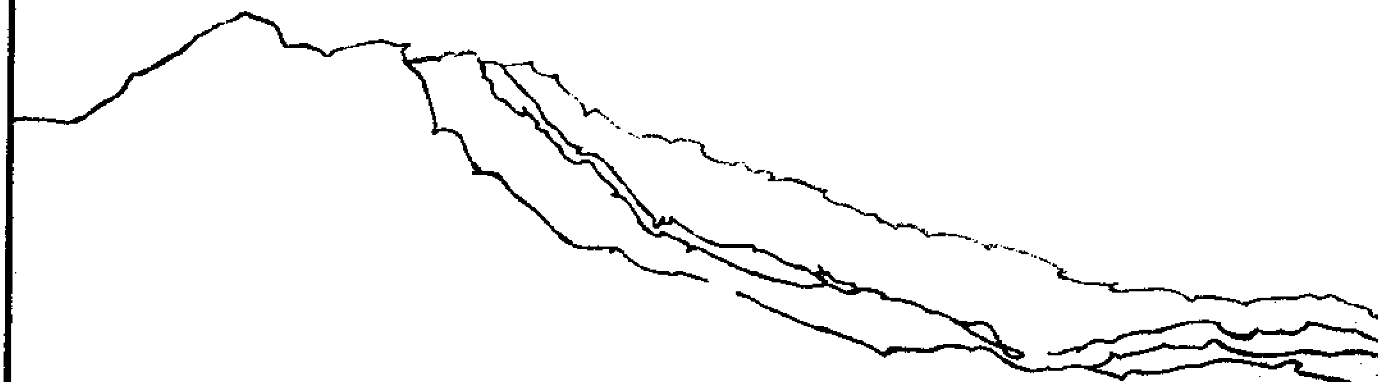
A Study of Shore Erosion Management Options in South Carolina



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A STUDY OF SHORE EROSION MANAGEMENT ISSUES AND OPTIONS IN SOUTH CAROLINA

James B. London
John S. Fisher
Gary A. Zarillo
John E. Montgomery
Billy L. Edge

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RESEARCH STAFF

John M. Armstrong, Director, South Carolina Sea Grant Consortium

John W. Brown, Resource Economist, National Marine Fisheries Service and the South Carolina Sea Grant Consortium

James S. Dykes, Graduate Research Assistant, The Center for Metropolitan Affairs and Public Policy, The College of Charleston

M. Richard DeVoe, Assistant to the Director, South Carolina Sea Grant Consortium

Billy L. Edge,* Professor, Department of Civil Engineering, Clemson University

John S. Fisher,* Associate Professor, Department of Civil Engineering, Clemson University

Miles O. Hayes, Professor, Department of Geology, and Director, Coastal Research Division, University of South Carolina

Rick Hepfer, Student Assistant, School of Law, University of South Carolina

James C. Hite, Professor, Department of Agricultural Economics and Rural Sociology, Clemson University

Diane C. Hudgins, Graduate Research Assistant, The Center for Metropolitan Affairs and Public Policy, The College of Charleston

Wyatt Hunter, Graduate Research Assistant, Department of Civil Engineering, Clemson University

Karen L. Jewell, Graduate Research Assistant, The Center for Metropolitan Affairs and Public Policy, The College of Charleston

James B. London,** Assistant Professor, The Center for Metropolitan Affairs and Public Policy, The College of Charleston

Joseph S. Lyles, Research Assistant, The Center for Metropolitan Affairs and Public Policy, The College of Charleston

James P. May, Assistant Professor, Department of Chemistry, The Citadel

John E. Montgomery,* Associate Dean, School of Law, University of South Carolina

Frank W. Stapor, Formerly Assistant Marine Scientist, South Carolina Marine Resources Research Institute

Roger R. Stough, Director, The Center for Metropolitan Affairs and Public Policy, The College of Charleston

Gary A. Zarillo,* Research Scientist, Department of Geology, University of South Carolina

* Major Author
** Major Author and Compiler

FOREWORD

The study described in this report is the first truly comprehensive examination of the problems of shore erosion in South Carolina. While there have been many excellent efforts carried out on various individual problems, this project has brought together the many geological, engineering, economic,and legal issues into one analysis.

The basic purpose of the report is to provide a basis for discussion of issues and options related to shore erosion. Several recommendations are made regarding state and local policy, research, and technical assistance.

The project was accomplished by a team of specialists from each of the Consortium's seven member institutions. The project was structured, assembled, and coordinated by the Consortium as one of several projects underway which are examining coastal and marine issues in the state.

John M. Armstrong
Director
South Carolina Sea Grant Consortium

EXECUTIVE SUMMARY

The damage associated with shoreline erosion has increased significantly in recent years. Although these erosional trends have been long-term, related property loss has accelerated largely due to increased activity along the coast. In response to this problem, federal, state, and local entities are reevaluating existing policy and formulating new approaches to more effectively manage coastal resources. It is for this reason that the present study was undertaken with attention given to shoreline management options applicable to conditions in the State of South Carolina.

In order to effectively manage coastal resources, it is appropriate first to examine the processes influencing beach systems. Studies of the South Carolina coast indicate that the shoreline is transitional between the wave-dominated North Carolina coast and the tidal-dominated Georgia coast. The arcuate strand along the northern coast is characterized by infrequent inlet formations. Although relatively stable from a long-term perspective, beaches of the arcuate strand are subject to short-term erosional trends as a result of storm and wave influence.

The central portion of the South Carolina coast is dominated by the Santee River Delta. This section of the coast is characterized by rapidly retreating shorelines due to the loss of sediment supply since the damming of the Santee River in 1942 and the rediversion of part of its flow into the Cooper River. From Bull Bay to the Georgia border, the coast is comprised of barrier islands separated by frequent tidal inlets and larger estuarine systems. The majority of these islands are comparatively stable beach ridge barriers, but several of the islands may be classified as erosional or transgressive.

Long-shore transport is predominantly to the south along the South Carolina coast, yet local direction reversals may occur on the downdrift side of inlets. Inlet formation is an integral determinant of sediment deposit; short-term shifts in inlet location due primarily to storm-effects may contribute to localized erosion at adjacent beaches. On balance, the historical trend of sea level rise continues to influence long-term erosion rates; yet, tidal, wave, and littoral influences may combine to reverse this trend in some locations.

Recently, a better public understanding of coastal dynamics and the observation of large-scale property loss have kindled a design with nature approach to coastal development. As a long-term approach to alleviate the potential for property loss and for interference with the natural system, the concept has considerable merit. Yet, where development has occurred previously and extensive property loss is imminent, short-term solutions to save property and/or beach areas bear consideration. In addition, future plans will continue to be subject to error given the uncertainty related to the coastal system.

From an engineering perspective, the most often considered alternatives for large-scale erosion control include:

- seawalls,
- bulkheads,
- revetments,
- groins,
- jetties and inlet control, and
- beach nourishment.

Seawalls, bulkheads, and revetments are structural solutions intended to prevent further erosion and/or maintain property. Seawalls are the most substantial of the three types of structures being designed to withstand wave attack. Bulkheads, generally consisting of wood pilings, and revetments, generally of stone rubble, are designed to maintain property lines. Although effective in some circumstances, each of these types of structure may accelerate erosion on the front beach and adjacent properties.

Groins and jetties are often employed to capture littoral sediment flow, causing accretion on the updrift side of the structure. The result is typically a loss of sediment to the downdrift side where erosion is accelerated. Inlet control also is designed to influence sediment transport by altering the volume and speed of discharge.

Beach nourishment is increasingly being employed as a non-structural solution to shoreline erosion. By transporting sand from an offshore borrow site, the technique is an imitation of nature. Often nourishment is combined with structural solutions such as groins or offshore breakwaters. Although effective, nourishment is generally expensive and requires periodic replenishment.

In addition to engineering solutions, management techniques are being used increasingly to direct development away from potential hazard areas. Although it is said that coastal sediment budgets are in continous equilibrium, development patterns are often out of equilibrium. Much of this situation relates to the rapid development that has occurred in recent years. Postwar development has been stimulated by a number of private incentives, including: 1) growth in personal income, 2) a shift in the geographic distribution of the population, 3) improved accessibility, and 4) learned behavior patterns among users. In addition, favorable climatic conditions and a series of government programs have contributed to accelerated building patterns.

The development of coastal areas has led to collective as well as individual benefit. Accessibility has been increased,and tourism, located predominantly along the coast, represents South Carolina's second most important industry. As a result, the value of the beach in terms of use and option accounts for significant benefit to both residents and non-residents. At the same time, the costs associated with coastal building patterns have increased. Perhaps the primary cost peculiar to coastal development stems from external effects. Because of the fragile, interrelated nature of the coastal system, external costs may become significant as the system's carrying capacity becomes strained. The remaining cost differentials for coastal development are largely informational or due to risk associated with coastal hazards, including beach erosion. While social costs have not been fully considered, public subsidization, in effect, has lowered the building cost in beach areas. At the same time, a lack of adequate information and the collective sharing of risk also have contributed lower perceived costs and often as a result to overutilization of the resource.

It is argued that resource use is optimal when public subsidization is equal to the anticipated social benefit accruing from the program. External effects should be minimized by forcing the responsible party to bear full costs where appropriate. In many cases, however, the interrelated and fragile nature of the coastal ecosystem require collective control to minimize community-wide damage. It is the responsibility of the state as well as local communities to develop an appropriate framework allowing for collective resource use and to provide information permitting rational decisions to be made. It is not the responsibility of the public sector, however, to assume the private risk of development. Within this framework, private property owners and communities should be allowed to pursue individual and community interests to the maximum extent possible consistent with state policy.

Current state programs with regard to erosion control stem largely from the Coastal Zone Management Act (1972) and Amendments (1976). Considered within the report are existing and proposed institutional frameworks at the federal, state, and local levels. Particular attention is given to the appropriate role of each jurisdiction and to funding responsibility in this regard.

From a legal perspective, the constitutionality of the setback concept has been upheld in South Carolina although coastal setback lines have not been addressed specifically. It is found, further, that a regulatory program promulgated either by the State Coastal Council or on a county-by-county level could successfully address the issue of land-use controls with minimal legal difficulties. In terms of beach accretion, a difference of opinion exists, but the existing decisions conform to the position that accreted land belongs to the littoral beach owner. With respect to engineering solutions to control coastal erosion, it appears that counties under existing law can finance erosion control projects assuming the determination of benefit can be established in a reasonable fashion.

With this background, case studies were conducted at four sites along the South Carolina coast to determine the feasibility of alternate erosion control projects at these sites.

The site studies include:

. Hunting Island,
. Hilton Head,
. Pawleys Island, and
. Myrtle Beach.

Each case considers beach morphology, engineering alternatives, and project evaluation for the site in question. It is found, based upon the existing data, that beach nourishment appears to be more feasible at Myrtle Beach and Hunting Island than at the other sites, while smaller scale projects considered at Pawleys Island also may be feasible. At each of the sites, and particularly at Myrtle Beach and Hilton Head where the most rapid development is occuring, management approaches to encourage and/or require development to factor erosional prospects in building patterns are seen as important in reducing both long-term property and recreational loss. Where engineering options are considered as short-term remedies, more detailed information on project costs and site specific erosion effects should be incorporated before extensive public monies are committed. Nonetheless, the findings serve as a point of departure and as methodological framework for similar studies at these or other sites.

In conclusion, the study strongly recommends that the state clearly define long-run policy and develop appropriate guidelines with respect to coastal erosion. From a long-term perspective, it is concluded that the primary functions of the state should be:

1) to provide information to individuals and the localities allowing more informed decisions to be made with respect to coastal development,

2) to provide guidelines to reduce the potential for and consequences of private actions having detrimental effects on adjacent beach properties, and

3) to provide for protection and maintenance of the public beach.

In order to provide for information exchange, a data collection program must be maintained monitoring coastal processes and their expected effect upon beach formations. The information accumulated should be disseminated through technical assistance programs for local authorities and public forums directed at present and potential beach dwellers as well as concerned citizens.

Because of the volatile nature of the beach system, the building patterns of indidviduals may have community-wide impacts detrimentally affecting both adjacent property owners and the public beach. To reduce the potential for such occurances, it is strongly recommended that the state as well as local entities enact coastal setback lines applicable to new oceanfront development. Although standard distances from mean high water and the primary dune may serve as bases, it is suggested that scientific data be incorporated to the extent practicable and that these setbacks be reviewed periodically to incorporate new data at specific dates in the future. In addition, a statewide building code should be instituted for coastal development, the primary rationale for such a code being that high occupancy rates by nonowners and the resale of structures greatly alter the issue of risk bearing by private property owners.

In the short-term, and particularly for development occuring under previous institutional arrangements, structural solutions may be required to prevent extensive property loss. Erosion control projects should meet guidelines previously documented (SCCMP IV-4c) and under review. Additionally, a justification indicating that the solution is in the public interest, the most feasible alternative, and identifying any detrimental effects to adjacent properties and the public beach should be included. Attention should be given, in some cases, to property acquisition and relocation where the solution is deemed more appropriate.

Because localities are more accessible and representative of community interests, the development of local erosion control plans should be encouraged. Technical assistance for developing such plans should be provided through the state's coastal zone management program. Principle components of these plans should include:

- an identification of legal authorities and management responsibilities,
- a local setback provision consistent and meeting as a minimum standards established by the state, and
- a provision addressing funding for the local share of erosion control structures should they be necessary.

Local setback and permitting authority is suggested to provide for additional local control as well as responsibility for development practices.

Future state funding for erosion control projects should be contingent upon the development of responsible local initiative to address erosion control problems within its jurisdiction. In terms of state funds of erosion control projects, highest priority should be given to public beaches followed by private beach areas allowing public access. All such programs should be justified as being in the public interest.

ACKNOWLEDGEMENTS

As is the rule in such studies, the final product owes much to the contribution of a number of individuals. With some reservation for fear of oversight, the authors wish to acknowledge the following individuals and institutions.

Primary acknowledgement must be extended to other members of the research staff whose combined expertise made the task far more manageable. Previous coastal process studies conducted by Dr. Miles Hayes and others at the Coastal Research Division at the University of South Carolina provided a firm basis on which to develop the present study. Field work and early working papers by research assistants Karen Jewell and Joseph Lyles provided much of the later documentation. Additionally, support within each of the member institutions as well as the individual departments and centers bears mention.

A number of federal, state, and local agencies proved helpful during the course of the study. Discussions with the staff of the South Carolina Coastal Council proved particularly useful throughout the project; while the staff of the South Carolina Sea Grant Consortium, and especially Mr. Rick DeVoe, provided assistance and arrangements for the final draft, which had long exceeded its original completion date. The directors of these respective agencies, Drs. Wayne Beam and John Armstrong, deserve special acknowledgement for their foresight and fortitude in addressing one of the critical resource problems in South Carolina as well as other coastal states.

Other organizations providing assistance included: the South Carolina Department of Parks, Recreation, and Tourism, the U.S. Army Corps of Engineers, the City of Myrtle Beach, the Waccamaw Regional Planning Commission, the Beaufort County Planning Department, and the Tax Assessor's Offices of Beaufort, Georgetown and Horry Counties. While in terms of individual contribution, commendation must be given to Wilhelmina Keith for her accurate typing and patience during several revisions of the report.

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INTRODUCTION

Coastal erosion is not a new phenomenon, having occurred historically due to changes in coastal processes. These processes have both created the present barrier island chain along the Atlantic and Gulf coasts as well as significantly changed their formation over time. Although short-term changes are often erratic, the dominant trend in recent geologic times has been one of gradual long-term erosion.

Despite the long-term nature of this erosional trend, related property loss has increased significantly in recent years due primarily to the rapid development of beach areas that has occurred since the end of World War II. This convergence of forces has led to a classic conflict of man against nature, i.e., man's desire for stable land-use patterns versus the dynamic nature of the coastal system.

In response to this conflict, the public as well as state and federal officials have expressed concern from which considerable attention has been given to methods of more effectively managing coastal resources. The issue of coastal erosion is addressed in the Coastal Zone Management Act of 1972 and more specifically in the 1976 Amendment to that act which states that:

> The management program for each coastal state include ...a planning process for A) assessing the effect of shoreline erosion (however caused), and B) studying and evaluating ways to control, or lessen the impact of, such erosion, and to restore areas adversely affected by such erosion.
>
> (Federal Register 923.25).

The program must include a method for assessing the effects of shoreline erosion and of techniques for controlling this erosion. It must also identify and describe "enforceable policies, legal authorities, and funding techniques" to be used in erosion management. (Section 305 (c)(2).

It is for these reasons that the present study was undertaken with emphasis given to the particular problems affecting the South Carolina coast. In the report that follows, issues affecting coastal erosion both from a physical and management perspective are addressed. Specific issues examined include:

1) the coastal processes influencing beach formation with particular emphasis given to the South Carolina coast,
2) the state-of-the-art in terms of engineering solutions for shoreline protection and the technical and economic feasibility of applying these measures,
3) the pertinent public policies affecting coastal development and erosion control at the federal, state, and local level,
4) a consideration of appropriate public management responsibility and options including control and funding provisions, and
5) the legal considerations associated with oceanfront properties and influencing alternate management strategies.

Also introduced is a framework for assessing the public benefit of alternate erosion control techniques. The framework is applied, in turn, to four sites along the South Carolina coast reflecting different physical and development characteristics. These sights include:

1) Myrtle Beach,
2) Pawleys Island,
3) Hunting Island, and
4) Hilton Head.

Finally, based upon the findings of this study, policy recommendations are suggested to provide for effective long and short-term management of the state's coastal resources.

CHAPTER II

COASTAL PROCESSES

Before designing erosion abatement strategies, it is appropriate first to consider the factors and processes affecting coastal geomorphology. The following section is based largely on previous and ongoing studies of beach erosion, barrier island morphology, and sediment transport along South Carolina barrier islands and adjacent tidal inlets. The majority of these discussions are based on work conducted by the Coastal Research Division of the Department of Geology at the University of South Carolina.

Geomorphic Zones of the South Carolina Coast

The South Carolina coast is transitional between the wave-dominated North Carolina and the mostly tide-dominated Georgia coast. Within South Carolina borders, the coast can be divided into four morphologic zones. The arcuate strand portion of South Carolina stretches from the border of North Carolina to Winyah Bay (Fig. 1). Here, beaches are mainland connected and salt marsh-tidal creek systems are absent or poorly developed. The shoreline is gently curving, convex seaward, and breached by only one major inlet (Little River Inlet) at the north end. The number of inlets increases to the south toward Winyah Bay with salt marsh-tidal drainage associated with inlet systems encompassing greater acreage. Beaches along the arcuate strand may be backed by a well-developed dune system up to 3 meters in relief, but, at many locations, the dunes have been leveled for real estate development.

The shoreline of the arcuate strand fringes the seaward side of Pleistocene beach deposits known as the Myrtle Beach Formation. The pre-

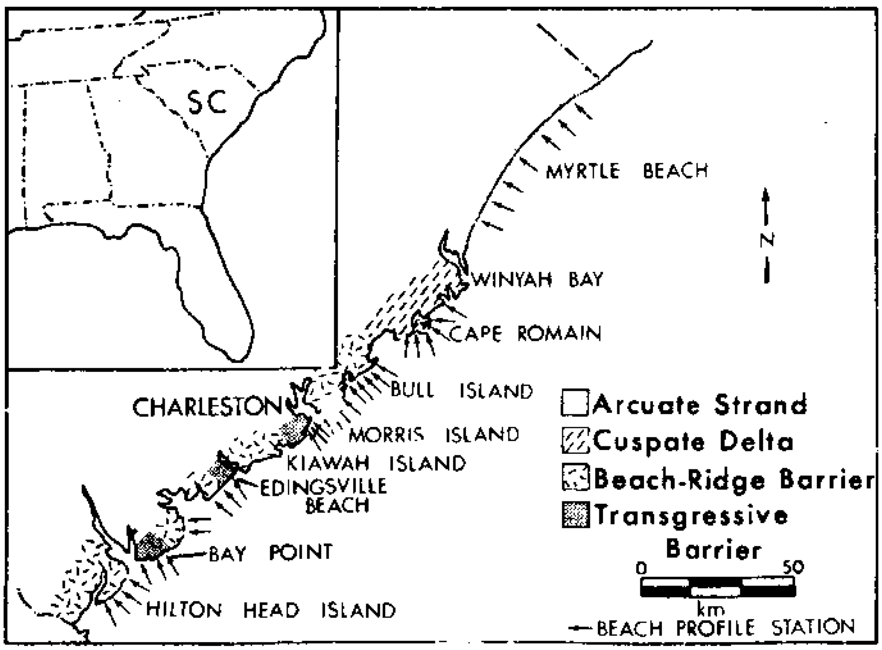

Figure 1. Map of the South Carolina coast showing the four major morphologic zones (after Brown, 1977).

sent day shoreline is parallel and subparallel to Pleistocene beach ridges, the erosion of which may be a local source of sand for modern beaches.

The cuspate delta section of South Carolina extends approximately 30 km from Winyah Bay to Bull Bay. The Santee River Delta complex is the largest on the east coast and consists of three morphologic components. The first, Cape Romain, is termed a cuspate foreland. The Cape is thought to have formed from deltaic deposits reworked by waves. The second component is a beach-barrier system known as Raccoon Key while the third component consists of distributary mouth bar sand and mud flats associated with the mouth of the present Santee River. Prior to damming of the Santee River and diversion of part of its flow into the Cooper River in 1942, the delta complex was in a stable or constructional stage (Aburawi, 1972). Since that time, the cuspate delta area has been in a destructive period due to the loss of sediment from the river bed. Numerous truncated beach ridges, washover terraces and the rapidly retreating shorelines of Cape Romain and Raccoon Key are indicative of this trend.

The South Carolina coast between Bull Bay and the Georgia border (160 km) is comprised of barrier islands separated by tidal inlets and larger estuarine systems such as St. Helena Sound and Port Royal Sound. Barrier islands can be subdivided into two distinct types. Beach ridge barriers are formed from sets of parallel beach ridges that have prograded seaward over time. The majority of barriers along the coast are the beach ridge type, but several of the islands can be classified as erosional or transgressive (Fig. 1). These islands characteristically have low relief and are composed of a thin veneer of sand activity retreating landward over salt-marsh deposits that are extensively developed behind most South Carolina barrier islands. The beaches are backed by extensive washover terraces with limited or no dune development. Examples of transgressive barriers on the South Carolina coast include Morris Island, Edingsville Beach,and Bay Point Island. Beach ridge type barriers may be converted to transgressive barriers by continued long-term erosion. Evidence for this type of evolution is found in historical nautical charts indicating beach ridges on Morris Island and Edingsville Beach in the 18th century.

