived from the Lake Rudee estuary. However, as the dredging activities moved further and further away from the project beaches, pumping efficiency decreased and the quality of the material fell. At this same time there developed an increasing public concern for the preservation of the estuarine environment. It was soon realized that either different sources of suitable sand deposits must be found, or the technique for controlling erosion would have to be changed.

It so happens that the Corps is also responsible for the maintenance dredging of Thimble Shoal Channel, which extends 11 miles from the Atlantic Ocean through the mouth of the Chesapeake Bay to the port of Hampton Roads. Material from this channel is considered unpolluted and safe for ocean disposal. Previously, the spoil material had been taken to an ocean disposal site some 20 miles away and dumped. At the request of the Norfolk District, the Coastal Engineering Research Center accomplished an extensive sand inventory program within the mouth of the Chesapeake Bay and found that a large deposit of sand suitable for beach nourishment purposes was centered around the eastern end of the navigation channel. It was thereupon decided to somehow combine the two Congressionally authorized projects by recovering the suitable portions of the dredge material and transfering it to the project beaches of Virginia Beach.

Sand Storage Program

The principals and methodology developed for the pumpout-sand storage operation were based on experience gained in two previous Corps operations at Sea Girt, N.J. (1966) and Jacksonville, Florida (1973). These two operations employed the use of the Corps hopper dredge GOETHALS and an attendant mooring barge which provides for the hook up between the hopper dredge and the pipeline leading ashore. The GOETHALS has both bottom dump and pumpout capabilities.

In the two previous operations, nourishment of the project beaches was accomplished by direct pumpout from the hopper dredge to the beach. However, at Virginia Beach, direct nourishment was not possible. The GOETHALS has a loaded draft of about 30 feet, and similar depth offshore of Virginia Beach is about 2 miles distance from the shoreline. This is too far to pump in an exposed ocean environment. Immediately inside the mouth of the bay, however, the 30-foot contour comes within 1000 feet of the shoreline. A number of potential disposal sites in this vicinity were identified and evaluated from both a capacity and environmental standpoint. With the permission of the U.S. Army, it was decided to pump the sand from the dredge to a large beach area on the Fort Story Military Reservation at Cape Henry, to be stockpiled for later use at Virginia Beach when needed. The entire storage area was maintained seaward of the existing dune system within an area about 500 feet wide and one-half mile long.

The mooring system used off Cape Henry for docking of the dredge consisted of a floating mooring barge secured to an elevated Delong Pier spud barge. The mooring barge was the same as used during the Sea Grit and Jacksonville operations, providing the connection between the dredge and pipeline leading to shore. The DeLong Pier barge is a self-elevating spud barge, 80 feet wide and 300 feet long. It is the same type used in Vietnam as an "instant pier" or mooring facility. The pier is raised by pneumatic jacks upon ten 6-foot diameter spuds.

The mooring facilities were positioned at the 30-foot depth contour, about 1000 feet offshore. A 30-inch submerged pipeline ran from the mooring facilities to shore, then along the beach to the stockpile site, a distance of about 2700 feet.

The discharge from the dredge was confined along the beach, parallel to the shoreline by a series of retaining levees about 1000 feet long so that the coarser grained material would settle out before the effluent returned to the ocean. The levees were reinforced and lengthened as the sand pile grew in elevation.

Within a period of two months, over 452,000 cubic yards of sand were accumulated on the beach. Weather conditions had very little effect on the operation since the dredge could dump the spoil at sea whenever docking was hazardous.

Over the three year period since completion of the sand storage operation, about 270,000 cubic yards of the Fort Story sand have been hauled to the project beaches. The sand is hauled over the public highway system in large trucks, dumped over the concrete promenade at points about 1000 feet apart, and then evenly spread along the beach to provide a berm 60-foot wide at elevation +8.0 feet above mean sea level.

Evaluation of Project Effectiveness

The effectiveness of the beach nourishment program at Virginia Beach can be evaluated through a review of three different parameters: retention of nourishment material within the project area; change in the character of the beach material; and cost of the nourishment program.

Repetitive beach surveys have been accomplished on a periodic basis since the beach restoration work first began in 1954. A system of 18 profiles were established over the project length each extending from the bulkhead a distance 2000 feet offshore, or about the 25-foot depth.

These profiles are surveyed annually and a volumetric comparison made between both the former survey and the design beach berm dimensions. By considering the area encompassed by the surveys as an individual coastal compartment, one can assume that the amount of material entering or introduced to the system, minus the material leaving the system will equal the net volumetric change in the system. For simple evaluating purposes it can be assumed that the sand supplied is equal to the sand bypassed across Rudee Inlet plus the nourishment material added from outside sources. Also, the net change is determined from a comparison of the annual surveys. Therefore, the amount of sand leaving the compartment can be determined by subtracting one from the other. A review of the data collected since 1954 indicates that, on the average, 235,000 cubic yards of sand were supplied to the project beaches either as inlet bypass or nourishment material. By the same token, surveys have shown that there has been a net annual loss of 50,000 cubic yards from the system. Therefore, about 285,000 cubic yards of sand leave the project area each year, either, as a result of longshore or offshore transport.

The obvious conclusion is that in order to stabilize the shoreline as is, at least 285,000 cubic yards of sand would have to be introduced to the system from either inlet bypass or nourishment sources; and a greater amount would be required to extend the project shoreline seaward.

Sediment samples of the native beach sand have also been taken throughout the project. Briefly, these samples seemed to indicate that during periods when significant amounts of fine grained nourishment material were introduced from the estuarine areas of Rudee Inlet, the character of the beach sand would tend to the finer side. Correspondingly, during periods of limited or no nourishment, the average grain size would increase toward its initial state. This phenomenon, however, was not true when the coarser material from Fort Story was added to the beach. Instead of the average grain size increasing, it tended to decrease slightly. Explanation of this occurrance is that when the latter beach samples were taken, the beach was usually high and wide. This could mean that the coarse borrow sand had been covered by a layer of fine sand from the offshore zone.

The final aspect to be considered is the cost of the two different nourishment techniques, the hydraulic dredging-feeder beach concept, and the nourishment of material obtained from the offshore and placed by truck. During the period 1972-74, 280,000 cubic yards of sand were dredged from Lake Rudee and pumped to various locations at the southern half of the project area. The actual dredge cost was about $1,092,500, reflecting a unit cost of $3.90. On the other hand, in the fall of 1974, 452,000 cubic yards of sand were dredged from Thimble Shoal Channel and stockpiled at Fort Story at a cost of $408,000, over and above the normal cost of maintenance dredging and disposal. This resulted in a unit cost of $0.90 for storage. In 1975 and 1976 the unit cost of the truck haul operations were $1.65 and $1.48, respectively. This results in a total nourishment rate of $2.55 and $2.38 for those years.