Coastal Processes

Coastal geomorphology and trends of erosion and transport and deposition of sediments along the South Carolina shoreline are controlled by several factors and dynamic processes. Among the most important factors are tidal regime and wave regime (Hayes, 1979).[1] In early work on coastal morphology, Price (1955) discussed the importance of the type and amount of hydrologic energy expended in the evaluation of any shoreline. The predominent scientific opinion on this matter attributes such occurrences as longshore sediment transport effects of inlets, sediment supply, storms, and short-term sea-level changes to tidal regime more often than wave climate and other processes. Earlier findings along the South Carolina coast reinforce this opinion (Hayes, 1979). Consideration of tidal regime is particularly important to the study area as spring tidal range varies from approximately 1.3 m at the North Carolina - South Carolina border to 2.7 m at the South Carolina - Georgia border (Fig. 2).

Tidal Regime

Davies (1964) suggested a general shoreline classification scheme based on tidal range. Microtidal coasts include areas where tides range

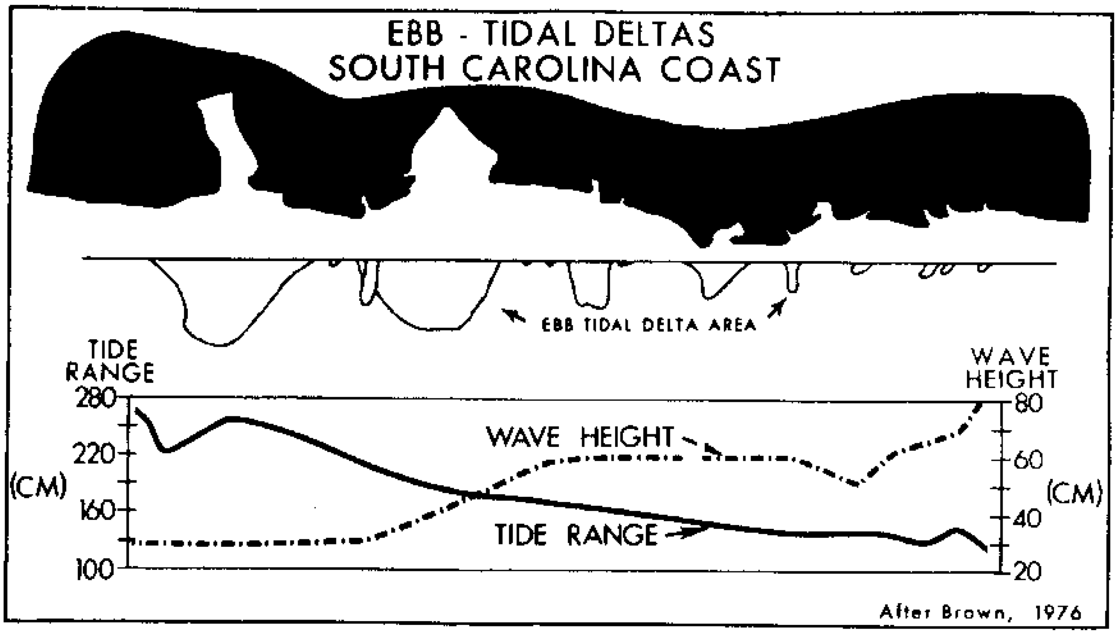

Figure 2. Variation in wave height, tidal range, and areas of ebb-tidal deltas along the South Carolina coast (after Brown, 1976).

from 0 to 2 meters, mesotidal coasts where tidal range is from 2 to 4 meters and macrotidal coasts of tidal range greater than 4 meters. The relative amounts of tidal energy to wave energy vary systematically among the three coastal classes. In areas of moderate to high wave energy and small tidal range (microtidal), the shoreline is dominated by waves (Hayes, 1979). Macrotidal areas are dominated by tide-related processes. Mesotidal areas show the effects of both waves and tides and may be termed mixed energy coasts (Hayes, 1965).

The main reason for emphasis on tidal regime is the fact that the wave climate is variable in many coastal areas; whereas at many locations tidal energy is relatively constant, even considering neap-tide to spring-tide variations. Price (1955) noted, however, that areas of small tidal range may be considered tide-dominated if wave energy is low.

Along coastal plain shorelines of moderate wave energy (such as the South Carolina shoreline), morphology varies systematically with tidal range (Hayes, 1975). On microtidal coasts, barrier island development and river deltas may be the most prominent geomorphic features. Typically, tidal deltas and inlets are poorly developed, and tidal flat and salt marsh deposits are absent or of only local importance (Fig. 3). Tidal deltas are best developed and inlets most frequent on mesotidal coasts. Barrier islands along such coasts tend to be poorly developed or absent in areas included in the upper portion of the mesotidal classification (3-4 m); whereas tidal flats and salt marshes are of increased importance. In macrotidal areas (embayments), tidal flats and salt marshes commonly extend over broad areas. Sand deposits are in the form of offshore linear sand shoals or tidal current ridges.

The South Carolina coast displays characteristics of shorelines transitional between microtidal and mesotidal and of a true mesotidal shoreline.

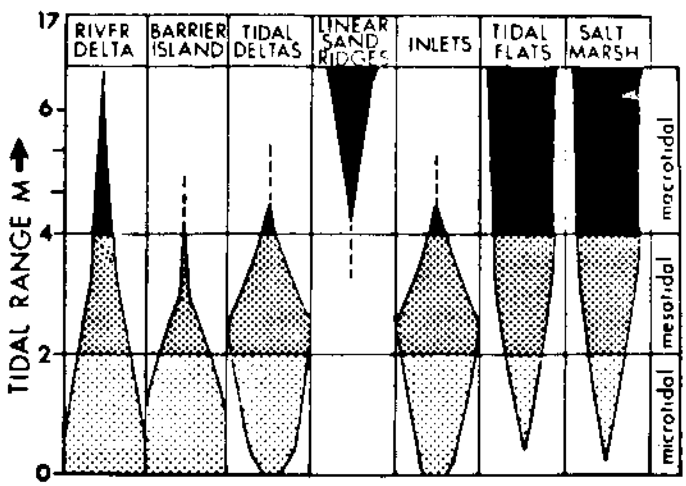

Figure 3. Variation is morphology of coastal plain shorelines with respect to differences in tidal range (after Hayes, 1975).

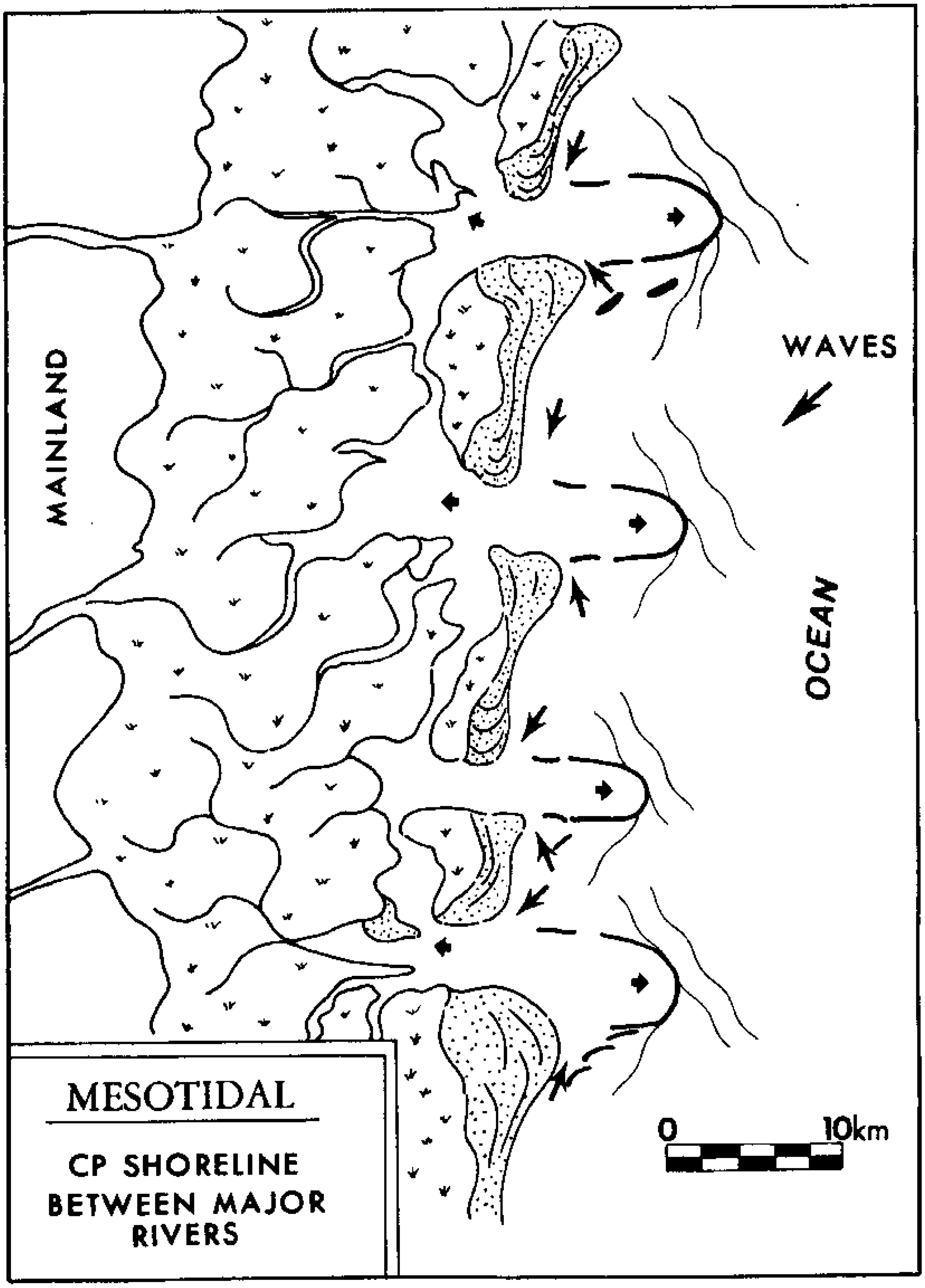

Figure 4. Morphological model of a typical mesotidal barrier island shoreline of medium wave energy.

The arcuate strand falls within the microtidal classification; although it does not have the typical long, linear barriers of microtidal areas, minimal development of tidal inlets, tidal flats and salt marshes are present. The barrier island section of South Carolina, and, in particular, the southern part of the coast is typically mesotidal, displaying the increased effects of tidal processes. South Carolina barriers have a short, stunted appearance and are separated by numerous inlets (Fig. 4). Shoal morphology associated with inlets within mesotidal area and in transitional areas between microtidal and mesotidal is significantly different. Mesotidal inlets (such as Fripp Inlet) are ebb-dominated due to extensive salt marsh development (Nummedal et al., 1977; Zarillo, 1979) and have large ebb-tidal deltas. Microtidal and transitional inlets (such as Little River Inlet and Murrells Inlet) where salt marshes are poorly developed tend to be more flood dominated. Flood tidal deltas and sand bodies therefore tend to be found behind and within the inlet throat. Such morphologic variations affect the efficiency of sand bypassing between barrier islands.

Wave Climate

Wave energy available in the nearshore zone varies systematically and inversely with tidal range along the southeast coast (Fig. 2; Nummedal et al., 1977). Mean annual wave heights decrease from a maximum of 1.2 meters along the wave-dominated North Carolina coast to a minimum of 0.1 meters in central Georgia.

Direction of deep water wave approach along with wind-velocity varies seasonally (Fig. 5). During the summer months wave energy flux is greatest from the southwest and south; whereas during fall and winter, wave energy flux from the northeast and east becomes increasingly important. Because of the orientation of South Carolina's shoreline,

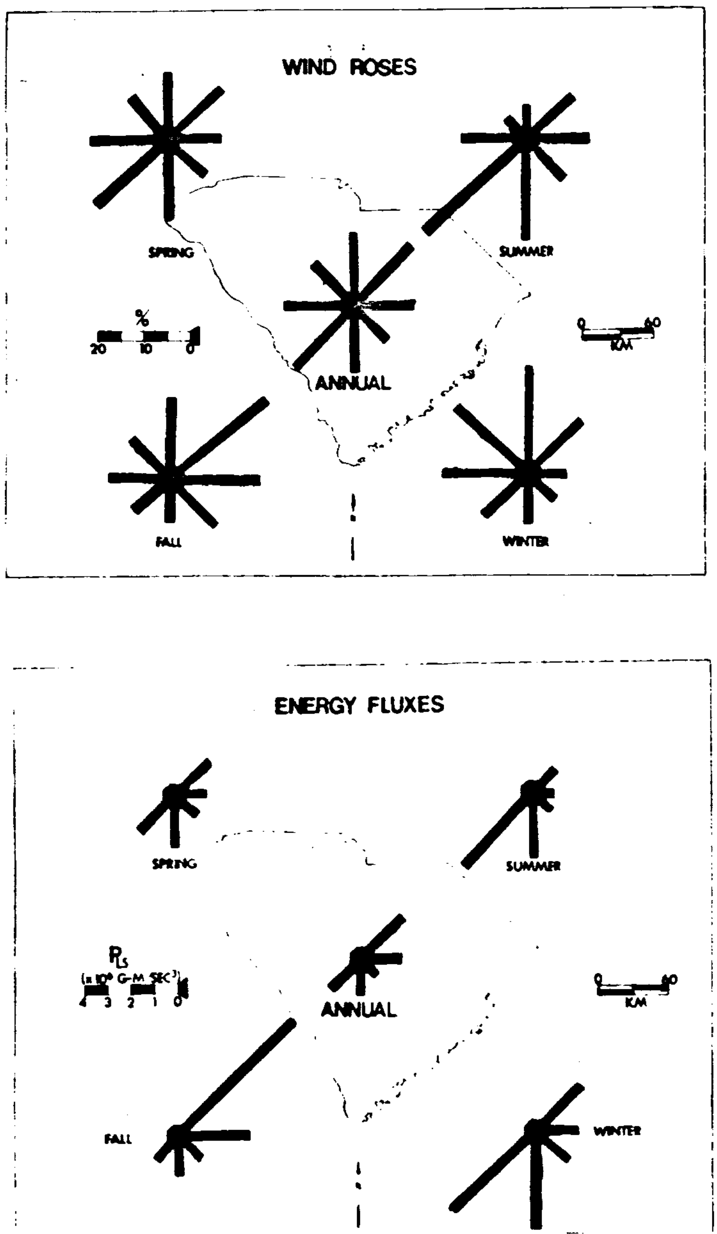

Figure 5. Seasonal variation in wind direction and wave energy flux in the Charleston SSMO data square (after Nummedal et al., 1977).

deep-water waves generated in northeasterly to southerly sectors are most important.

Waves generated by storm winds are important to short-term beach erosion trends. The most frequent storm waves approach from the northeast and east, generated by passing extratropical storms. In a wave refraction study (Fico, 1977), hypothetical storm waves approaching from the east at a 10-second period wave orthogonals (wave energy) tend to diverge along the arcuate strand and converge in certain areas south of North Inlet such as the Price - Capers Dewees Inlet vicinity and Cape Romain.[2] Refraction analysis of hypothetical waves from the south and southeast generated by tropical storms indicates increased concentration of wave energy along the arcuate strand compared with extratropical storm conditions.

Longshore Sediment Transport

An important process that affects the sediment budget of South Carolina's beaches and barrier islands is the longshore transport of sand. In South Carolina, longshore currents that transport sand are generated by waves striking the shoreline at an oblique angle, by prevailing winds, or a combination of both. Longshore currents generated by waves vary in speed and direction depending on wave height, wave period and wave angle. Waves most effective in generating longshore currents are high angle, steep, low period wind waves generated locally. Longshore currents in combination with wave forces that erode and suspend sand from the beach and shoreface may move large volumes of sand along the shoreline.

Rates of sediment transport have been estimated at several locations in South Carolina. Finley (1976) and Nummedal and Humphries (1977) estimated yearly longshore transport rates for Debidue and North Islands from wave energy flux calculations based on seasonal wave process measurements.

The net transport rate of sand along Debidue was directed southward and estimated to vary between 150,000 to 500,000 tons per year depending on the frequency of northerly and northeasterly winds. Kana (1976) estimated yearly longshore sand transport on Capers Island and the south-facing beach of Bull Island from wave energy flux and measurements of suspended sediment load and longshore current velocity. Estimated transport rates ranged from 90,000 to 300,000 metric tons per year, all directed to the south.

Knoth and Nummedal (1977) estimated longshore transport on the east-facing beach of Bull Island from the dispersal of dyed tracer sand in addition to estimates from wave energy flux. Here, net transport is directed north and on the order of 90,000 to 230,000 metric tons of sand per year. Net sand transport on North Island is also directed north, probably due to local wave refraction patterns around the ebb-tidal delta associated with adjacent North Inlet.

Longshore sediment transport studies conducted in South Carolina are localized and subject to significant error. Sediment transport rates estimated thus far are similar among several locations, and, if this pattern holds, transport in other sections of South Carolina will be on the order of 10^5 metric tons per year, directed predominantly to the south. Local direction reversals may occur on the downdrift sides of inlets because of wave refraction around inlet-associated shoals. This effect may be the cause of the downdrift offset of many of the mesotidal barriers in South Carolina (such as Kiawah Island and Fripp Island).

Tidal Inlet Processes

On the South Carolina coast, inlets and associated tidal deposits are an integral part of barrier island systems. As previously described, mesotidal shorelines are breached by numerous inlets that have large ebb-tidal deltas and in some cases well-developed flood tidal deposits. Studies of barrier islands in several areas (Moslow and Heron, 1978; Hayes, 1979) indicate that tidal-inlet shoals volumetrically may contain 30 to 60 percent of the sediments deposited in nearby barrier islands. In order to maintain the sand budget of downdrift beaches some of this sediment must eventually bypass the inlet system. The mechanism of sand bypassing varies with inlet type. At wave dominated, microtidal inlets where ebb-tidal deltas are poorly developed and do not extend far offshore, sand may easily bypass the inlet along the outer shoals or outer bar of the inlet.

Sand bypassing at more tide-dominated transitional and mesotidal inlets is more complex. Ebb-tidal deposits may extend for several kilometers offshore, and updrift and downdrift shoals are separated by a large ebb-dominated tidal channel. Here sand can only be bypassed by a channel reorientation or abandonment process. Generally, sand is collected or trapped on the updrift side of an inlet, forcing the inlet channel to migrate laterally in the downdrift direction until the configuration becomes unstable. A new channel may cut through the updrift shoals and, in effect, transfer the shoals to the downdrift side. The bypassed sediment then may migrate landward under the influence of wave refracting around inlet shoals and be added to the littoral system of the downdrift beach or barrier. This migration is responsible in part for the downdrift offset of barrier islands and is the most common method of sand bypassing found along the barrier island section of South Carolina. As a consequence, portions of barrier islands adjacent to inlets are typically unstable, and large and rapid change may occur depending on inlet morphology. The distal ends of barrier islands in South Carolina are thus subject to periodic rapid deposition, ridge and runnel activity and to episodes of rapid erosion depending on shifts in tidal channel position.

Storm Effects

The effect of storms has been mentioned in the section on wave climate but deserves separate mention because of accelerated rates of erosion that occur during storm conditions. One of the main aspects of storms along the coast is storm surge, which can be described as the rise above normal water level. Storm surge results from a combination of wind stress and reduced atmospheric pressure.

Storm surges can cause unusually high tides which when combined with high waves produced from strong winds may cause extreme beach erosion in a short period of time. Hurricanes are easily the most destructive storms to strike the South Carolina coast, but their low rate of occurrence makes them less significant in long-term shoreline change than more frequent extratropical storms approaching from the northeast.

Sea-Level Rise

A factor that must be considered in any study of beach erosion is the effect of sea level change. A continuous rise in sea level will result in a long-term erosional trend and landward barrier retreat. From 3,000 to approximately 2,000 years B.P., sea level along the east coast of North America rose at a rate of about one foot per century (Kraft, 1971). At present, the long-term rate of sea level rise may be on the order of a half foot per century, although rates have accelerated along the east coast (Fig. 6) and may be contributing to recent trends of beach erosion. Accelerated sea level rise is probably only a short-term fluctuation, yet the destabilizing effect on shorelines may be significant.

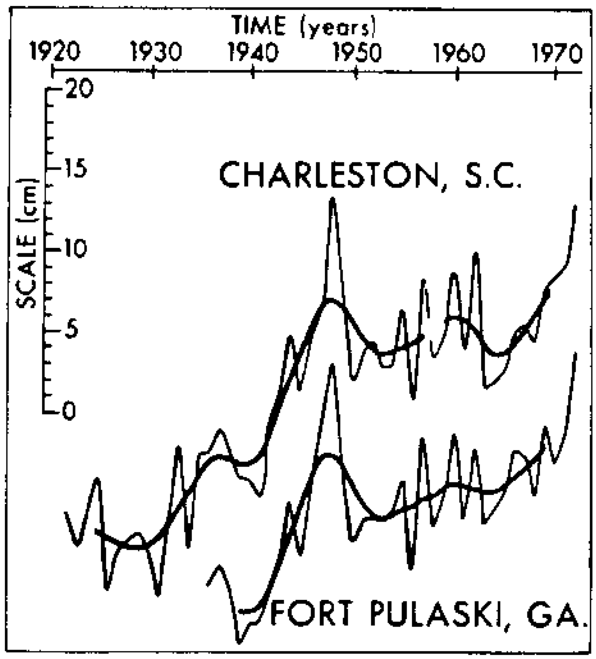

Figure 6. Sea level change between 1920 and 1970 compiled from tide records at Charleston, S. C. and Fort Pulaski, Ga.

At some locations, the effect of sea-level rise may be more than offset by abundant sediment supply. A notable example of this is the northeast end of Kiawah Island, South Carolina where several sets of new beach ridges have developed over the past fifty years.

Coastal Processes and Beach Erosion

The major factors and processes that are important in controlling beach erosion trends have been discussed individually. The final result produced by combinations of these parameters are depositional-erosional trends displayed by South Carolina beaches. In addition to net erosion or accretion at any particular location, the effect of coastal processes can be clearly seen in the overall morphology of the beach. Beach morphology to a certain degree reflects recent history of sedimentation. Overall, South Carolina beaches are wider and lower compared with other beaches along the eastern United States. This is a function of the large tidal range and finer grain size of beach sands along the South Carolina coast. Within each morphologic shoreline type, beaches vary significantly. Beach morphology along the arcuate strand region is characterized by a relatively flat beach face that may become concave during erosional cycles (Fig. 7). Erosional beaches of the transgressive barrier and cuspate delta sections of South Carolina generally have steeper beach faces and are narrower than other South Carolina beaches. These characteristics are, in part, a function of coarser-grained sands that are available to the littoral system in these areas. Profiles of beach-ridge barriers in a construc-

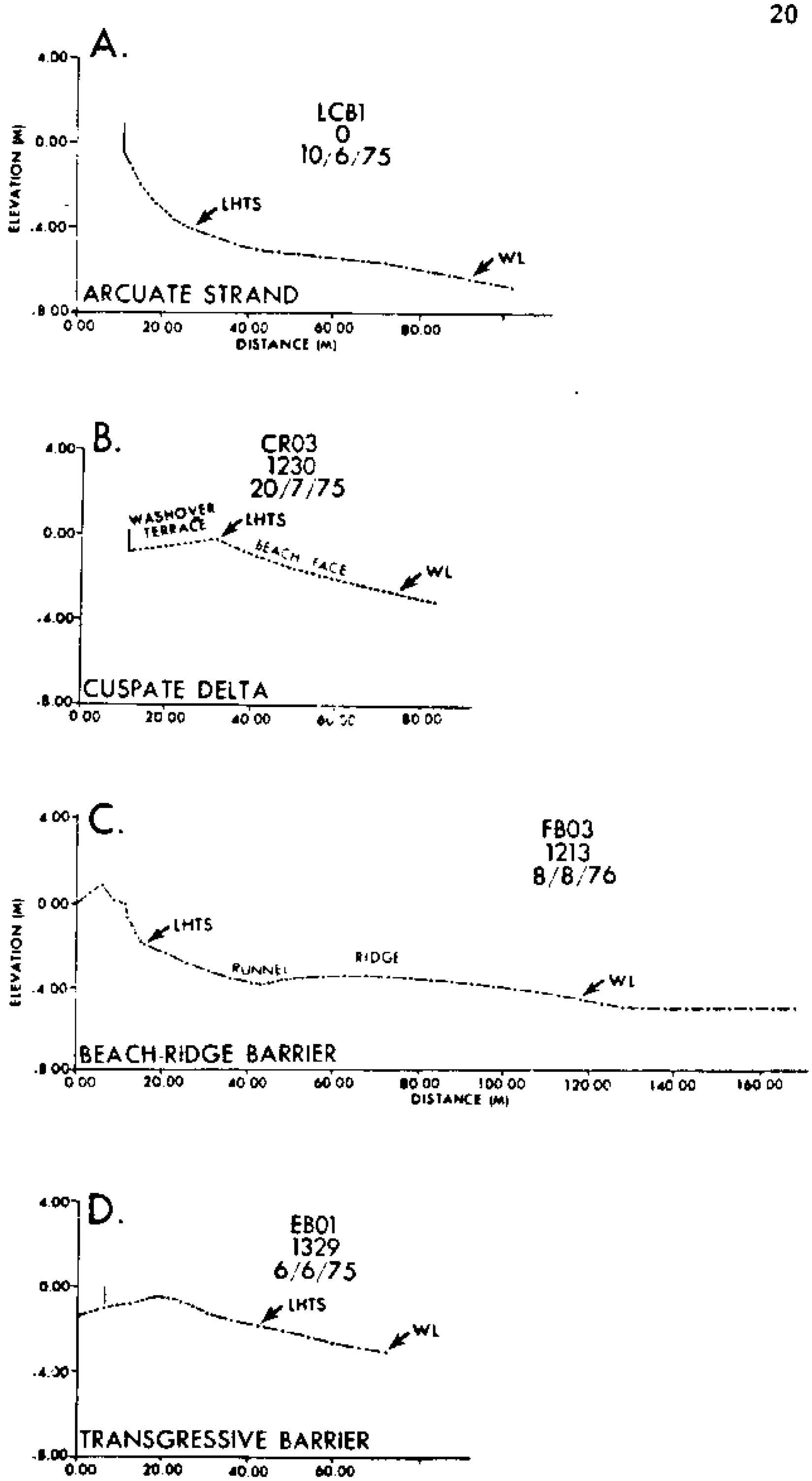

Figure 7. Representative beach profiles from each of the four morphologic zones of South Carolina (WL = water line; LHTS = last high tide swash).

tional cycle are wide and have a flat beach face across which distinct sand ridges frequently migrate, giving the beach a ridge and runnel type of morphology. A series of computer-plotted profiles at one location from each of South Carolina's four beach types show the variation in beach morphology over a two-year period between 1974 and 1976 (Fig. 8). Short-term volumetric fluctuation in all four beach types are large and maybe, in part, seasonal or storm related, but net changes may be small. The most prominent morphologic changes and greatest loss of beach sand and shoreline retreat took place on the cuspate delta and transgressive barrier type beaches. These changes can be seen clearly from the shoreward retreating dune line and subdued dune relief.

In general, depositional trends are likely to occur at the downdrift end of a barrier island which, in South Carolina, is usually the south end. This trend may be occasionally reversed when large volumes of sand are discussed under tidal inlet processes. At this time, the updrift end of the adjacent downdrift barrier may undergo a strong depositional episode as the bypassed sediment is transported onshore by wave action. As a consequence of the inlet bypassing process, lateral migration of inlets, and wave refraction patterns that change with inlet shoal morphology, beaches adjacent to most inlets are typically unstable and subject to rapid short-term fluctuations.

Depositional-erosional trends during the recent past and present along any particular section of South Carolina's coast depend on a combination of the various processes and factors discussed above. Along the arcuate strand, wave climate, sediment source and the presence of only a few inlets combine to result in a long-term relatively stable trend.

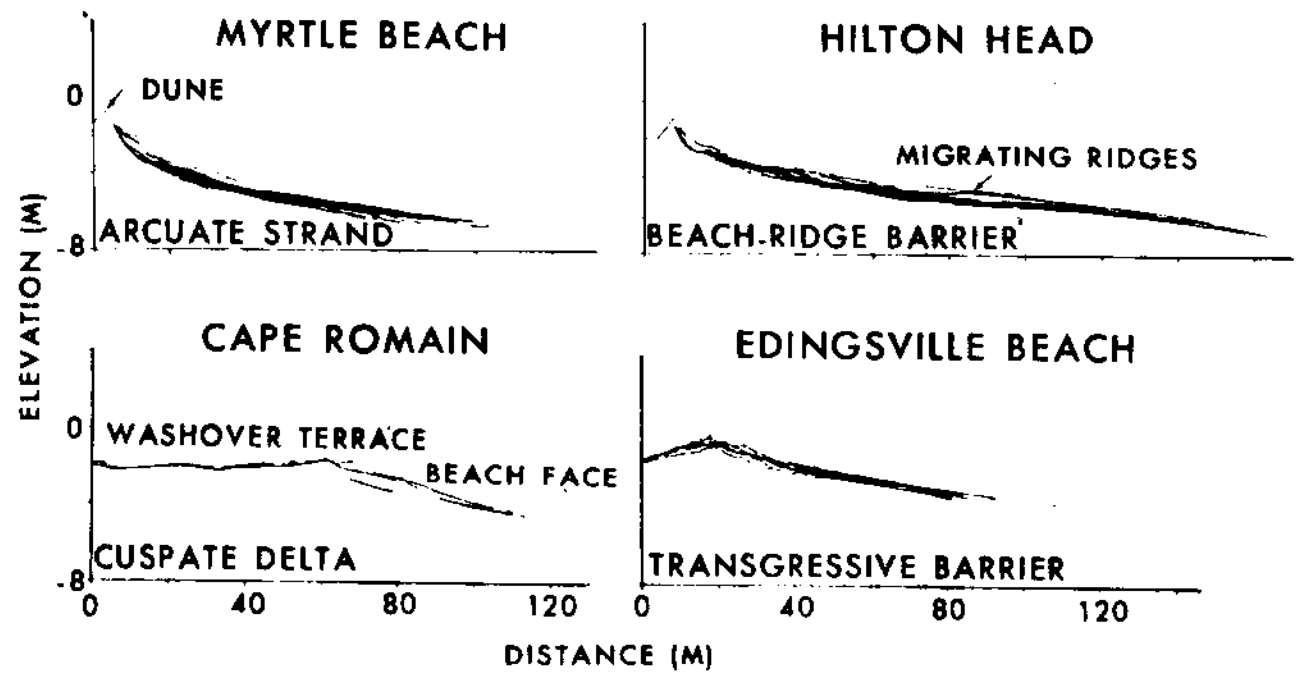

Figure 8. A series of beach profiles showing depositional-erosional trends at locations representative of each of the morphologic types of the South Carolina coast.

Exceptions to this trend are in the vincinity of Little River Inlet and Murrells Inlet.

South of the arcuate strand, where inlets are more closely spaced, abrupt and large changes in shoreline position are superimposed on longer-term trends. For instance, rapid and significant changes in the morphology and close spacing of Price, Dewees and Capers Inlets have resulted in abrupt shifts in shoreline position at certain locations on Bull, Capers, and Dewees Islands and the north end of the Isle of Palms. This influence encourages rapid erosional or accretional episodes adjacent to the inlets superimposing longer term erosional trends on Bull, Capers, and Dewees Islands and stable or accretional trends on the Isle of Palms.

Additional factors that may affect shoreline stability are man-made structures and changes. Many man-made alterations such as construction of groins, beach nourishment and seawalls may not have long-term, permanent influence on coastal processes, but may slow erosion rates sufficiently to be cost-effective. Larger scale projects can alter the nature of shoreline processes permanently. Already mentioned are changes along the Santee Delta section caused by trapping of coarse-grained sediments up-river. Not yet discussed are possible effects of jetty construction to stabilize Charleston Harbor Entrance. Some evidence exists which suggests that accelerated depositional trends on Sullivans Island and erosional trends on Morris Island are related directly to construction of the massive jetties and to changes in shoal morphology after completion of the jetties (FitzGerald, et al., 1979).

When considering shore erosion management options in South Carolina, all processes and factors discussed above must be considered. The shoreline of South Carolina is generally transitional between wave-dominated and tide-dominated types found elsewhere along the East Coast of the United States. Therefore, in addition to considering how other states have approached erosion control, it is necessary to develop an erosion management program particularly suited to the shoreline characteristics in South Carolina.

Discussed later in the report are four individual examples of barriers and beaches typically found in South Carolina. Coastal processes and factors such as sediment source combine in a different manner within each area to give rise to a different set of shoreline erosion problems in each case. In addition, the amount of residential and commercial development varies among the examples adding another dimension to beach erosion problems. Hilton Head Island is a resort area that, has recently undergone rapid development. Erosion rates here are not great, but serious problems have arisen because the island's most erosional areas coincide with the more highly developed sections of shoreline. Hunting Island is presently part of the State Park system and has a long history of erosion. Until the present, the beach has been maintained artificially by repeated nourishment projects. Pawleys Island at the south end of the arcuate strand is largely residential; whereas Myrtle Beach, at the heart of the arcuate strand, supports a large tourist industry. Existing data concerning depositional-erosional history and coastal processes affecting each of these areas are outlined below in case studies pertaining to each of these areas.

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CHAPTER III

ENGINEERING SOLUTIONS

There are several approaches for treating or coping with shoreline erosion. Increasingly, attention is being given to approaches allowing nature to take its course and the relocation of endangered property, utilities and facilities away from the eroded or threatened areas. Often, this concept has been advocated by individuals who feel that the coast should remain (or return) to an undeveloped state. Still more extreme is the notion that we should do nothing and let the endangered property be destroyed (Pilkey and Kaufman, 1980). Institutional measures have been developed and implemented in some locations to accomplish the objectives of these two approaches.

From a long-term perspective, the concept of design with nature, requiring property owners to assume the risk associated with development in coastal areas may offer promise. In the short-term, however, these approaches offer little satisfaction for the developed, high-use areas of South Carolina coast. For these areas a more explicit program of control is needed including a mix of structural and nonstructural solutions. Prudent engineering in the coastal area for erosion control need not resist the forces of the ocean but should instead work with these forces to stabilize the coastline. Unfortunately, structures have not always been so designed and, in such cases, have met with little success. Several very successful projects which worked with ocean forces were documented by O'Brien and Johnson (1980).

It is indeed intriguing to travel along the South Carolina coastline and notice that some coastal structures are successful in certain locations and not in others. In many instances, the structures are very much the same, so it is the environment in which they are located that controls their degree of success. If these structures are designed to work with the natural forces instead of in opposition to them, the solutions will work; otherwise, they will only be another testament for the do nothing alternative.

In this section, several engineering alternatives are presented for addressing shoreline erosion. At the outset it is recognized that all structural and nonstructural solutions for shoreline protection will be expensive, albeit in some cases, economical, relative to the property being protected. In the case of low cost alternatives, much research and development has taken place in the past several years. Unfortunately, little success has been achieved to date. Although available solutions have not changed significantly through time, the application of the solutions to specific situations and ocean environments has evolved to the present state-of-the-art which, if prudently followed, can lead to successful designs of shoreline protection.

The basic types of shoreline protection structures are discussed in the following sections. Emphasis is given to a description of the generic types rather than detailed characteristics of the variations of each type that are possible. Only a brief indication of the structural details and construction techniques are given. In addition to a description of the structural alternatives, an analysis of beach nourishment is given. This approach is now commonly used for shoreline protection and is one that is in harmony with the natural processes. No discussion is presented in this report of vegetative devices or dune construction. These topics are very important to shoreline control and should be used as a part of most construction plans. Vegetative devices and dune construction are covered in Sperling and Edge (1978).

A Consideration of Alternatives

From an engineering perspective, the most often considered engineering alternatives include:

1) beach nourishment,
2) seawalls,
3) bulkheads,
4) revetments,
5) groins, and
6) jetties and inlet control.

Each of these alternatives is discussed in turn.

Beach Nourishment

In the past, man has found that some of the best means of protection against the sea have come from the imitation of nature's successful methods. Beach nourishment is an imitation of nature. It permits more of the natural processes to go unhampered. In the cases where nourishment is used without other stabilizing devices, an unencumbered area is provided for recreational uses. This solution is often considered aesthetically better in addition to being safer for use by the public than the use of structures. (Fisher et al., 1976). Additionally, a wide beach provides a large berm for the surging and breaking of waves and is also a source of sand for the protective sand dunes and offshore bars. The latter are very important in times of storm to act as a submerged breakwater and help dissipate the wave energy before it reaches shore.

One of the most important considerations in nourishment is the determination of a suitable borrow area. Some past locations used as borrow sites have either proved ineffective or are now environmentally unusable. It is important to find a borrow area as close as possible to keep transportation costs low. However, an even more important consideration is the composite grain size characteristics of the borrow site in comparison to that of the natural beach characteristics. To make the determination more difficult, it is possible to have the grain size distribution vary in four different dimensions along the natural beach, a) along a beach profile intercepting various energy zones, b) parallel to the beach within one energy zone, c) by depth within the active profile's sediment envelope, and d) seasonal changes for the three dimensional profile (Hobson, 1977). Therefore, finding a compatible borrow site can be difficult. Studies have shown that if it is not possible to duplicate the characteristics of the natural beach it is better to have a slightly coarser material if it can economically be found. This will produce a slightly steeper beach and, most of the smaller material will be lost. A finer material may be lost all together and the renourishment project could be a failure. One example of this point is the 1966 renourishment of Cape Hatteras (Dolan, 1972). Similar situations occurred at Hilton Head and Hunting Island.

Once a potential borrow site is located, a series of calculations must be made. Factors such as the necessary slope of the beach, berm width and height, and the placement locations must be resolved. From these determinations, the required amount of fill is estimated and the actual transfer of fill to the site can begin. Once in place, it may appear that a nourishment project has lost considerable amounts of sand over a period of time. While in reality this occurrence is only a case of relocation of the sand into an inner bar system. The sand is still part of the protection devices that nature uses to help break the energy of approaching waves.

Frequently, nourishment is used in conjunction with other projects. Groin fields are sometimes filled to offset the detrimental effects down-drift, while offshore breakwaters are occasionally used to stabilize the fill behind the breakwater. However, in some cases the groins and break-waters are built to protect the beach fill from being lost and thereby prolong the time period between renourishment.

One advantage of nourishment is that it is a short-term technique. If for some reason the project results are not beneficial the project can be abandoned without problems of deteriorating structures. It is simply a matter of not performing the follow-up renourishment schedule. If the project is to be retained, renourishment must be periodically performed to offset the continual losses of sand. Nourishment is not a permanent device; it is a continual process.

Seawalls

Seawalls are large massive structures built to provide a permanent separation between the water and land. They are often confused with bulk-heads and revetments which are much lighter structures. Seawalls are designed to protect against direct wave action and the associated scour which frequently occurs with bulkheads and revetments. An important part of most seawalls is a sheet pile cutoff wall to prevent the undermining of the structure by wave scour, leaching from storm drainage, or wave overtapping

Most also have some method of dissipating the wave energy. This could be a curved face structure as found in the Galveston Seawall, a stepped face as is found in the Gulfport seawall, or a combination of the two as is found in the San Francisco seawall. The above are all concrete structures, however a seawall need not be of concrete. Many are made of riprap like the Fernandina Beach, Florida structure. Occasionally riprap is placed in front of a seawall for protection from scour at the toe. It is not likely that seawalls will be a primary solution on South Carolina beaches except at the most energetic and developed areas.

Bulkheads

The primary purpose of bulkheads is to retain the fill behind them. Second, they provide some protection from wave action. Bulkheads are not generally located in a large wave environment. The traditional bulkhead is a vertical or near vertical structure, usually of a sheet pile design with proper penetration to prevent undermining of the foundation by scour. Riprap is often placed at the base to prevent scour. These are very common structures in South Carolina. Most have been adequately constructed and provide reasonable service; others have not been as successful.

Revetments

Revetments armor either the bluff or the dune slope. It is, therefore, a sloped structure of either a rigid cast-in-place concrete design or, more frequently, of a flexible armor (typically rubble) unit type. In planning a revetment, care must be taken to provide for the relief of the wave generated hydrostatic uplift pressure. This is commonly done by providing a filter layer of either cloth or crushed stone to allow the pressure to dissipate with a loss of material behind the structure.

Several types of intlerlocking blocks have been developed for use as revetments (Mohl et al., 1967). A second type of precast block which does not interlock is simply laid on top of a filter layer. Gobi blocks and nonlocking concrete blocks are examples (McCartney et al., 1977). An advantage of this type revetment structure is the ease of installation. Blocks are not the only type of man-made structures used in forming revetments--concrete dolos or stapod units may be chosen. Synthetic bags filled with either sand or concrete and placed along the slope can be used. A mat type form is also available to form the revetment (Intrusion-Prepakt, 1975). Not all revetments are of man-made materials. Rubble revetments work very well where materials are readily available as well.

Revetments, like seawalls and bulkheads, are designed only to protect areas behind them anything forward will not be protected by the structure. In fact, unless they are used in combination with other protection devices, they may well lead to the destruction of the area to the front and the sides of the structure. This accelerates the erosion in the area and will eventually lead to the failure of the structure unless adequate protection is given to the structure. The sheet pile prevents a rapid seaward flow of the groundwater drainage but encourages erosion of the areas to the front of the wall. The area to the sides of these structures may be eroded due to the reflection and concentration of wave energy. It is for this reason that these structures are not usually satisfactory in protecting small areas of shorefront.

Groins

Groins are very common along the South Carolina Coastline. They have been quite successful in some applications while some installations have not only been unsuccessful but have contributed to additional erosion. The groin is a long, low, narrow structure, usually starting at a point landward of the predicted shoreline and running perpendicular to the coast into the water. Groins are classified by their design type and may be high or low, long or short, permeable or impermeable, as well as fixed or adjustable. Groins must always be built as a system covering the desired area. A single groin should never be used except as a terminal structure to retain sand at the end of a project or to keep it out of an inlet.

The function of a groin field is to trap the moving sand in the littoral zone. This sand is deposited on the beach in the vicinity of the updrift side of the groin. Unfortunately, if a single groin is used the downdrift side is deprived of the moving sand; therefore, the groin may actually cause erosion immediately downdrift. In South Carolina, the groin normally extends out into the water to approximately the six foot contour on the South Atlantic coast. To extend the groin farther out is uneconomical as most of the littoral drift movement is within the zone landward of the normal breaker line. If the groin is too long and completely blocks the littoral drift, the downdrift area will be severely eroded. A second possibility is that the drift will be pushed offshore and lost to the area entirely.

A number of methods have been developed to control the downdrift erosion. The low groin, for example, permits the overtopping of the groin in periods of storm wave attack or high tide. The littoral drift is therefore not completely blocked. A permeable groin obtains the same action by allowing the drift to actually move through openings in the groin. Care should be taken to keep these groins permeable as marine growth will sometimes block the flow. Permeable groins do have the advantage that the sand will usually build up on both sides of the groin. Shore groins work by not completely stopping the flow; however, they should be long enough to stop some of the drift. Often groins are used in conjunction with beach nourishment to slow the rate of erosion from the beach face. It must be emphasized that groins will not work unless there is a sizable gross drift.

Jetties and Inlet Control

A jetty is a device which extends from the shore out into the water much like a groin, yet its function is quite different. The jetty is used to control inlet areas, to help prevent shoaling, or to direct and confine an inlet or river. It may also act like a breakwater by protecting a channel entrance against wave action and cross currents. While not always necessary, jetties are usually built in pairs, one on each side of the channel. They are fairly long structures, generally longer than the groins they resemble. The jetties at Murrell's Inlet, for example, are several thousand feet long. They also are quite massive; the Humblodt Jetties in California have 43 ton dolosse units as a part of their structure (Magoon et al., 1976). The actual design of a jetty structure is quite complex and, due to the siting problems, professional help should be obtained.

While jetties protect inlet areas, they do present problems. Because of their length, they extend well out into the littoral drift zone, in some cases blocking it entirely. However, techniques have been developed to prevent the windrift erosion. Special impoundment areas are developed into the jetty design with methods to transfer the sand to the downdrift side. This feature may be an elaborate sand pumping system with floating dredges or fixed pump systems (U. S. Army COE, 1973).

As far as coastal erosion is concerned, jetties can be important factors in controlling that erosion caused by dynamic, shifting inlets. Of course even in this regard they provide navigational benefits.

Breakwaters

A breakwater is by definition "a structure protecting a shore area, harbor, anchorage, or basin from waves." (U.S. Army COE, 1977). The above definition is purely navigational, not indicating any erosion control aid. However, as the structure does exist in the littoral drift area, it sets up erosion and accretion patterns.

Within the past decade considerable emphasis has been placed on the concept of the crenulate bay and headland defense. Silvester (1974) advocates the use of the artificial headland, or breakwater, to imitate natural defense mechanisms. The concept is not new, an offshore breakwater system was completed in Venice, California, in 1904. In spite of the use of the artificial headland for such a considerable period, design criteria is quite lacking (Magoon and Edge, 1978).

Actually the offshore breakwater is used in two distinct ways to control erosion. One is the artificial headland concept mentioned above and the other is as a sand trap. The breakwater works as an erosion control device because of its wave calming action. Some of the wave energy is reflected back out to sea by the breakwater, some may be transmitted, but at considerably lower energy levels, and some waves are diffracted around the ends of the breakwater. When the wave shadow of the breakwater enters into the littoral drift zone, the ability to transport sediment is lowered in that area and the sediment is dropped. The shore tends to build toward the breakwater. However, it represents a blockage to the littoral drift and illustrates the erosion deposition features associated with groins. By the placement of such a breakwater just updrift of an inlet, an effective sand trap can be developed to help stop inlet shoaling and provide a convenient location for pumping sand around the inlet. The breakwater at Channel Islands Harbor, California, is an excellent example of this use of breakwaters.

Offshore-shore connected is only one descriptive category of breakwaters, there are several other categories. Not all breakwaters are built to exist above the water level; some are submerged, even at low tide. The submerged breakwater accentuates the wave energy and has the added advantage of not interfering with the aesthetic qualities of the view. The submerged breakwater does present somewhat of a navigation problem in that it must be well marked. They are, however, less expensive to build. Wave accentuation to provide a better bathing beach area was the goal of one scheme at Bat-Yam, Israel. The submerged breakwater proved to be the best overall design (Tauman, 1976). Most breakwaters are fixed in location; however, a few are mobile. Silvester (1974) discusses the ability to use mobile breakwaters to build up large sections of a shoreline by the progressive movement of the breakwaters offshore (Silvester, 1974).

Selection of Alternatives

The actual selection of a shore protection device is dependent on the dynamics of the area; what might work very well in one area could be disastrous under different environmental conditions. Hubbard et al. (1977)

have divided the 255 km South Carolina coastline into three zones; arcuate strand, cuspate delta, and barrier island. Each zone has its own unique dynamics and, therefore, different erosion control techniques would apply to each.

Many devices are used in combination rather than alone, for example, offshore breakwaters and groins are often used with beach nourishment. Each of the three zones must be studied in detail to determine both the dynamics of the zone and the need for erosion control. It is anticipated that several devices could be selected as workable in some areas. The final selection of a device for a particular site will have to be made based on a detailed engineering analysis, an economic study of the area and a review of the total costs and effectiveness of each device under consideration.

A number of lists of available devices have been published which could be used in selecting an appropriate alternative for erosion control. Sperling and Edge (1978) and Dames & Moore (1980) are examples of recent lists of the characteristics of various types of devices. In these lists, erosion control devices are presented with short comments on their individual requirements and problems encountered in their general use. Subheadings appear under each control device on types of materials available for use. Additional comments are included on specific problems and requirements for each of these materials. Specific examples of material types and forms are listed along with a location of where they have been used and a rating of their performance. There is one final column on approximate cost per foot of protection which has only been filled in where recent information is available. It is emphasized that this information must be used with extreme caution as low cost protection devices have been included in the chart along with the "high cost" units.

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CHAPTER IV

THE MANAGEMENT OF COASTAL DEVELOPMENT

Coastal processes have been at work since time invariant, creating a volatile physical condition. As a result, the formation of the present barrier island chain along the Atlantic and Gulf Coasts has been both created and significantly changed over time. Although these changes have been long-term, losses in terms of real property have increased significantly in recent years. These property losses have resulted in large part due to the rapid development of beach areas since the end of the Second World War and to some short-sighted building practices that have failed to appreciate the dynamic nature of the physical environment.

Although intensive development is a relatively recent phenomenon, South Carolina planters were building summer beach cottages by the late 1700's. Among the first locations were Pawley's Island and Edingsville where relief was sought from the hot summer climate and cool nights on the plantation from which it was felt malaria bred (Prevost and Wilder, 1972.) At Edingsville, Sea Island cotton was soon introduced and proved so profitable that by 1820 there existed sixty large "comfortable" houses (Crayden, 1955.) In Charleston, where heat and occasional outbreaks of yellow fever made summers unpleasant, residents began to make use of nearby Sullivan's Island. A legislative resolution of 1791 granted the right to spend the summer on the island to any South Carolinian who thought it "beneficial to health". By 1880, streets were laid out, and by 1824, the summer population was said to be "a thousand or more" (Brewster, 1947.)

Development of the Grand Strand area of South Carolina, now the state's most popular resort area, began after the turn of this century with the majority of development occurring in the post-war period. Despite out-migration from rural areas, the population of Horry County which includes Myrtle Beach doubled between 1930 and 1976.[1] Still more recently, the number of visitors to the Grand Strand grew from 2.9 million in 1972 to 6.5 million in 1978 despite the attention given gasoline shortages and price increases.[2] While the Grand Strand has become one of the most popular vacation areas on the Atlantic Coast, exclusive resort communities have developed further down the coast at Hilton Head, Fripp, Kiawah, and Seabrook Islands. The most significant development of the group has been Hilton Head where population increased from 1,000 in 1960 to 2,546 in 1970 and is estimated to be 10,500 in 1980.[3] The value of building permits issued over the past decade which increased from $12 to $91 million is further indication of this growth.[4]

This recent development of oceanfront beaches has provided greater accessibility for vacation and year-round accommodations. In turn, benefits have accrued to a far wider audience, and an important tourism industry has spawned in South Carolina as well as other coastal states. This development has not been without cost with much of it occurring in hazard areas subject not only to long-term recession but also to storm and flood damage. In addition, the cumulative effect of the demands being placed on the delicate coastal ecosystem requires careful attention.

The following chapter will examine in greater detail the peculiar benefits and costs associated with such development and the private and institutional inducements that have contributed to this growth. The chapter will also consider the present use of coastal resources and examine the appropriate role of the public sector in effecting optimal use of the resource.

Inducement to Development

A number of factors have contributed to rapid development in coastal areas. One of the more significant factors has been climatic. Since 1960, the number of hurricanes striking the Atlantic coast has been unusually sparse with no major hurricanes having occurred during this time period. Although the present trend is cyclical rather than permanent, a feeling of security has arisen among coastal residents, many of them new to the coast. In Florida, for example, it is estimated that 90 percent of coastal residents have never witnessed a major hurricane.[5] This influence is felt not only in the quantity of developments but also in terms of quality as building patterns reflect a lack of appreciation for dynamic natural processes. The remaining inducements can be generalized as being either privately or publicly inspired.

Private Incentives

Among economic and demographic factors that have contributed to the rapid development, the most significant appear to have been:

1) growth in personal income,
2) a shift in the geographic distribution of the population,
3) improved accessibility, and
4) learned behavior patterns of users.

Since World War II, the real per capita income in the United States has risen 33 percent.[6] Although increased leisure time often has been cited as a reason for increased recreational demand, the greater involvement of women in the work force has actually decreased family leisure time.[7] The more important factor stems from higher standards of living, allowing the same wage-earner or family to participate in more expensive, capital-intensive recreational activities. As a result of this phenomenon, the beaches have been transformed from the playground of the rich to increasingly include the vast middle class.

A second factor contributing to this trend is the shift in geographic distribution of the population. Presently, 50 percent of the population in the United States resides within 50 miles of the coast.[8] Physical proximity is further reinforced by increased accessibility via the private automobile and better transportation arteries, especially since the advent of the interstate highway system. Consequently over the last two decades, frequent day and weekend excursions have become feasible in strictly physical terms to a wider segment of the population.

Collectively, the increased accessibility to broader income classes and geographic regions has introduced regular beach visits to a far wider audience. This exposure has led to a secondary effect in terms of learned behavior patters by individuals and families. In other words, once exposed to various recreational activities a greater appreciation of the activity may be gained, i.e., a "learning by doing" phenomenon (Krutilla, 1967.) A recent study by the South Carolina Department of Parks, Recreation, and Tourism indicated that half of the individuals surveyed listed beach swimming as an activity that they participated in during the one-year study period.[9]

Institutional Inducements

In addition to private inducement, a number of federal activities have stimulated and subsidized development of coastal areas. Activities having both direct and indirect effects on development include bridge and highway construction, shoreline protection, flood insurance, wastewater treatment facility grants, small business loans, economic development grants, urban planning assistance, and home mortgage insurance. A brief discussion of the role of each of these programs in stimulating development is presented in the sections to follow.

Bridge and Highway Construction Programs:

Bridge construction is vital to barrier island development since development costs would be prohibitive in most cases without easy island access. As a result, the federal government authorizes bridge construction and road system development to facilitate access. In addition, if the bridge or road is part of a planned highway system, the government may provide funding toward its construction as well.

Road and bridge construction programs are administered by the Department of Transportation, the bridge permit program is administered by the U. S. Coast Guard, and the road construction grant program is administered by the Federal Highway Administration. The Coast Guard has had authority to review bridge construction proposals since 1966. Notwithstanding bridge statutes, the Code of Federal Regulations, and case law, a bridge permit has never been denied by the Coast Guard because of environmental impact.[10]

The road construction grant program as administered by the Federal

Highway Administration is an important influence in determining land-use patterns. This multi-billion dollar per year construction program makes it practical and economically rewarding to convert from low to high-density developments. Road construction, by improving accessibility, increases pressures for residential, recreational and commercial uses.

Shoreline Protection Programs:

One of the most influential agencies on coastal development is the U. S. Army Corps of Engineers. Since the Rivers and Harbors Act of 1899, the Corps of Engineers has had responsibility for navigational projects and flood control. Traditionally, the Corps has favored structural solutions to flood control, beach erosion and navigational problems. Construction of such projects has involved local rises in employment and attendant rises in demand for housing and services.

A secondary factor involves the enhancement of recreation brought about by the proposed project. Enhanced value may be claimed as a project benefit if the beach is either publicly owned or open to public use. Moreover, the federal government is prohibited from participating in a shore protection project unless the public will have access to the shoreline in the project area. This requirement means federal projects often create public access to areas previously denied to the public.

Flood Insurance Programs:

In order to be eligible for federal financial assistance for acquisition or construction purposes in time of disaster, communities in special flood hazard areas must enter the National Flood Insurance Program. (This provision is part of the Flood Disaster Act of 1973.) The goals of the National Flood Insurance Program as administered by the Federal Insurance Administration are to encourage state and local governments to make adjustments to constrict development of land in flood hazard areas and to impose tighter building codes to minimize damage caused by flood losses. Before a community is offered flood insurance, it must institute flood-plain management regulations. However, enforcement and administration of these regulations generally has been inconsistent and ineffective in the past. In an attempt to encourage sound management practices, FIA offers low flood insurance premiums to residents of coastal areas. The distribution of risk to residents of hazard and non-hazard areas has caused coastal residents to discount the risk factor along the oceanfront. Although often given more than just credit for influencing development, it has been estimated that federal subsidies for flood insurance amount to only 6 percent to public expenditures on barrier islands. Still, the psychic as well as monetary influence of the program is greater than that figure. Congressional Review of the program in the next legislative session will provide a reading of Congressional sentiment toward such programs.

Many financial institutions refused to grant mortgages in coastal areas prior to the National Flood Insurance Program because of the high risk of coastal development. However, as flood insurance became available, banks reversed their previous policy of denying construction loans in hazardous areas. In this way, tax money supports insurance and development in flood-prone and ecologically fragile areas.

Wastewater Treatment Facilities Grants:

Grants for the construction of wastewater treatment facilities are primarily funded by the Environmental Protection Agency (EPA), the Department of Housing and Urban Development (HUD), the Farmers Home Administration (FmHA) and the Economic Development Administration (EDA). HUD's emphasis is urban and FmHA's is primarily rural. In terms of wastewater treatment, EDA's program is small when compared to the other agencies mentioned.

Section 201 of the Federal Water Pollution Control Act Amendment of 1972 authorizes EPA to grant up to 75% of the cost of construction of new wastewater treatment facilities.[11] A problem arises from the fact that inadequate areawide planning may precede construction of these facilities.[12] When poorly planned, 201 projects contribute to growth which may lead undesirable residential and commercial growth in coastal areas.

Regulations of the EPA do not specifically designate coastal areas as areas of environmental concern. By concentrating more on the adequacy of the justification and design of the wastewater treatment facilities, environmental assessments are left to engineering firms which may be unaware of the special conditions of coastal areas. This specifically contributes to construction which might otherwise be prohibited.

Small Business Loans:

The Small Business Administration (SBA) provides two types of direct or guaranteed /insured loans--Economic Injury Disaster Loans and Physical Disaster Loans. These loans are designed to assist business concerns which suffer economic injury due to designated disasters and to restore damaged property to predisaster conditions. These loans are granted for up to thirty years at relatively low interest rates.

Physical disaster loans are made to individuals, businesses, churches, private schools, hospitals, colleges and universities. This broad range of disaster assistance eligibility contributes to a reduction in concern for hazardous area development.

Further, an amendment to the Federal Water Pollution Control Act of 1972 authorizes the SBA to make loans of up to 90% of the cost small businesses incur by making additions to, or alterations in, facilities required for water pollution control. This concern, in effect, is removed for businesses considering construction in coastal areas.

Economic Development Grants:

Under the provisions of the Public Works & Economic Development Act of 1965, the Economic Development Administration has primary responsibility for the Economic Development Grants program. Development grants can be used for such public facilities as access roads to industrial areas, water & sewer systems, harbor facilities, flood control projects and site improvements for industrial parks. These grants are made for up to 50 percent of the development cost; however, severely depressed areas may receive supplemental grants to bring the federal contribution to as high as 80 percent of cost.

Loans, available for public works and development facility projects, may pay the full cost of a project and run as long as 40 years. A community unable to provide a share of the cost may receive a grant for 50 percent of the cost plus a federal loan for the remainder. Such grants and loans designed to provide public facilities on barrier islands contribute to development for urban use. Urban Planning Assistance grants through HUD similarly facilitate the development of comprehensive plans for construction and capital improvement programs.

Home Mortgage Insurance:

By insuring commercial lenders against capital loss, the Federal Housing Administration encourages these lenders to invest in the home mortgage market. Loans are insured by FHA for up to 97 percent of value for up to 30 years. The loans finance homes in urban areas as well as in rural areas where construction standards are less rigid. Neither the FHA nor the FmHA differentiates between barrier islands or mainland sites in program administration.

The Benefit of Development

Recreational benefit is difficult to quantify. We know that the minimum benefit derived is that amount individuals pay for the activity. Yet, as the beaches are held in public trust and, in general, are non-exclusionary, payments are made only for ancillary services, food, and accommodations. As a result, the expenditures on beach related services represent a first approximation for much of the benefit derived from beach experiences. In 1976, $845 million in travel expenditures were spent in the 6 oceanfront counties in South Carolina.[13] Horry and Charleston Counties rank first and second respectively in travel expenditures and together account for 41 percent of such expenditures among the 46 counties in the state.[14] Particularly for the coastal counties, tourism represents a significant component of the economic base. For the state as a whole, tourism ranks as the second most significant industry, and tourist related employment as of 1975 totaled 28,274 (Ellerbrock and Hite, 1979).

Properties adjacent to the beach or within its influence reflect differential rent, i.e. aesthetic value due to location. Much of this value is captured in land prices for both residential and commercial property. It is estimated, for example, that oceanfront property at Myrtle Beach sells for a 50 percent premium, compared with comparable property on the second row.[15] As development continues in coastal areas, the beaches and adjacent properties become scarce commodities. Oceanfront properties then demand scarcity rent, i.e. value above and beyond normal returns on investment, because of their location. Findings of the present study suggest, for instance, that despite the recent downturn in the housing market, properties at Hilton Head appreciated at an annual rate of 25.4 percent between 1978 and 1980. At the same time, the natural aesthetics of beach areas become increasingly valuable due both to increased demand and to limited available supply. Although landowners should be encouraged to make the highest possible use of their properties, it is from the ocean and the beach that private properties gain value and not vice versa.[16] Collective benefit is achieved, therefore, through long-term maintenance of the aesthetic qualities of beaches.

In addition to pecuniary benefits derived from the coast, significant nonmarket benefits may accrue as well. Because beaches are public and, in general, no fees are charged for their use, the use value derived from beach visits may exceed the price paid. Economists refer to this outcome as consumer's surplus, implying that the benefit derived exceeds the market price. To stereotype an example, a surfer who camps on the beach may derive a great deal of pleasure despite minimal expenditures. The day user may derive significant personal benefit with minimal or no expenditure within the beach community, while, at the same time, the therapeutic properties of the beach produce social benefit. Despite the fact that these activities occur without transaction, they represent significant value to beach users and therefore must be approximated to accurately reflect social value. In the case studies to follow, a value for beach user days will be assigned.

Finally, whether we use the beach or not, value is derived from the option of doing so. For example, an individual that has never visited the Grand Canyon (or South Carolina beaches) may derive option value from knowing that the canyon exists and that he/she and his/her descendents may at some time derive enjoyment from that experience. Implicit in the concept of option value is the fact that alterations of the natural environment may be irreversible. Changes to the coastal ecosystem, for example, may diminish or eliminate the resources environmental amenity.

The benefit derived from the coastline has resulted in increased usage and development for residential and commercial purposes. It is appropriate, given the public nature of the resource, to consider the consequences of this development and to consider the appropriate role of the public sector in affecting maximum long-term enjoyment of the beaches.

The Cost of Development

Development in coastal areas is not without cost, some of which is peculiar to oceanfront environs. The most obvious cost differential associated with such development is the risk to life and property as the result of locations in areas subject to coastal hazards and long-term erosion rates. In 1969, Hurricane Camille, with a rating of five on a scale of five and a 24-foot storm surge, caused over $1 billion in property loss. Additionally, 144 lives were lost for which we do not wish to place values. In 1900, the most destructive storm to date hit Galveston, drowning 6,000 residents and killing another 2,000 on shore (MacLeish, 1980). More subtly, it is estimated that annual losses due to coastal erosion amount to $300 million (Sorenson and Mitchell, 1975). Attempts to alleviate the property loss from shore erosion are certainly not without cost. It is estimated, for example, that a beach nourishment program in progress by the City of Miami Beach will amount to $64 million.

The fact remains that the risk of property loss due to natural forces is a risk incurred from coastal development. Attempts to minimize that risk are also with cost whether the solutions are of a(n) engineering, management, or information variety. As indicated above the costs can, in some cases, be quite significant.

The cost in terms of environmental damage stemming from coastal development may also be large. The salt marshes lying behind barrier islands and coastal reaches are the most productive ecosystem on earth. More than 70 percent of coastal fish and shellfish breed in these waters and hundreds of wildlife species inhabit the waters or adjacent lands (Clark, 1977). Although capable of a large assimilative capacity and sewage discharge, construction patterns, in some cases, have had serious effects on the ecosystem. Depletion of ground water reserves and the resultant effect of saltwater intrusion have accompanied development in a number of instances. Attempts to alleviate or mitigate for these effects have been costly. Public service delivery likewise has been costly due to the remoteness of many oceanfront areas and their seasonal nature which often results in excess capacity to be maintained during the off-season.

More subtlely perhaps, the actions of man by disturbing the natural system may exacerbate erosional trends and thereby property loss. It is well understood now that the earlier leveling of dune systems and the removal of beach vegetation has had serious consequences. Intensive development also has limited the absorbability of the land resulting in serious problems with stormwater runoff. The City of Myrtle Beach is a case in point where discharges onto the beach currently violate water quality standards and contribute to beach erosion. Aesthetically, the better than 280 discharge pipes represent a further cost to the community (Waccamaw Regional Planning Commission, 1980).

Attempts to lessen the effect of erosion, although well-intentioned, have occasionally caused more harm than good and, at other times, merely redirected wave energy causing erosion elsewhere. A 1930's WPC program to rebuild the dune system at Cape Hatteras built 9-foot dunes to assure that sufficient sand was stored to withstand the most severe storm. Natural washover effects were eliminated, preventing relocation of the dunes and leaving them helpless admidst the retreating shoreline (Leatherman, 1978). Seawalls and bulkheads, built to protect landward property, cause wrap-around action resulting in erosion to adjacent property. At the same time, the wave energy is directed downward at the base of the structure, undermining the structure and accelerating erosion rates seaward of the construction. As the scowering effects are likely to occur below mean - high - water, the property loss is to public lands.

Finally, stop gap measures to control structural changes which alter sand transport patterns may hasten erosion rates. Ironically, many of these structures are built as a preventive measure. To the degree that sand is robbed from adjacent landowners and/or the public, that portion of the cost is borne externally to the landowner. Structural solutions to alleviate erosional loss should be allowed only in the most severe cases or where external effects are deemed to be small. Still, a means of compensation for injured parties should be incorporated subject to prior approval or subsequent arbitration.

The Optimal Use of the Resource

Although dynamic, coastal processes are in continuous equilibrium. Sand budgets remain in balance albeit positioned in varying proportions depending on seasonal or climatic conditions. The disequilibrium that has developed along coastal beaches evolves instead from a conflict between man's desire for stable land-use patterns amidst volatile natural conditions. The resolution of this issue requires a balancing of objectives regarding the proper use of the resource, i.e., the coastal environment.

In order to achieve efficient solutions, resources should be used to the point where the value derived from the last unit is equal to the cost of accessibility. This situation is indicated in figure IV-1 on the following page depicting the marginal benefit and cost derived from beach utilization. The marginal benefit, MB, reflects enjoyment from the last unit of activity. It is downward sloping as, beyond some point, the value from additional use becomes less and less significant through saturation. The marginal cost, MC, reflects the expenditure required for access to the activity. As shown, costs are assumed to be constant for each user occasion. From a private perspective, where MC_1 reflects private cost, collective use will occur at point U_1 at the cost of V_1. Individuals, it should be noted, will not utilize the resource where their personal cost exceeds the benefit to be derived. To provide for greater collective benefit, public programs have lowered, in effect, the cost of accessibility by subsidizing development as well as by reducing the inherent risk to property owners. Conceptually, the effect is to

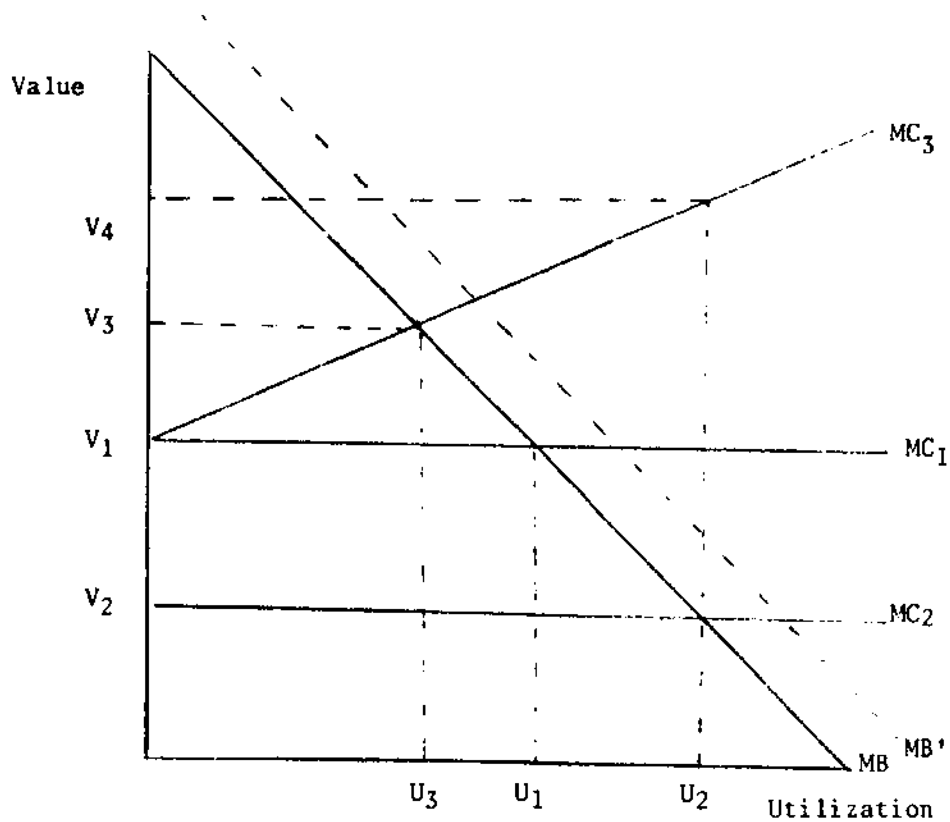

Figure IV-1. The marginal benefit and cost accruing from beach usage.

lower marginal cost to MC_2; utilization is increased thereby from U_1 to U_2 meeting the program objectives. From a standpoint of efficiency, this solution may not be optimal as the true cost, MC_1, exceeds private benefit of the last visit by the amount of the subsidy, $V_1 - V_2$. Yet, we have not included the social benefit associated with such visits nor correction for matters of equity. Where such benefit exists, the social optima occurs where the level of subsidization is equal to social benefit thereby internalizing this effect.

In the case of beach usage, however, significant social costs may also occur as noted in the previous section and must be incorporated in the decision-making process. Beyond some point or threshold, social costs appear to increase at an increasing rate as environmental carrying capacities are taxed. Therefore, if MC_1 represents full pecuniary cost (including contributions from taxpayers), MC_3 reflects both pecuniary and environmental cost and is upward sloping. Ignoring for the moment the fact that social benefit may also occur, the social optima is achieved at use level U_3, and the value (and cost) of the last visit is equal to V_3. Even with the inclusion of social benefit denoted by a paralleled shift of the benefit line to MB', $MC_3 > MB'$, i.e., cost may exceed benefit for the last units consumed, implying an overutilization of the resource. At high levels of utilization, this result is likely, in fact, as marginal cost is increasing due to environmental effects and marginal benefit is decreasing due to saturation.

To solve this dilemma a number of environmental groups and public officials are calling for tighter controls on use, the removal of subsidy programs, and the public acquisition of undeveloped areas. Each of these positions represent an appropriate component of coastal policy and will be addressed in turn. Many of the proposals that have been made, however, reflect a strong conservationist sentiment. Although selective conservation is appropriate to assure variety of opportunity at a later date and to prevent beach areas from exceeding their carrying capacity, access to the beach resources through both public and private means must also be assured to meet demands for such recreation in the coming years. Despite a leveling of population growth and a slower rate of economic growth projected for the coming decade, the fact that greater numbers of individuals have been exposed to oceanfront experiences over the last generation will assure a continued and growing demand for such activity. The denial of sufficient access will preclude the potential for significant social gain. Closer attention must be given then to methods of reducing the social cost of development and of internalizing as many of the remaining costs as possible to encourage responsible actions by individuals. The primary costs of development that must be addressed include costs stemming from:

1) spillover effects,
2) information, and
3) risk

Because the coastal ecosystem is so closely interrelated, imbalances that arise are likely to have spillover effects, i.e., repercussions throughout the system. Where two or more noncompatible activities occur and the potential for compensation exists, such options should be considered. For example, suppose that individual A builds a seawall or other form of erosion control structure which it is known will have a detrimental effect on neighbor B. If B is sufficiently compensated for his/her expected loss of property, both parties are potential gainers. If B suffers greater than expected losses requiring the construction of further seawalls, the leapfrogging effect that often occurs with the use of seawalls might evolve. Were this loss accruing only to private property, effective solutions still might be achieved. Risk and uncertainty would soon be incorporated such that at some point the cost of compensation exceeded personal property loss and the seawall would no longer be extended. Yet, the extent of damage to the public beach also must be considered, and the appropriate compensation to the public in terms of taxes and fees would likely be prohibitive given the use value of the beach and the community-wide effects that might be induced from this initial action.

Where spillover effects are community-wide in their impact and not amenable to compensation, solutions must be community-wide in scope. Activities falling under this category generally involve either overuse of the natural (or social) carrying capacity or alterations of the natural system which, in turn, impact others. In terms of erosion control, alterations of the beach and dune system or to sand transport may significantly affect beach formation and subsequent erosion rates within an entire beach reach. It is appropriate to develop erosion control measures as static land-use patterns prove inadequate.

Compatible development along the oceanfront requires that structures conform to the natural environment as presently configured as well as to the expected beach configuration over the useful lifetime of the building. The useful lifetime of the structure may vary depending on its purpose and construction. Typical housing mortgages run for 30 years, although a 50 year planning horizon might be a more reasonable target to reflect a longer life expectancy and to allow a buffer in the event of anticipated rapid erosion.

Where development does not accommodate changes in beach formation, the potential for property damage is greatly increased. Although patterns are by no means consistent and many areas are presently accreting, the dominant trend along the Atlantic and other ocean coasts has been one of gradual long-term recession. In addition, and perhaps more significant in terms of property loss, there has been short-term erosion caused by ocean storms or by changes in sand transport patterns, be they natural or man-made changes. Where shoreline migration is allowed to run its course, dune and beach systems often are stabilized considerably seaward of their inland penetration. Erosion control structures and building foundations, on the other hand, often prevent natural adjustment processes, lending instability to the immediate beach system. Furthermore, threatened homes and commercial establishments encourage the use of structural solutions which may provide immediate relief but which may also contribute to long-term erosion inflicting cost on the owner and neighboring property owners. Internalization of these costs require either a method of private compensation or of land use controls restricting use of long-term erosion control structures or of discouraging unwise building patterns. The latter of these two options is the less costly long-term solution as property is removed from potential hazard areas.

A number of states and communities have instituted coastal setback laws either precluding or requiring a variance for location seaward of the line. Criteria employed include but are not limited to: flood maps and storm history, past erosion rates, site specific observation, or some combination of the above. The legal foundations for such laws are the police power of the state while their general intent is to protect the health, safety, morals and general welfare of the community.

Present property owners i.e., those having structures in place, are generally exempt from such provisions, having built under earlier institutional arrangements. New construction must be treated in a universal fashion to prevent or minimize the loss of view which often encourages building at the front of waterfront lots. Additionally, the alleviating of potential loss also alleviates the need for short-term 'bandaid' solutions which may have detrimental long-run effects.

The taking issue associated with zoning law is discussed in greater detail in Chapter V. In general, the courts have maintained that set-back laws do not constitute a taking. Yet, where reasonable use of the land is precluded, public acquisition should be an available option. The loss of private discretion through land-use control is balanced against the public interest. Because of the fragile nature of the coastal system in terms of both physical and biological resources, individual actions may be community-wide in their effect. Optimal solutions require that external costs be internalized where possible;

where they cannot be internalized, potential social costs should be minimized where doing so does not seriously restrict private property rights.

The second peculiar cost associated with coastal development cited previously is the cost of information. The science of coastal geomorphology is most complex. With the number of variables influencing beach formation, extensive research activities are often necessary to explain coastal processes influencing long and short-term shoreline patterns. As such, an understanding and appreciation of these processes is generally lacking among potential buyers. It is, therefore, in the public interest to disseminate information to both individuals and to local communities through technical assistance programs. In addition, although setback provisions are restrictive, they serve as a line of demarcation and information system indicating high hazard potential. Individuals, based on this information, are allowed then to build at or beyond the setback line depending upon their aversion to risk.

With the last point having been made, we come to the final identified cost that must be incorporated to assure proper resource utilization. Because the oceanfront is a hazardous area, the risk associated with location in such areas is substantial. Still public policy has effectively minimized risk through programs such as Federal Flood Insurance and Disaster Relief. As a result, individuals often undervalue the potential loss of building in hazard areas while significant federal and private insurance payments are required to correct for this situation. Unlike the spillover costs discussed previously, risk can be internalized, i.e. borne by the property owner, given adequate information. More effective use of coastal resources can be obtained where private property owners incorporate the full cost of development into their decision-making process. The public sector in turn, should provide a framework which corrects and/or minimizes social costs and provides information. At the same time, the framework should encourage individuals in making personal decisions to pursue objectives consistent with stated public policy.

FOOTNOTES

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2. Final Evaluation of Stormwater Runoff Control Alternatives for the Myrtle Beach Stormwater Study submitted to Waccamaw Regional Planning and Development Council by Moore, Gardener and Associates, Inc., Consulting Engineers, Surfside Beach, S. C., March, 1980.

3. The Hilton Head Island Chamber of Commerce, Based on estimates by Donald Hobart, Sea Pines Plantation, Hilton Head Island, S. C., 1979.

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11. Ibid., p. 74.

12. Ibid.

13. South Carolina Department of Parks, Recreation, and Tourism, The Dynamic Impact of Tourism and Travel on the Economy of South Carolina, Columbia, S. C., 1978.

14. South Carolina Department of Parks, Recreation, and Tourism, ibid. Much of Charleston's tourism is admittedly not tourism related. Nevertheless, the dominance of these coastal communities to the state's tourism industry seems obvious.

15. Estimates taken from samples of beachfront and second row lots at Myrtle Beach based upon the 1979 Horry County Tax Assessment.

16. Once development occurs with spinoff activities, the direct effect of the beach may become less important. Restaurants, nightclubs, and golf courses may become, to some individuals, as important in attracting visitors. Nonetheless, the initial and predominant caused effect seems clear.

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U. S. Department of the Interior. Office of Heritage Conservation and Recreation Service. Report of the Barrier Island Work Group.

CHAPTER V

PUBLIC POLICY TOWARD EROSION CONTROL

Because the negative effects associated with coastal development have intensified only in the last century, public policy in this regard evolved slowly with programs generally instituted in piecemeal fashion. Recently, however, policy makers at all levels of government have begun to reevaluate existing programs and to seek more effective measures of control for natural hazards. The following chapter will examine the existing institutional framework at the federal, state, and local level and explore a variety of policy options being considered.

Federal Policy

Federal responsibility for erosion control traditionally has been that of the U. S. Army Corps of Engineers. Present federal policy in this regard has been shaped largely through passage in succession of the Federal Flood Insurance Act (1968), the National Environmental Policy Act (1969) and the Coastal Zone Management Act (1972). Proposed Barrier Island Legislation in Congress has been delayed but may in its present or altered form significantly impact federal policy along the coast.

The Corps of Engineers

The Corps' powers with regard to erosion control were broadly interpreted from Congress' initial authorization of navigation improvement projects in 1824. The scope of Corps projects broadened over time including specific authorization for shore protection projects in 1946. Although major attention in the past has been given to engineering criteria, the Corps has begun in recent years to incorporate a more sophisticated management approach including a committment "that the social consequences of contemplated water resource development actions be considered and taken into account during the planning process."[1]

The Corps is presently involved in a number of beach protection/restoration projects. These projects are restricted by law to the restoration of beaches to their historic limits, i.e. new beach areas are specifically forbidden. As with all such federal programs, all beaches receiving erosion control benefit from federal projects must be open to use by the public. Projects providing hurricane protection are exempt from this requirement, although multiple-purpose hurricane protection and beach control projects may justify further federal support.

The Federal Flood Insurance Program

The Federal Flood Insurance Program is administered by the Federal Insurance Administration (FIA). The goals of the program are "to encourage state and local governments to make appropriate land use adjustments to constrict the development of land which is exposed to flood damage and minimize damage caused by flood losses," and "to . . . . guide the development of proposed future construction, where practicable, away from locations which are threatened by flood hazards."[2] As noted in an earlier section, neither of these goals appears to be met at the present time.

In part, because of concern over the effectiveness of the program, the Federal Insurance Administration was transferred to the Federal Emergency Management Agency (FEMA) by Executive Order 12127 on April 1, 1979. Still, FIA retains its identity as an agency within FEMA. Internal review of the program is currently being conducted and reauthorization of the Agency before the next session of Congress will provide a significant gauge of Congressional attitudes and future federal policy. At question is the role of the federal government in sharing the risk associated with coastal development.

The Coastal Zone Management Program

The Coastal Zone Management Act of 1972 (CZMA) represents a statement of need and desire to provide wise management of the nation's resources. The Act includes provisions for coordination of federal and state activities in the coastal zone. To do so, it employs incentives for states to develop comprehensive management programs; federal funding is provided to develop and implement programs which meet standards established by the Secretary of Commerce. Provisions for federal/state consistency are included in the Act which states that:

1) each federal agency conducting or supporting activities in a manner which is to the maximum extent practicable, consistent with approved state management plans, (Section 307(c)(1)), and

2) federal agencies shall not approve proposed projects that are inconsistent with the coastal state's management program, except upon a finding by the Secretary that such a project is consistent with the purposes of this title or necessary in the interest of national security. (Section 307(d)).

The 1976 Amendment to CZMA includes more specific language with regard to shoreline erosion/mitigation planning. Section 305(b)(a) mandates that:

> The management program for each coastal state include. . . a planning process for A) assessing the effects of shoreline erosion (however caused), and B) studying and evaluating ways to control, or lessen the impact of, such erosion, and to restore areas adversely affected by such erosion. (Federal Register 923.25).

Provisions of the Amendment addressing erosion control are included in Appendix A. The program must include a method for assessing the effects of shoreline erosion and of techniques for controlling this erosion. It must also identify and describe "enforceable policies, legal authorities, and funding techniques" to be used in erosion management (Section 305(c)(2)). As such, the CZMA provides the framework for state and federal committment relating to erosion control and management.

New Directions in Federal Policy

In his Environmental Protection Message of May 23, 1977, President Carter outlined policy with respect to barrier islands indicating that:

> . . . barrier islands are a fragile buffer between wetlands and the sea . . . Many of them are unstable and not suited for development, yet in the past the Federal Government has subsidized and insured new construction on them. Eventually, we can expect heavy economic losses from this shortsighted policy.

The designation of 1980 as the Year of the Coast is symbolic of a new awareness of the importance and fragility of the coastal ecosystem. Perhaps more importantly, the introduction of Barrier Island Legislation in both houses of Congress reflects a clear departure from past federal policies. The House Bill (HR 5981) introduced by Rep. Phillip Burton (D. Calif.) would provide for federal protection of undeveloped barrier islands. The legislation would empower the Secretary of the Interior to acquire undeveloped islands or undeveloped portions of developed islands and place them in a National Barrier Islands Park System. The bill would further prohibit federal assistance on undeveloped islands for roads, airports, erosion control projects and reconstruction of privately owned buildings after natural disasters. A grandfather clause would exclude existing development.

Of some 300 barrier islands, 184 will be wholly or partly included within the map of "Barrier Island Units of the National Park System."[3] A major criticism of the bill has been the failure of sponsors to produce a cost estimate for acquisitions in a time of fiscal conservancy. Proponents argue that the total cost of acquisition will be substantially less than will be expended for development and hazard mitigation based on present trends. In Congressional testimony, Crane Miller, an outspoken advocate of the concept, estimated that "the cost of land acquisition authorized by the bill is conservatively estimated to be less than one-fifth of the federal costs for access, infrastructure, and disaster relief than if the same islands were developed to less than half their potential (44%)."[4] Purchase of undeveloped sections of previously developed islands would considerably raise the cost, and no concensus has been reached as to the appropriate price to be paid property owners. In addition, no estimates of loss from removing these lands from extensive use or of providing public access for 'optimal' use have been made. Still, the realization that lands can be purchased by the federal government for less than is being paid in terms of subsidization for intensive development is a sobering indictment of past federal policy.

The Senate Bill (S. 2686) sponsored by Senator Bumpers (D. Ark.) does not provide for acquisition. Like the Burton Bill, it does forbid the use of federal subsidies for islands comprising the "Barrier Islands Protection System." The bill additionally establishes a Barrier Islands Advisory Council to be chaired by the Secretary of the Interior and to include representatives of 15 federal departments or agencies. The functions of the Council would be to provide for coordination and consultation among agencies to assure a consistent federal policy with regard to barrier islands and to study and make recommendations with respect to regulation and management plans.

The thrust of the two bills reflects a strong yet rigid committment to conservation. Little attention is paid to the wise use of currently developed beaches nor to making undeveloped lands available for use in either a public or private framework. In addition, control is vested at the federal level rather than at the state level as designed under the Coastal Zone Management Act. It seems obvious that a greater federal committment is necessary as state consistency review is politically difficult in the face of lucrative federal programs which may conflict with state coastal programs. Until a federal conscensus is achieved, states, whether they wish to or not, will be required to assume major responsibility with respect to beach management. It is to the role of the state that we now turn.

State Policy

Coastal policy in many states has been clouded historically by legal questions as to tidelands ownership, i.e. with regard to lands lying below or seaward of mean high water. Major attention to the issue of coastal erosion control has evolved over the past decade with the primary catalyst being the Coastal Zone Management Act of 1972. Prior to this time, some attention was given to dune protection, and broad guidelines were drawn with regard to engineering works, yet legislation pertaining to coastal conservation and resource management was sparse.

Policies Employed by Other Coastal States

In 1970, Florida passed a statewide construction setback law requiring that any construction on excavation must be at least 50 feet upland of mean high water. The following year a second piece of legislation extablished a basis for the Coastal Construction Control Line to remedy inadequacies and problems of enforcement with the earlier act. The primary emphasis of the law is that area seaward of the construction control line should not be disturbed nor constructed upon. In its defense, the act explains that "establishment of a control line does not preclude reasonable use of coastal property . . ." (16 B - 33. 05).

A permit system was established to provide variances where "reasonable" exceptions are warranted. Applicants must prove that the exemption is reasonable before a Review Board or the Executive Director of the Department of Natural Resources. In no cases, however, shall the Department "contravene setback requirements on zoning or building codes established by a county or a municipality which are equal to, or more stringent than, the requirements provided herein." (16 B - 33.06). Seven counties, some islands and several keys were made exempt from the permit requirements of the act.

Since 1972, a number of other states have developed or proposed programs. In Hawaii, the Shoreline Setback Law prohibits development within 40 feet of the shoreline; while in the Territory of Guam, the Seashore Protection Act strictly limits construction within 10 meters of the shore. The Texas Setback Law designates critical dune areas and provides a basis for local governments to establish setbacks. North Carolina's Coastal Zone Management Law identifies "Ocean Hazard Areas" as beaches, frontal dunes, inlet lands, and any other areas subject to excessive erosion flood damage. The boundaries for the areas fall between mean low water and the extent of shore which is subject to erosion or change in the next 50 years (Section .0300). Still more recently, ambitious programs have been proposed in Alabama, and the New Jersey Plan is the most elaborately developed to date including a single. Special Area Policy (7: 7E-3.19) relating to beaches, high risk erosion areas, overwash areas, and dunes. Although New Jersey has had an erosion planning process in place for a number of years, the primary statutory basis for the present Shore Protection Master Plan is the 1977 Beach and Harbor Bond Issue.

Increasingly, states have indicated a preference for non-structural solutions including regulatory and management provisions. The extent and manner of implementation of coastal land-use restrictions vary by state. Programs in Rhode Island and New Jersey, for example, represent examples of strong state-level administration, while in California, the state and the Regional Coastal Commissions permit development in erosion as well as earthquake-prone areas. Maryland encourages localities to establish erosion control districts with programs meeting state guidelines; state funding is used as leverage. Similarly, Washington State mandates local jurisdictions to prepare "Master Programs" which may address a variety of options including shoreline setbacks.

Policy in South Carolina

Erosion control policy for the State of South Carolina is identified in the State Coastal Management Act of 1977. The act designates the South Carolina Coastal Council as the responsible party for management and regulatory activities in the coastal zone. A regulatory program was established "for the purpose of promoting the public health, safety and welfare, and the protection of public and private property from beach and shore destruction."[5] It provides for permit authority within critial areas, i.e. seaward from the trough behind the primary dune line. In addition, Council is granted responsibility to develop and implement a comprehensive beach erosion control program and permit jurisdiction over erosion control and water drainage structures not otherwise covered by the law.[6] Council is also designated as the authority to accept federal monies and to administer state monies allocated for erosion control.

The South Carolina Coastal Management Program (SCCMP) was approved in 1979. The program states a preference for non-structural solutions where possible, employing the natural sand deposits and flood protection of dune systems. It is further stated that dunes should be protected and preserved and that buffer areas should be established where possible to allow for their "natural movement and growth."

The SCCMP identifies considerations that must be addressed before erosion control projects can be approved (Section IV C(4)(b)). These items include:

1) The type of materials employed, their useful life expectancy along with anticipated maintenance and replacement costs;
2) Rate of rise or fall of sea level at the location;
3) Sediment transport and sand budget in the project area;
4) The economic justification of the proposed project in comparison with available erosion control alternatives including consideration of the anticipated damage and economic loss due to failure;

5) Extent of up or downdrift damage due to installation or lack of installation of the erosion control structure;

6) The extent to which the project fits into a comprehensive shore protection program for that particular stretch of beach, aimed at preserving the beach profile in its present slope and configuration.

In addition, the policy of Council with regard to specific erosion control activities is identified in Section IV C(4)(c) which is included as Appendix B. A revised plan entitled Specific Project Standards for Beaches and Dunes has been drafted but has not been approved as of this writing. The plan includes similar language to that contained in the previously cited Erosion Control Policies (Section IV C (4)(c). In addition, evaluation criteria are specified including: 1) the requirement that the best available data on sediment and sand budget A (1) (a), 2) the preference for natural features as opposed to artificial protection A (1) (b), and 3) requirements that public access be assured and protected if state monies are committed. Similar provisions are contained in the SCCMP under Funding Policies (IV C(4)(a)) and General Considerations (IV C(4)(b)).

The inclusion of state policy and funding considerations as a preface to the design considerations outlined is appropriate. If the intent of the standards is to incorporate state policy on erosion abatement including funding provisions, the policy should be stated more clearly. Included should be a clear identification of the state's long-run policy with respect to erosion control. The wording might state that the primary aim of the state is to provide for maximize enjoyment of the state's beaches in a manner consistent and not in opposition to coastal processes.

Although included in the SCCMP, the revised standards do not require that the project be economically justified from the state's perspective before state monies are expended, and no requirement is made that the best available data and methodology be employed in balancing in accessing the economic feasibility of the project. Further discussion of funding arrangements is reserved for a later section.

Finally, to assure consistency with state programs, it is recommended in the State Management Plan (SCCMP IV - 59):

> 1) The Council recommends that local governments in shoreline areas institute shorefront construction setback lines as part of their land-planning activities and/or local building codes, subdivision regulations, or zoning ordinances.
>
> 2) Private property owners and developers are encouraged to consult with the Council or with technical consultants to learn the erosion trends and shoreline dynamics in their particular area before initiating construction.

The incorporation of local entities into the management plan is the subject of the following section.

Local Policy

Effective management to lessen the damages inflicted by coastal hazards requires active involvement of local jurisdictions. The intent of Federal and State Coastal Zone Management Programs has been to delegate as much authority as possible to coastal communities under the assumption that local government can achieve maximum responsiveness to local conditions, better accountability, and greater public accessibility. The actual level of involvement is largely subject to state and local discretion as incorporated in state management plans or amendments thereto.

The California Coastal Program provides a particularly active role for local governments. Each local government in the coastal zone (15 counties and 53 cities) prepares a Local Coastal Program. Programs may be prepared by either the local government or the State Coastal Commission although preference is given to the former entity to allow local interests to dictate policy as long as the guidelines of the state program are met. Regional commissions also participate in a review and advisory capacity.

The State of Washington is continuing to enhance the role of local governments in the areas of program administration and enforcement. Local masters programs are currently being revised and refined. Other states including Oregon, Maryland, and North Carolina require local governments to prepare local management plans in order to participate in all or specific areas of the state program. In Alaska, district programs have been developed; while in Florida, regional planning councils play an active role.

The South Carolina Coastal Management Program provides a basis for local involvement, and the State Coastal Council provides technical support to local governments in developing either specific or comprehensive programs. Yet, as the South Carolina Program is relatively new by national standards, the extent of local program development remains limited at this uniting. Particularly with respect to erosion control the development of local programs should be strongly encouraged. Not only can it be argued that local interests by right should have the greatest input in the structure of community identity, but, as in most states, land-use in South Carolina controls are vested at the local level.

Through enabling legislation, local jurisdictions in South Carolina are delegated the police power to zone (47 - 1001 et. and more recently . 14 - 350. 16 et. seg). As the critical region for state jurisdiction extends, at most, only to the trough of the primary dune and with respect to erosion control structures affecting public interest, for it is appropriate for local governing bodies to supplement state permitting activities as a means of limiting spill overs effects along the beachfront. To date, Beaufort County has introduced the notion of Beach Development Districts, while the City of Myrtle Beach and Town of Folly Beach are drafting programs at this time.

On September 11, 1978, Beaufort County adopted a Development Standards Ordinance. In addition to the standard purposes of a zoning ordinance, the intent of the Beaufort Ordinance is "to preserve the environmental, historical, and social heritage and character of Beaufort County . . ." (Art. 1). The ordinance as is the current trend in land-use planning, establishes special districts relating to:

1) Conservation,
2) Beach Development, and
3) Flood Hazard

More specifically, with respect to beach areas, the ordinance protects sand dunes and dune vegetation (4. 3. 2. 1 and 5. 3. 2. 4). Public access to the beaches is guaranteed and must be provided using elevated walkways (4. 3. 2. 2). In addition, "Public beach access shall be provided by the developer for any development including more than one-thousand (1,000) feet of beach frontage . . ." (5. 3. 2. 2).

Later, the ordinance reads: "No development shall be undertaken that directly or indirectly increases the erosion of land or its potential for erosion" (5. 2. 7). Perhaps the most significant provision reads: "No structure will be constructed within 75 feet landward of mean high water or 40 feet landward of the crest of the primary dune except for beach pavilions of less than 400 square feet elevated with pilings; beach boardwalks or structures whose specific purpose is to protect or improve the beach and dune." (5. 3. 2. 4). This section outlines the guidelines for a beach setback line, the principle details of which are included in deeds for beachfront property as covenants or deed restrictions. Reasonable variances are provided, and, in general, permits are issued on an administrative rather than a quasi-judicial basis.

Local ordinanaces of this type are consistent with state policy and provide a framework for more effectively managing development in erosion prone areas. Where possible, setback lines should incorporate scientific information to allow for highly erosional zones along the beachfront or in inlet areas which may display volatile rates of erosion. In addition, particular care should be taken to assure that loopholes to development do not exist. In the Beaufort Plan, for example, some question remains as to jurisdictional responsibility where maritime forests replace the primary dune as the first landmark. Such a situation suggests that the area is highly unstable and not an appropriate building site.

As state and local interests overlap with regard to erosion control, it is appropriate that consistent policies be pursued. Local and state permit authority may overlap with regard to dune management, erosion control structures, and public access. Land use authority beyond the primary dune line is currently the primary responsibility of local entities. For technical reasons and perhaps more importantly to shelter local zoning boards, serious consideration should be given to state as well as local review of building setbacks along the oceanfront. The initiative might be taken either locally or at the state level. A further discussion of this arrangement is included in the following section and in the following chapter under legal considerations.

The funding of coastal erosion control projects is a relatively new and complex process. Public monies may be provided on a federal, state, or local level in accordance with certain policies and requirements as follows.

Funding Responsibility

Public responsibility for funding erosion control projects rests collectively with federal, state, and local authorities. Involvement and level of funding committment vary with the type, location, and impact of the project being considered. The following section summarizes funding criteria appropriate at each jurisdictional level.

Federal Responsibility

Under existing legislation, Congress has authorized the U. S. Army Corps of Engineers to conduct beach erosion control projects. Corps involvement is restricted to shores owned by the Federal Government, other public entities, or private entities when the shore is open to public use. The intent of this legislation is to prevent or control shore erosion caused by wind and tidal generated waves and currents along the coasts and shores. Such adverse effect extends only the distance up tributory streams where it can be demonstrated that the dominant causes of erosion are ocean tidal action and wind generated waves. Federal participation is limited to restoration of the historic shoreline.

The determination of local cost is based on the public use and ownership of the beach protected. The federal participation cannot exceed one million dollars. Federal participation is 50 percent of the first cost of protection of shores owned by non-federal public agencies, exclusive of land costs. Protection of certain shores not publicly owned may be eligible for federal cost sharing up to 50 percent provided it can be shown that there would be significant public benefits arising from public use or from direct protection of nearby public facilities.

Under special conditions, beach erosion protection is eligible for federal cost sharing up to 70 percent of the total project cost, exclusive of land costs. In order for the maximum 70 percent federal participation to be applied to parks and conservation areas, all of the following criteria must be met to the satisfaction of the Corps:

(a) The land must be publicly owned.

(b) The park must include a zone extending landward from mean low water line which excludes all permanent human habitation. This excludes summer residences but not residences of park personnel and administrative buildings.

(c) The park must include a beach suitable for recreational use.

(d) The park must provide for preservation, conservation and development of the natural resources of the environment.

(e) The park or conservative area must extend landward a sufficient distance to include protective dunes, bluffs or other natural features which will absorb and dissipate wave energy and flooding effects of storm tides.

(f) Full park facilities must be provided for appropriate public use.

No federal contribution toward project maintenance is authorized.

However, federal participation may be made toward periodic beach nourishment when found to comprise a more suitable and economical remedial measure for beach erosion control than other construction (U. S. Department of the Army, 1975.)

Legislation does not specifically define federal interest in projects to protect against hurricane, abnormal tidal and flood damage. In accordance with the President's proposed cost sharing policy, projects for Hurricane, Tidal and Flood Protection require the local sponsor to contribute 20 percent of the construction cost. Previously this program also had a 70 percent federal share limit. Successful protection against hurricane and tidal flooding on the open coast frequently requires that the shoreline be concomitantly stabilized against erosion. For multiple-purpose hurricane protection and beach erosion control projects, Section 208 of the 1970 Flood Control Act provides discretionary power to the Secretary of the Army to authorize a federal share up to 70 percent. (Massoni, 1980).

Specific administrative rules on cost sharing can be promulgated by the Office of Management and Budget, the Water Resources Council and the Secretary of the Army. Before Congressional authorization of a Corps project, a District Engineer prepares a document with recommendations for federal involvement. Along with these recommendations, the District Engineer will suggest a cost sharing ratio to the Congress through the Chief Engineer. This ratio can be changed at any point, prior to authorization, but recommendations of the District Engineer are typically approved.

State Responsibility

The Office of Coastal Zone Management requires participating states to include an erosion planning process in their coastal management programs. In the Federal Register, Vol. 44, No. 61, March, 1979, Section 923.25* states that funding responsibility must be considered in their management programs:

> "There must be an identification and description of enforceable policies, legal authorities, funding techniques that will be used to manage the effects of erosion as the state's planning process indicates is necessary."

In 1977, the South Carolina Coastal Council was established as the responsible party for management and regulatory activities in the coastal zone. Included is the authority to accept federal monies and to administer state monies allocated for erosion control. Decisions on funding beach erosion control must be based on careful reasoning and follow approved funding policies at both the federal and state levels. Section IV C(4) (a) of the South Carolina Coastal Management Program describes state funding policies:

1) Public funds can be expended for beach or shore erosion control only in areas, communities, or on barrier islands to which the public has full and complete access (as defined in the shoreline access segment of the program).

2) Public funds can be expended only for beach erosion control measures which are deemed by the Council to be consistent with the Beach Erosion Control Policies in this section and any applicable rules and regulations promulgated pursuant to the Act.

3) Public funds can be expended only for erosion control measures which are consistent with the overall coastal management program.

*See Appendix

4) Funding for particular erosion projects shall be approved by the Coastal Council only after adequate consideration has been given to the erosion control problems and needs of each coastal county and the relative benefits of the particular project.

5) Consideration will be given to the extent to which the proposal will maximize the protection of public health, safety, and welfare.

6) For expenditure of public funds, the full range of alternative erosion control measures which are possible, including no action, must be studied. Before decisions are made, consideration must be given to the long and short-range costs and benefits of the various alternatives.

7) Removal or modification of existing publicly-funded control structures will be authorized by the Council based on the applicable policies in this section and determination that the structure has an adverse impact on the public interest, as mandated by Section 12(C) of the Act.

Act 1377 of 1968 (State Capital Improvement Bonds) as amended in 1978, provides $600,000 of state monies for beach erosion or groin repair to be managed by the State Coastal Council. The Coastal Council may allocate the funds provided that equitable consideration to the relative needs of the coastal counties is considered, provided that public access is maximized (no funding is allowed in any beach area not accessible to the public), and provided that consistency with federal funding is achieved.

At present, the state share is 90 percent of non-federal expenses, with the remaining 10 percent of costs being met locally. The funding criteria as defined in Section IV C(4)(a) of the State Management Plan must be met before funds are committed.

Local Responsibility

As erosion control projects are often expensive, communities may be strained to raise the local match even with the state meeting the majority of the non-federal share. Present enabling legislation allows municipalities in South Carolina six options to raise local matching funds. Sources for these funds include:

1) property tax,
2) licensing fees, franchise fees and fines,
3) user charges,
4) bonding (restricted largely to capital improvement projects),
5) state shared revenue (e.g. beer and wine taxes and gasoline tax), and
6) federal grants-in-aid.

Although property taxes may offer the greatest potential revenue source at the municipal level, beach communities may have an inadequate tax base. Meanwhile, county-wide assessments may be inappropriate as the tax burden should rest more heavily on beach-front property. User charges where collection costs are reasonable should be explored as a means of assessing costs of beach maintenance on beach users. Public parking fees offer an appropriate source of such funds.

Existing South Carolina legislation does not permit local sales or income taxes nor does it permit the adoption of an accommodations tax. However, a Local Option (one-half cent) Sales Tax Bill (S-2) has been prefiled with both the South Carolina State House and Senate for consideration during the 1981 session. As currently designed, if a local government opts for the local sales tax (municipalities may opt for this tax even if their county does not), 85 percent of the yield must be used to "roll back" local property taxes. The remaining 15 percent of the yield is discretionary and could be used for local match. The bill would provide for the use of more than 15 percent of the yield, however, if these funds are used for bond reduction.

A local options accommodations tax is also being drafted and will be filed with the legislature early in 1981. It is the opinion of legislative observers that the proposed bill will state that the proceeds from the accommodations tax must be spent on tourist related activities. Since erosion abatement can probably be tied quite closely to tourism in most of our coastal communities the passage of a local options accommodations tax bill could provide a major source of revenue for local match requirements. It is not anticipated that support for this bill will be as broad based as for the local options sales tax. Yet, both of these potential revenue sources offer the advantage of shifting tax burden more appropriately to beach users to whom the greatest benefit accrues.

FOOTNOTES

1. United States Department of the Army, Office of the Chief of Engineers, "Digest of Water Resources Policies", January 1975.

2. United States Constitution, Section 4002(e).

3. United States Department of the Interior, National Park Service, "Barrier Island Units of the National Park Service", 1980.

4. H. Crane Miller, Testimony before the Committee on Interior and Insular Affairs, U. S. House of Representatives, March, 1980.

5. United States Department of Commerce, Office of Coastal Zone Management, "State of South Carolina Coastal Management Program and Final Environmental Impact Statement", Section IV C (6), 1979, p. IV-6

6. Ibid.

CHAPTER VI

LEGAL CONSIDERATIONS

Authority to Regulate Erosion Control Activities

Regulatory authority over various methods of erosion control exists at all levels of government; federal, state, and local. Federal authority derives from the commerce clause of the Constitution of the United States[1] which vests in Congress virtually complete power over all matters affecting interstate commerce.

Congress has enacted several pieces of legislation[2] dealing directly with erosion of ocean beaches. First, the Federal Rivers and Harbors Act,[3] as modified by the Federal Water Pollution Control Act Amendments of 1972,[4] authorizes the U.S. Army Corps of Engineers to regulate any activity which affects the navigable capacity of waters of the United States. Erosion control structures, to the extent they affect navigation, are thus subject to regulation by the Corps. Dealing more specifically with erosion of ocean beaches is the Federal Coastal Zone Management Act[5] which expresses federal concern with the problem and directs the coastal states to address it in their coastal zone management plans. As a practical matter then, Congress has left development and implementation of beach erosion policy largely to the coastal states.[6]

State authority over beach erosion derives from two sources. The State of South Carolina, as is the case in many other coastal states, generally owns land seaward of the mean high tide line.[7] Power thus exists to control any encroachment on state owned submerged land and waters, and construction of structures such as groins and seawalls is subject to regulation by the state. In other areas, the general police power confers broad powers to control any activity affecting the public health, safety, and welfare. Because of the obvious effect of beach erosion on property values, it is subject to state regulation.

Based on these powers, the South Carolina General Assembly addressed the problem of beach erosion, along with other issues of coastal management, in the South Carolina Coastal Management Act of 1977.[8] The legislation directs the Coastal Council to "develop and institute a comprehensive beach erosion control policy"[9] and empowers the Council to issue permits for erosion control structures "on or upon the tidelands and coastal waters"[10] of the state and to remove "all erosion structures which have an adverse effect on the public interest".[11] The statute thus establishes a permitting system for erosion control structures on state owned land or waters (tidelands and coastal waters) and asserts control over all existing structures, regardless of location, if their existence adversely affects the public interest. Regulation over erosion control structures not on state land or waters but in "critical areas" can be accomplished under the general permit provisions of the Act.[12] Non-structural approaches to erosion control such as construction setback lines are not specifically authorized by the Act.

To the extent that zoning concepts can be applied to the control of beach erosion, counties and municipalities have the authority via zoning regulations to exercise controls.[13] The General Assembly had delegated broad zoning powers to local governments,[14] and it is clear that techniques such as setback lines can be adopted by local zoning authorities. In addition, any zoning requirement which applies to "critical areas" under the South Carolina Coastal Management Act is subject to incorporation into the Coastal Council's management plan.[15] In effect, a local zoning regulation affecting property subject to beach erosion, if consistent with state policy, can become part of the state coastal management plan and be enforced by the Coastal Council.

In summary, there is adequate power to regulate beach erosion control methods, structural or non-structural. While primary responsibility for the problem has been assumed by the General Assembly, it has not acted to the fullest extent of its authority. Non-structural solutions have not as yet been addressed by the Legislature and, consequently, the Coastal Council has no authority to proceed in this area.

Problems Associated with the Control of Beach Erosion

Non-Structural Solutions and the Taking Issue

As discussed above, the South Carolina General Assembly has authorized setback lines as a land use control device which may be employed by local zoning authorities. The constitutionality of legislation authorizing setback lines has been established since the United States Supreme Court upheld use of the technique in Goreib v. Fox.[16] The general validity of setback lines rests on several factors. First, a setback line, since it prohibits use of only a portion of the property, has minimal impact and allows beneficial use of the remainder of the land. Secondly, restrictions on the owner's use of his land are generally considered to be balanced by benefits such as uniformity of appearance and assurances of space for light, air, and recreation. Finally, considered on a community-wide basis, setback restrictions are considered as contributing to the public good by furthering health, safety, and welfare. These same considerations have resulted in the upholding of the constitutionality of the setback concept in South Carolina.[17]

Setback lines are currently used in several coastal states as a method for restricting construction in areas with critical beach erosion problems.[18] The constitutionality of setback lines specifically for preventing erosion damage has been upheld in Spiegle v. Borough of Beach Haven.[19] The New Jersey Supreme Court there upheld a local ordinance which established setback lines for oceanfront property subject to severe storm damage. The court concluded that in light of the possible property losses setback restrictions could prevent, their benefit to the public outweighed any decrease in the plaintiff's property values. Significantly, the court stated that even though the effect of the setback ordinance might be to prohibit all construction on a particular piece of property, that alone was not sufficient to support a claim of unconstitutional taking. The owner, to sustain such a claim, must also show that no beneficial use could be made of the property as a result of the setback line. Construction of a building likely to be damanged or destroyed by future erosion was not viewed by the court as a use bringing real economic benefit to the landowner. In a companion case where the landowner was able to demonstrate that a proposed building would be economically feasible and able to withstand storm forces, application of the setback line to prevent construction of the building was held to be a taking.

The Spiegle decision is of course significant for its upholding of the constitutionality of setback restrictions for the purpose of protection against property loss from beach erosion. Because of the general use of setback restrictions in the United States and in South Carolina, its application to oceanfront property here most likely would be viewed favorably by the courts. Less clear is whether South Carolina courts would uphold the validity of setback restricitions on facts as extreme as the Spiegle decision -- this is, where the landowner's property is not deep enough to allow any significant construction landward of the setback line. While there are South Carolina cases suggesting that a zoning scheme which depreciates property values is not a taking merely because of the decrease in value itself,[20] there has generally been another use which could be made of the land (for example, use as a residence but not as a business).

While setback lines appear to be a viable approach to prevention of property damage from erosion oceanfront property,[21] there likely will be individual cases where courts will find application of the restriction unconstitutional. Such a case may occur where the restriction totally precludes construction on the property or so significantly reduces the owner's options (building a small house where larger homes would be allowed on adjacent property) that he is placed at a significant disadvantage relative to adjoining property owners.

Engineering Solutions

Liability for Damages Caused by Engineering Approaches

It is of course possible that construction of an erosion control structure at one point on a beach will result in damage to another property owner, perhaps by increasing erosion rates at the adjacent site. If these circumstances arise as a result of a structure approved by the Coastal Council, the question becomes one of whether the state may be liable for approving a structure whose propensity for causing damage should have been foreseen. A corollary issue is whether the landowner having the structure built could be liable.

Controlling the first issue is the existence of the sovereign immunity doctrine in South Carolina.[22] The state and its agencies cannot be sued unless permitted by statute or unless state action results in a taking of property without just compensation. On the question of authorization of suit against the state, the South Carolina Coastal Management Act of 1977 is silent; however, Coastal Council regulations specifically state that "in no way shall the State be liable for any damage as a result of the erection of permitted works."[23] While administrative interpretations are not binding on the courts they are persuasive, and in light of the absence of a specific statutory waiver of immunity in the Coastal Management Act itself, there is little likelihood that damage suits would be permitted against the state as a result of Coastal Council action.

State liability for damages caused by permitted erosion control structures, if it exists, must then be based on the taking of property.[24] While direct confiscation by the state of privately held land to control erosion would clearly support a taking claim, situations not involving a direct physical invasion, but which do cause damage, are more troublesome. The law is relatively clear that such non-trespassory invasions can be takings, prime examples being government owned airports whose externalities so interfere with the use and enjoyment of surrounding land that property values are diminished.[25] Construction of an erosion control structure which physically interferes with adjacent property by increasing erosion rates arguably is an analogous situation if the structure is state owned and on state land. No cases appear to exist directly on this point and the issue is unresolved.[26]

Liability of private property owners is somewhat clearer. In general, ordinary priciples of tort law apply to the design, construction, and effect of erosion control structures. Assuming the elements of the case can be established, an owner or contractor could be liable in negligence or nuisance if the structure damages adjacent property. Specifically, if damage should have been foreseen in light of available information then a private action could succeed. Difficulties seem to lie more with proof than with the theory of liability itself. Sand transport processes are complex and affected by so many factors that it might be difficult to establish that erosion or other damage is the result of an erosion control structure and not due to some other combination of factors. Assuming adequate proof, however, improper design, construction, or location of an erosion control structure which causes damage could subject either the property owner or builder to liability.

Ownership of Accreted Land

Assuming that erosion control structures are successful, there may be incidences of beach accretion significant enough to raise the question of ownership of the newly formed beach. This problem may be of special significance if the accreted land becomes deep enough to permit new development. The South Carolina Coastal Management Act of 1977 specifically addresses this point. S.C. Code 48-39-120 provides that "no property . . . accreted as a result of natural forces or as a result of permitted structures shall exceed the original property line or boundary" and that accreted property ". . . shall remain the property of the state held in trust for the people of the state." The statute also prohibits development of accreted property ". . . beyond the mean high water mark as it existed at the time the oceanfront property was initially developed."

The provision clearly seems designed to prevent development of any kind on accreted land and does so by attempting to vest title to the land in the state and by directing the Coastal Council to permit no development. Several justifications for this position can be raised. Public access to beaches is protected under this approach. It also insures a structure-free zone in areas where the beach is shifting, thus minimizing the possibility of property damage if the newly accreted land is subsequently eroded.

There exists judicial authority for this position. California courts have viewed accreted land as part of the tidelands trust with title to accreted land vested in the state.[27] Because accreted land is part of the public trust, it can only be alienated for uses consistent with trust purposes.[28] California's position is justified primarily on the importance to the state in retaining control over trust property. Allowing private control over trust land could deprive the state or its subdivisions of the power to regulate coastal development, especially in harbors and recreational areas. Finally, beach access could be significantly affected if accreted land falls into private ownership. The California approach, distinguishes between accretion due to natural or artificial means.[29] Land accreted as a result of man-made structures such as groins or jettys is considered to be trust property belonging to the state while naturally accreted land is the property of the littoral owner. Little justification is given for this distinction. Perhaps it is based on the idea that all oceanfront property owners are entitled to an equal opportunity to have littoral current sand deposited on their land, and any artificial interference with the sand transport mechanism deprives the owner of his right to the sand. Whatever the justification, the effect of the distinction is to vest title to artificially accreted land in the state.

Generally, courts have not accepted the approach taken by California or by the Coastal Management Act. Most jurisdictions which have considered the matter have held that accreted land is the property of the upland owner.[30] They reason that, since the oceanfront property owner must bear the loss if land is eroded away, fairness dictates that he receive the benefit if additional land accretes. Further, a significant component of the value of littoral property is direct and immediate access to the ocean. Denying the oceanfront landholder title to accreted land could significantly affect the value of his property. Finally, some courts assert that economic efficiency is promoted by vesting title to accreted land in the littoral owner because it will encourage productive use.

The South Carolina Supreme Court has dealt directly with the issue of accretion only infrequently,[31] and no case has interpreted the accretion provisions of the Coastal Management Act. However, existing decisions seem to conform to the generally held position that accreted land belongs to the littoral landowner and not to the state. In Epps v. Freeman[32] the Court indicated that, at least with regard to natural accretion, such land would belong to the landowner and not the state. This ruling suggests that the South Carolina Supreme Court's position on title to accreted land may differ from the position taken in the Coastal Management Act. Given the potential importance of the issue, litigation is likely and there is at least some likelihood that the accretion provision could be held unconstitutional on the ownership issue.

Implementation of Erosion Control Policy

Non-Structural Solutions

Coastal Council adoption of erosion controls based on land use philosophy, such as setback restrictions, has not been authorized by the General Assembly. In order for the Council to take such action, the Coastal Management Act of 1977 would have to be amended to give the Coastal Council needed authority. As an alternative, especially if the need for uniformity is not important, local zoning authorities seem to have the power to adopt setback restrictions or other land use controls which could limit development on the oceanfront.[33] Such regulations, once approved by the Council, would then be enforceable as Coastal Council regulations under the Coastal Management Act. This approach could work reasonably well in areas of localized critical beach erosion assuming, of course, that the local zoning authority will enact the necessary controls. In conclusion, either a uniform approach with regulations promulgated by the Coastal Council or a county-by-county approach could successfully address the problem with a minimum of legal difficulties.

Engineering Solutions

Legal problems associated with implementing engineering solutions to the problem of beach erosion appear to be minimal. The Coastal Council has adequate permitting authority over erosion control structures on state lands and waters and general control over any structure in "critical areas" in the coastal zone. The Coastal Management Act appears broad enough to regulate whatever engineering solutions that might be proposed and legal problems associated with Council regulatory activities do not appear significant. The major problem to be anticipated seems to be over the question of title to accreted land. This problem probably will not affect Council authority since, regardless of ownership of accreted land, the Coastal Council retains regulatory power over structures on the land.

Problems with implementing engineering solutions may lie more in terms of financing than with anything else. Major projects too expensive to be financed by individual landowners will have to rely for funding on either federal or state money[34] or on a local financing arrangement such as a county tax or special assessment district.

Prior to the adoption of Article 8, section 7 of the South Carolina Constitution which vested broad powers of government in the individual counties, the General Assembly created a special erosion district for Pawley's Island and a public service district for Fripp Island, which also could deal with erosion problems. These districts had authority to issue bonds to pay for erosion control activities[35] and the bonds were to be retired by taxes on property owners within the district. After the adoption of that article, counties now have the power to provide public services and to provide for their financing. The statute authorizing counties to provide for and finance public services, while not specifically mentioning erosion protection, is so broad that such an activity almost certainly is within the power of the county to undertake. As long as the cost of the improvement falls on those who receive it and not on residents of the county, assessments could be made on less than a county wide basis.[36] There appears to be no significant problem, then, should coastal counties decide to establish erosion control districts and tax the residents of the districts to pay for improvements. Determining who benefits for the purpose of inclusion within the district will of course have to be established in some reasonable fashion. Assuming that can be accomplished, counties under existing law can finance erosion control projects.

FOOTNOTES

1. United States Constitution, Article 1 § 8.
2. Excluded from this discussion is legislation dealing only with federal cost sharing of erosion control projects. Numerous statutes establish cost sharing and cost analysis procedures for the Office of Management and Budget, the Water Resources Council and the Army Corps of Engineers. In essence, the federal share of beach restoration projects is as follows: 50% on publicly owned shores, 50% on privately owned shores with public access, and 70% on shores which can meet criteria for public shore parks. In addition, federal flood control legislation authorizes up to 70% federal funding for hurricane protection and beach erosion projects. For additional information, see Digest of Water Resources Policies, Department of the Army, EP 116S-2-1 (1975).
3. 33 U.S.C.A. § 401 *et seq*.
4. 33 U.S.C.A. §§ 1251-378.
5. 16 U.S.C.A. §§ 1451-64
6. Not only do the coastal states have policy making and regulatory authority over private activites which affect the coastal zone, but the Federal Coastal Zone Management Act requires that federal agencies conduct activities in a manner "to the maximum extent practicable, consistent with approved state management programs." Applicants for federal license or permits must obtain state certification that the activity requested is consistent with the state coastal zone management plan. The effect of the consistency provision of the federal state is to allow states significant control over federal activities within the coastal zone.

7. See State v. Yelsen Land Co., 265 S.C. 78, 216 S.E.2d 876 (1976); State v. Hardee, 259 S.C. 535, 193 S.E.2d 497, Cape Romain Land & Improvement Co. v. Georgia-Carolina Canning Co., 148 S.C. 428, 146 S.E.2d 434 (1928).

8. S.C. Code Ann. 48-39-20 (1979 Supp.)

9. Id. § 120(A).

10. Id. § 120(B).

11. Id. § 120(C).

12. Id. § 130.

13. The Coastal Management Act deals exclusively with the permitting of structures and alterations of "critical areas" in the coastal zone. The Legislature did not make any general grant of regulatory power to the Coastal Council aside from the power to require permits for certain activities in the coastal zone. For a comprehensive discussion of the Act, see Note, The South Carolina Coastal Zone Management Act of 1977, 29 S.C.L. Rev. 666 (1978).

14. See, e.g. S.C. Code Ann. 4-27-10, authorizing counties to establish zoning plans, and S.C. Code 5-23-10, vesting the same powers in municipal corporations.

15. S.C. Code Ann. 48-39-100(B) (1979 Supp.).

16. 274 U.S. 603 (1927). See also City of Miami v. Romer, 58 So. 2d 849 (Fla., 1952).

17. Dunbar v. City of Spartanburg, 266 S.C. 113, 221 S.E.2d 848 (1976). See also, S.C. Code Ann. 5-23-10 which authorizes municipal corporations to establish regulations on the percentages of lots which may be occupied.

18. Florida and New Jersey probably have the most comprehensive regulations utilizing this approach.

19. 46 N.J. 479, 218 A.2d 129 (1966), cert. denied, 385 U.S. 831 (1966); 116 N.J. super 148, 281 A.2d 377 (App. Div. 1971).

20. Talbot v. Myrtle Beach Board of Adjustment, 222 S.C. 165, 72 S.E. 66 (1952).

21 There are other possible approaches. For example, open space preservation regulations which require developers to set aside a certain portion of land for public use are an accepted land use control device. They are, however, generally more susceptible to constitutional attack than setback lines, because they require the entire tract to remain undeveloped which limits most economical use.

22. See Morris v. South Carolina Highway Dept., 264 S.C. 369, 215 S.E.2d 430 (1975); Graham v. Charleston County School Board, 262 S.E.2d 314, 204 S.E.2d 384 (1974).

23. South Carolina Coastal Council Regulation R 30-4(F).

24. Under generally accepted principles of law, a "taking" can occur when a substantial reduction in the value of the affected property occurs. The South Carolina Supreme Court has interpreted Art. 1, § 13 of the South Carolina Constitution, the provision which requires just compensation for a "taking", to mean that "taking" and "damaging" are synonymous. See Spradley v. South Carolina State Highway Dept., 256 S.C. 431, 182 S.E.2d 735 (1971).

25. For South Carolina cases establishing this principle, see Kline v. City of Columbia, 249 S.C. 532, 155 S.E.2d 597 (1967); Owens v.

South Carolina State Highway Dept., 239 S.C. 44, 121 S.E.2d 240 (1961).

26. The argument was raised in Carpenter v. City of Santa Monica, 63 Cal, App. 2d 772, 147 P.2d 964 (1944). There a city-owned breakwater caused erosion to the beach. Plaintiff argued that the city was responsible for causing the erosion and should be liable in damages or under a taking theory. The claim was mooted because the court held that the plaintiff did not in fact have title to the land lost.

27. City of Los Angeles v. Anderson, 206 Cal. 662 275 P. 789 (1929).

28. Marks v. Whitney, 6 Cal. 3d 251, 491 P.2d 374, 98 Cal. Rptr. 790 (1971).

29. For a discussion of the difficulties in distinguishing natural versus artificial accretion, see Carpenter v. City of Santa Monica, 63 Cal. App. 2d 272, 147 P.2d 964 (1964).

30. A leading case is Michaelson v. Silver Beach Improvement Association, 342 Mass. 251, 173 N.E.2d 273 (1961).

31. The most recent decision is Epps v. Freeman, 261 S.C. 375, 200 S.E.2d 235 (1973). See also Town of Port Royal v. Charleston, 136 S.C. 525, 134 S.E. 497 (1926); Spigener v. Coomer, 8 Rich. 301, 64 Am. Dec. 755 (1855).

32. 261 S.C. 375, 200 S.E.2d 235 (1973).

33. See discussion accompanying note 14. Beaufort County has already adopted such an ordinance.

34. See note 2 for a short treatment of funding for beach erosion projects.

35. See S.C. Statutes at Large 994 and 1042 (1962).

36. S.C. Code Ann. 4-9-30.

CHAPTER VII

CASE STUDIES

To consider the appropriateness of alternate erosion control strategies along the South Carolina coast, case studies are presented for the following locations:

- Hunting Island,
- Hilton Head,
- Pawleys Island, and
- Myrtle Beach.

The four sites differ in both physical characteristics and development patterns. As such, they offer a good cross section from which to evaluate erosion control projects. The following section outlines the methodology employed; it is hoped that the suggested methodology will provide a basis for evaluating future projects.

Methodology

Each of the analyses begins with a consideration of beach morphology at the site in question. Long-term and short-term beach profiles are examined to determine the relative stability and erosional-depositional trend at specific locations along each of the sites. In addition, significant influences affecting the beach's dynamics are considered.

Based upon these observations, alternative solutions deemed to be most appropriate for the site are suggested. The construction costs for each of the alternatives are made. In some cases, high and low cost estimates are made pending on site study. To the extent possible, the relative effectiveness of the proposed solutions is projected.

The benefit derived from erosion abatement is collectively equal to the potential prevention of property and recreational loss. Potential loss is estimated by projecting past erosion trends along sections of the beachfront. It is well understood that shifts in any of the significant variables affecting beach formation may alter present erosional trends; nonetheless, past trends serve as logical first approximation for projection. Current property values are estimated from county tax assessments (and updated where appropriate.) Lots in the affected area are delineated to reflect depreciation during erosion.

Recreational benefits are estimated as the difference in visitation potential with and without the proposed projects. Visitation projections are made for each of the sites, while beach capacity is estimated by calculating the area of dry sand beach (at MHW) and dividing by 100 square feet, the necessary space for one visitor assuming a turnover rate of one. Visitation is valued at $2 per visitor day.

Benefits and costs are projected in constant dollars, i.e. without allowing for inflation. As such, an inflation-free discount rate is applied to estimate present values of both costs and benefits. By comparing these figures, the benefit-cost ratios are estimated for each of the proposed projects based upon the available data and the assumptions being made.

Limitations of the Analysis

The evaluations are intended to serve as a point of departure in evaluating the proposed projects. They are based upon interpretation of the best available data sources. As noted previously, the accurate projection of erosion rates requires both an interpretation of past trends as well as an understanding of the dynamics affecting beach formation currently and over the projection period. Without accurate information on wave climate, tidal influence, and onshore and offshore formations, it is difficult to project with confidence beach width and location. Particularly when estimating carrying capacity for recreational use, such imput is obviously important.

The alternatives considered at the sites are engineering solutions. Their feasibility is considered relative to the "no action" alternative which assumes that erosional trends continue unabated and that present land uses are representative. Redevelopment to higher uses and new development are not considered which may understate the potential benefit of the solutions considered. On the other hand, the incorporation of management solutions may lessen the need for engineering approaches by positioning new development at safe distances from the oceanfront. Perhaps more importantly, given the rapid depreciation schedules used in most resort communities, and as a result, the frequent redevelopment of sites, the location of replacement structures away from the eroding shoreline may limit potential property loss and reduce the need for engineering alternatives as a long-run solution. Under such an option, the 50-year planning horizon employed below may be longer than appropriate. Formal incorportion of depreciation schedules and management solutions applied to replacement is not considered; yet, it is speculated that the benefits of such an approach from a long-run perspective could be most significant and bear closer attention to complement the alternatives considered below.

No attempt is made to factor out state and local shares of benefits and costs. As such, the relative distribution of project costs and of recreational benefits must be disaggregated by state and local policy-makers in evaluating returns on project expenditures.

CASE A: HUNTING ISLAND

Beach Morphology

Hunting Island is bordered by Fripp Inlet at the south and St. Helena Sound to the north. The island is presently eroding at a rate of about 300,000 yd^3 /yr. (230,000 m^3/yr).

The data base documenting depositional-erosional trends on Hunting Island is more extensive than for other areas in South Carolina because of interest generated by repeated nourishment projects. Available data sources span different time scales (Table A-1). Information provided by each source, therefore, has particular limitations and advantages and must be treated accordingly.

Long-Term Shoreline Changes

The trend of long-term shoreline changes of Hunting Island has been strongly erosional with the highest rate of erosion near the entrance of Johnson Creek (Fig. A-1). Low water positions compiled from nautical charts (1857-1979) show that the greatest sediment loss took place at the north and south ends (Fig. A-1). Continuous erosion between 1857 and 1979 resulted in shoreline retreat of 300 to 750m along the northern half of Hunting Island. The southern half has also suffered significant erosion historically, but portions of this section have reversed to short-term accretional trends. In part, long-term changes in the position of the beach are related to sediment budgets around the shoals associated with Fripp Inlet at the south end and St. Helena Sound and Johnson Creek to the north. The correlation between morphologic changes in the Fripp Inlet system with shoreline changes on Hunting Island clearly

Table A-1 DATA BASE: Hunting Island Shoreline Changes

Nautical Charts (National Ocean Survey)

Chart 154 1857 1:80,000

Chart 154 1920 1:80,000

Chart 793 1937 1:40,000

Chart 793 1961 1:40,000

Chart 793 1972 1:40,000

Chart 11517 1979 1:40,000

Aerial Photo Sets

1939

1951

1955

1959

1968

1972

Beach Profiles

1974-76 Survey

Station HI01, HI02 (7-8-74 to 8-17-76; sixteen surveys).

Station HI03 (9-20-75 to 8-17-76; six surveys).

1979-80 Survey

Stations HI-1, HI-3, HI-5, HI-6, HI-7 (11-18-79 to 7-23-80; at approximately monthly intervals).

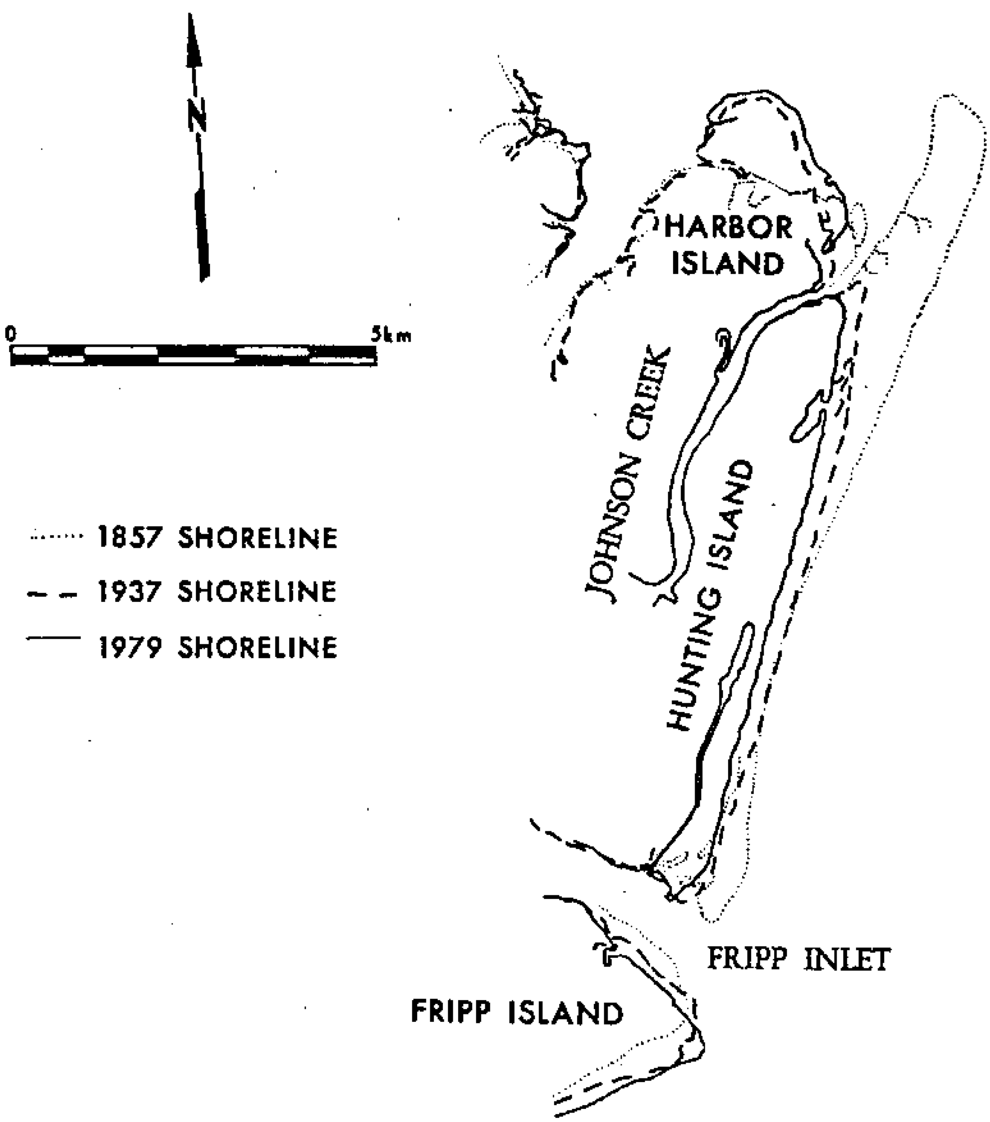


Figure A-1 Long-term changes on Hunting Island compiled from nautical charts between 1857 and 1979.

indicates the interrelation between inlet and shoreline dynamics. There has been an apparent net exchange of sediment between Hunting Island and Fripp Island. Net accretion at the northeast point of Fripp Island amounted to approximately 500 m from 1857 to 1979. Correspondingly, the southwest point of Hunting Island was cut back by 400 m in the same period. An inverse relationship exists between accretional and erosional trends on the sections of Hunting Island and Fripp Island near the inlet.

The effects of bathymetric changes in St. Helena Sound on Hunting Island are apparent from computerized wave refraction analysis using the 1857 and 1978 bathymetry of St. Helena Sound. A wave refraction diagram of a 4-second wave from the east superimposed on the bathymetry of the 1857 nautical chart shows a convergence of wave orthogonals on the northeastern end of Hunting Island (Fig. A-2). The historical changes already documented indicate heavy erosion along this section. A wave refraction diagram based on the 1937 nautical charts still shows convergence of wave energy near the northeast end of Hunting Island (Fig. A-3). Much of the wave energy concentration was due to the presence of the ebb-tidal delta developing at the mouth of Johnson Creek that drained eastward since erosion of the north section of Hunting Island. Between 1937 and 1978, erosional rates slowed at the northeast tip of the island, although shoreline retreat continued. Changes in shoal configuration and shifts in channel position in St. Helena Sound also affect the long-term erosional trend of Hunting Island. In the period between 1857 and 1978, significant changes took place in the tidal channel system of St. Helena Sound. By 1978, much of the energy of eastward approaching waves was dissipated over the shoaling areas where deeper tidal channels

Figure A-2 Refraction of 4-second waves from the east over the 1857 bathymetry in the vicinity of Hunting Island and St. Helena Sound.

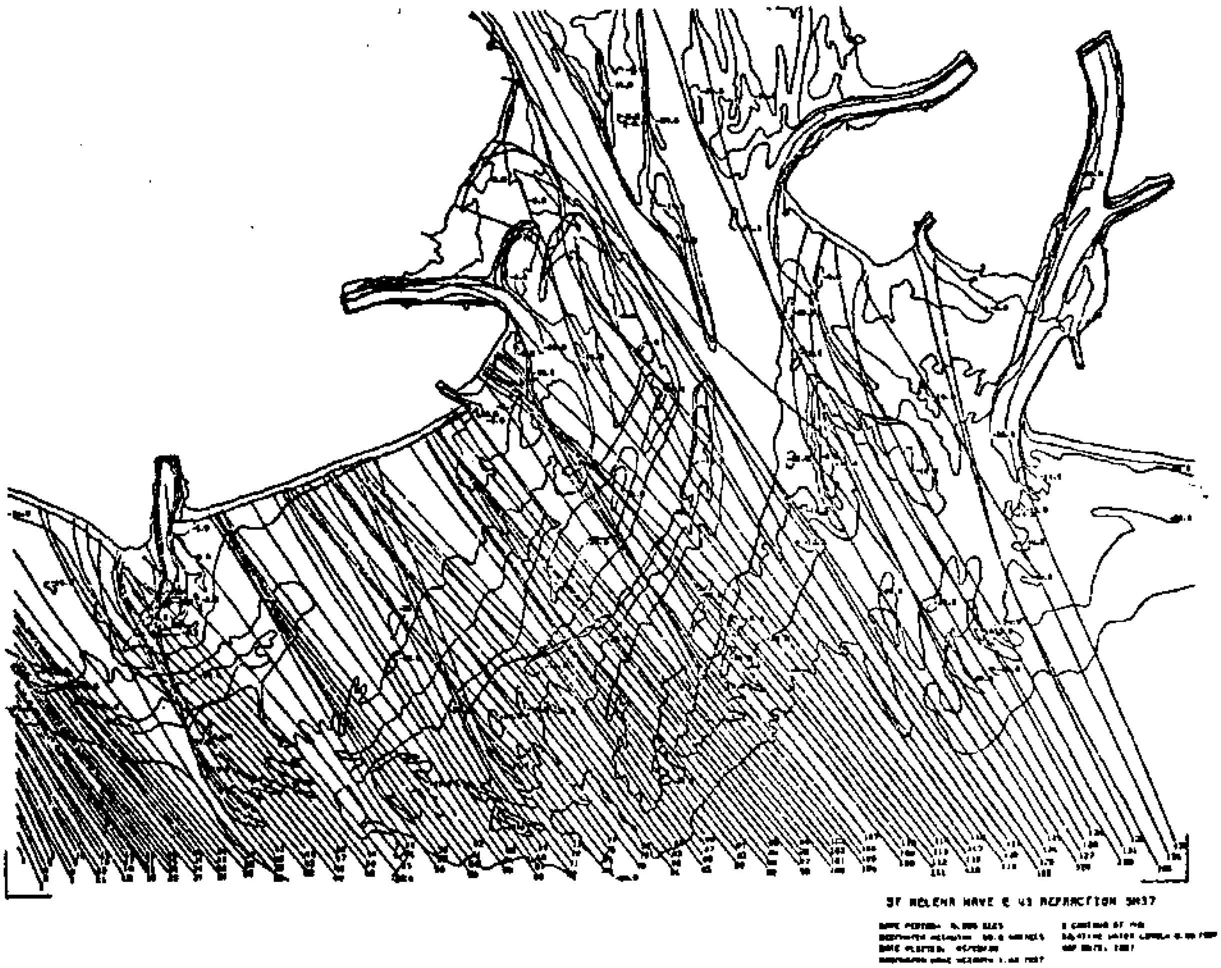


Figure A-3 Refraction of 4-second waves from the east over the 1937 bathymetry.

formerly existed in St. Helena Sound (Fig. A-4). In addition to the effect of changes in St. Helena Sound bathymetry on wave refraction patterns, the Fripp Inlet ebb-tidal delta is also a zone of concentrated wave energy (Fig. A-4). This indicates the importance of waves in the by-passing process exchanging sediment between Hunting and Fripp Islands.

Shoreline Changes from Aerial-Photographs

Sequential vertical aerial photography of the Hunting Island Beach taken at four to twelve year intervals between 1951 and 1972 was used to determine shoreline position by Hubbard et al. (1977). This survey shows net changes over shorter intervals than published nautical charts and indicates more recent depositional-erosional trends.

Data from six photo reference points between the years 1951 and 1972 are summarized in Table A-2. Also included with these data are shoreline changes measured from nautical charts between 1859 and 1933. Deposition-erosion graphs for several of the photo control points summarize trends of shoreline change along Hunting Island (Fig. A-5). Superimposed low water shorelines from the 1951, 1959 and 1972 aerial photo mosaics of Hunting Island indicate more recent and shorter-term shoreline changes (Fig. A-6).

From the tabulated and graphical data, it is clear that a 5000 m section of Hunting Island beyond the direct influence of Fripp Inlet and Johnson Creek has been eroding continuously over time. Because the data acquisition techniques provide net shoreline changes over variable time intervals, calculated average yearly rates of shoreline change depend on the time interval selected. Table A-3 lists yearly rates of

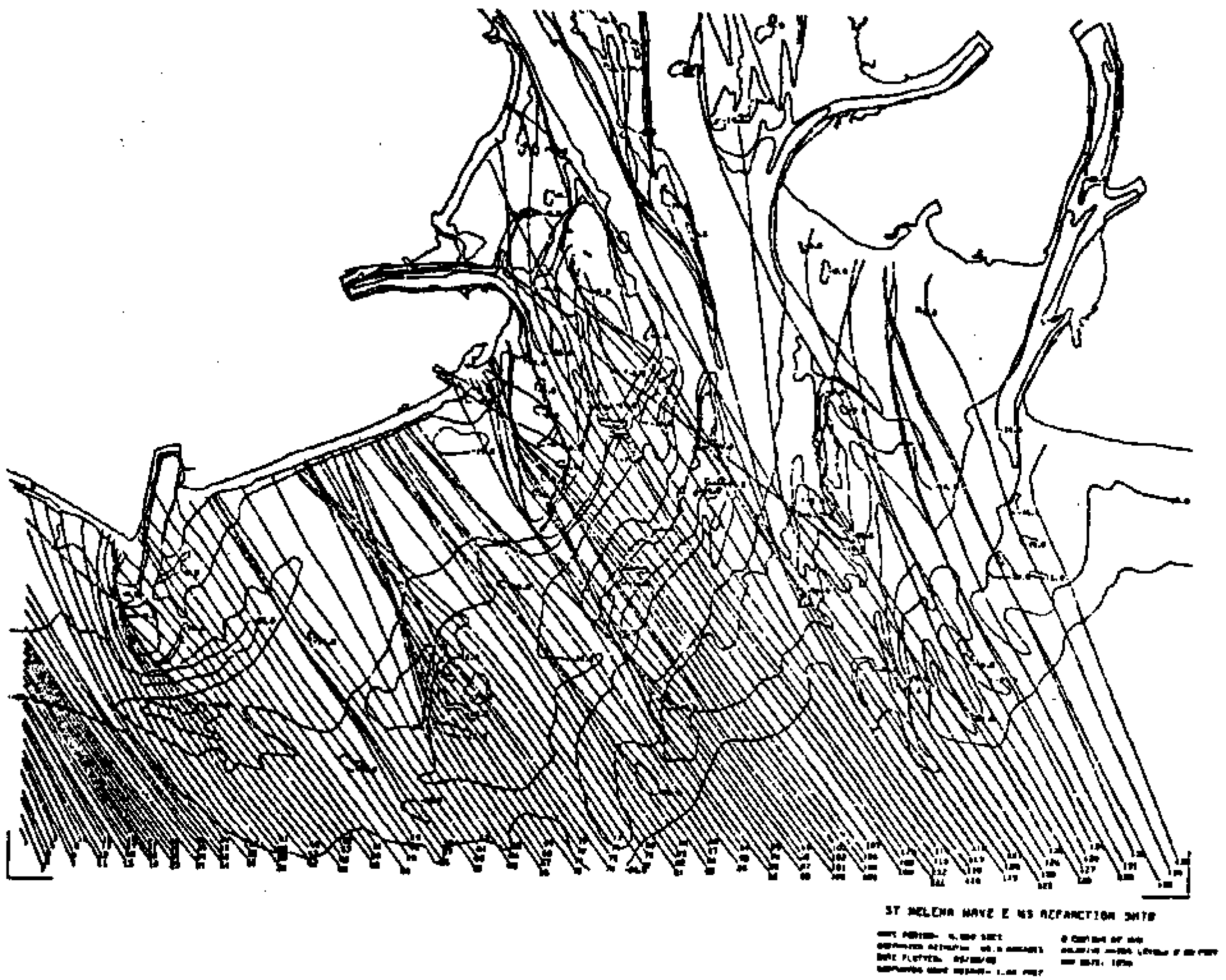


Figure A-4 Refraction of 4-second waves from the east over the 1978 bathymetry.

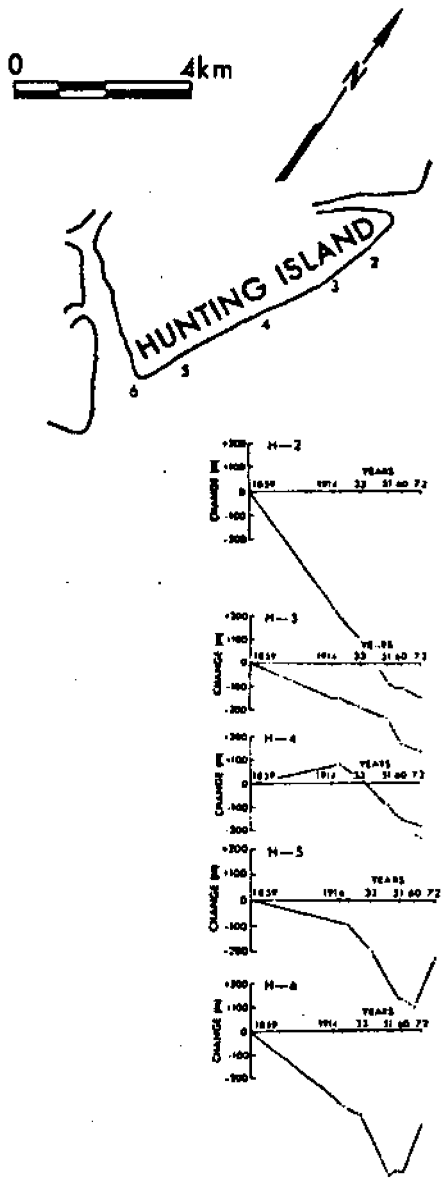


Figure A-5 Depositional-erosional trends along Hunting Island compiled from vertical aerial photographs and nautical charts.

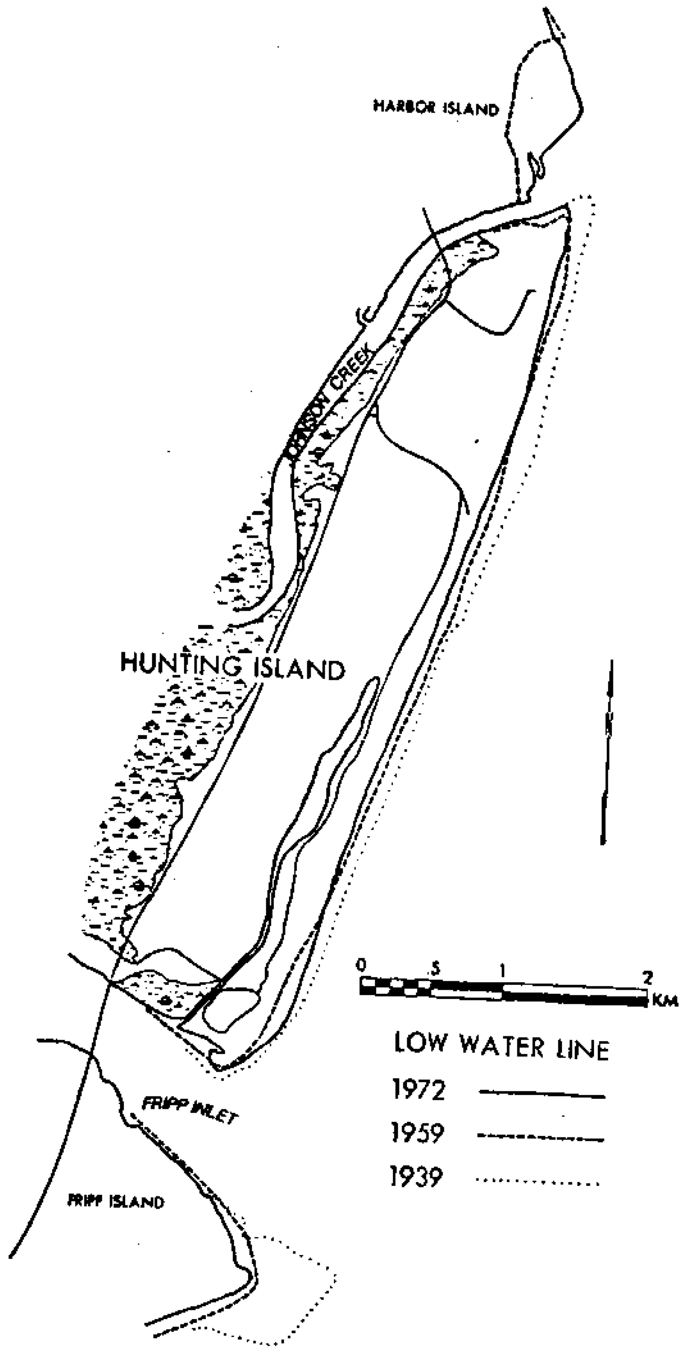


Figure A-6 Superimposed low water shorelines from 1951, 1959 and 1972 aerial photo sets.

Table A-2 Hunting Island shoreline changes in meters (1859-1972)

Reference point	Change 1859-1914	Change 1914-20	Change 1920-33	Change 1933-51	Change 1951-55	Change 1955-60	Change 1960-72
H 1	-1478	36	-73	-46	-27	-89	544
H 2	-491	-41	-106	-188	-17	0	-39
H 3	-154	0	-37	-51	-52	-55	-32
H 4	85		-65	-124	-36	-26	-24
H 5	-102		-101	-177	-14	-25	77
H 6	-337		-22	-284	22	0	197

Table A-3 Average yearly shoreline change in meters, based on 25, 50 and 100 year trends on Hunting Island.

Station	25 Years	50 Years	100 Years
H 1	+20.3	+5.9	-10.0
H 2	-2.7	-6.7	-7.8
H 3	-6.6	-4.4	-3.4
H 4	-4.1	-5.3	-1.7
H 4	+1.8	-4.6	-3.0
H 6	+10.4	-1.7	-3.8

change for the six Hunting Island reference stations based on 25, 50 and 100 year intervals. Rates of shoreline change are similar in magnitude for all three intervals, but, in the shorter term, erosional trends at the north and south ends of Hunting Island reversed.

At present, shoreline changes along the extremities of Hunting Island are controlled by sediment budgets and sand by-passing at Fripp Inlet and Johnson Creek. Shoals associated with the ebb-tidal deltas of the inlets adjacent to Hunting Island have been built up recently and provide some protection from wave attack. A portion of the sand for these shoals may be derived from erosion of the central portion of Hunting Island. Inlet tidal channels and inlet shoal systems are dynamic and continually evolving, however, and local sediment budgets can be altered drastically in short periods of time. For this reason, effect of inlet changes must be included in any consideration of beach erosion management options for Hunting Island.

Short-Term Changes

Beach profile surveys have been conducted over periods of 6 months to two years at one month or two month intervals (Hayes, Moslow and Hubbard, 1977). The beach profiling technique described by Emery (1961) can be used to measure elevation changes at an accuracy of $\pm$ 1 cm. The detail of each profile depends on the discretion of field personnel. Enough detail is included to record the morphology of the primary dunes, incipient dunes, any berm development and slope of the foreshore to the low water line.

I Hunting Island beach profiles: 1974-1976. - A beach profile survey conducted at one to two month intervals between July, 1974 and

August, 1976 was designed to monitor three locations of the Hunting Island beach undergoing rapid change. Station HI01 was located at the south of the island within 500 meters of Fripp Inlet (Fig. A-7). Station HI02, located near the lighthouse and Station HI03, located 500 meters from Johnson Creek, were within the limits of the 1975 nourishment project.

The beach at Station HI01 was typified by a relatively flat profile during the study period except for occasional low-amplitude ridge and runnel topography (Fig. A-8). The dunes near this location are 2 to 3 meters high. The seaward face of the dune at HI01 was cut back by approximately 10 over the study period (Fig. A-8). Much of the dune erosion may have occurred during a storm between the July and August, 1975 surveys. The beach at this profile underwent net accretion, but was subject to an unusually large volumetric change (Fig. A-9). The mechanism of these changes was not observed but may have been due to the influence of the nearby Fripp Inlet tidal delta. Here, large volumes of sand are transported by waves and tidal currents as the configuration of the shoal complex continually evolves. The sharp decrease in sediment volume at profile HI02 between the June and August surveys of 1975 approximately correlates with dredging in the borrow area on the Fripp Inlet delta (Fig. A-9). Dredging operations apparently interfered with the normal sediment budget during this time. After dredging was completed, sediment volume at this profile quickly rebounded (Fig. A-9).

Profile HI02 is characteristic of the erosional trend of Hunting Island. Prior to the beach nourishment project, HI02 was generally flat and featureless without any measurable berm development. The beach was

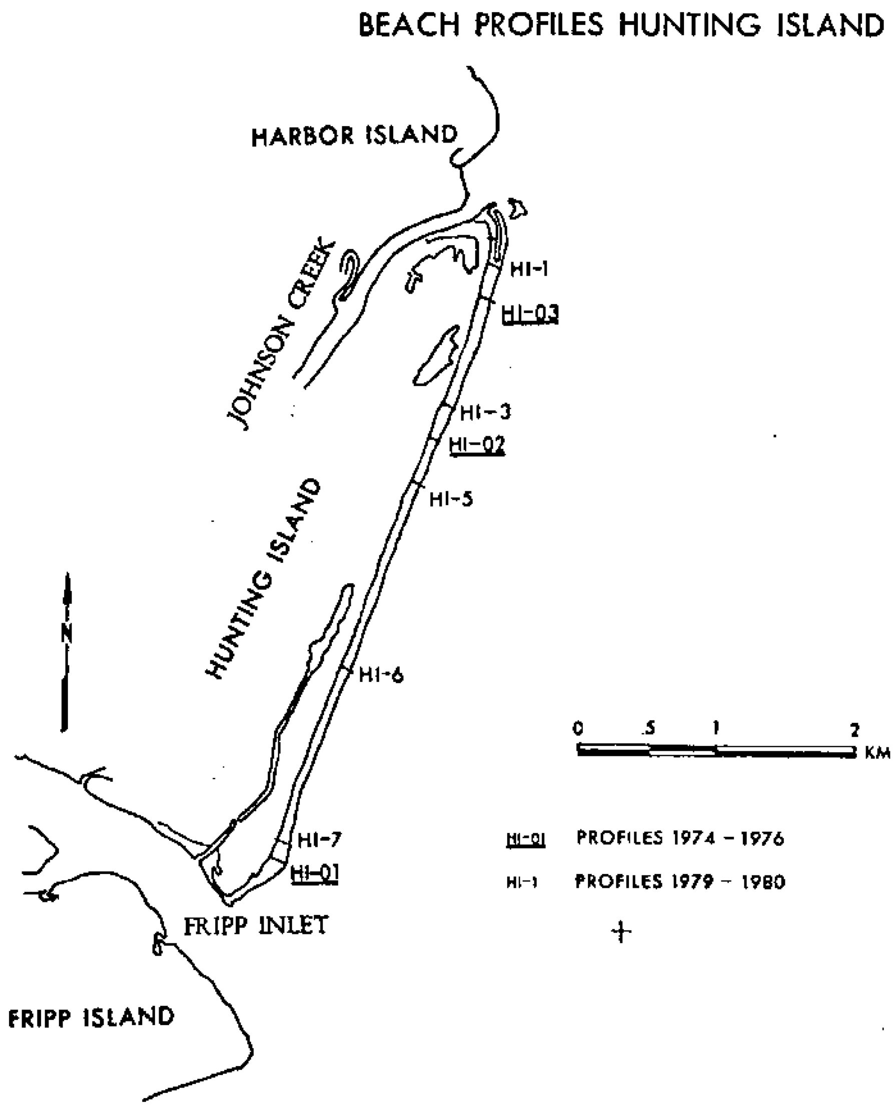


Figure A-7 Location of Hunting Island beach profile stations.

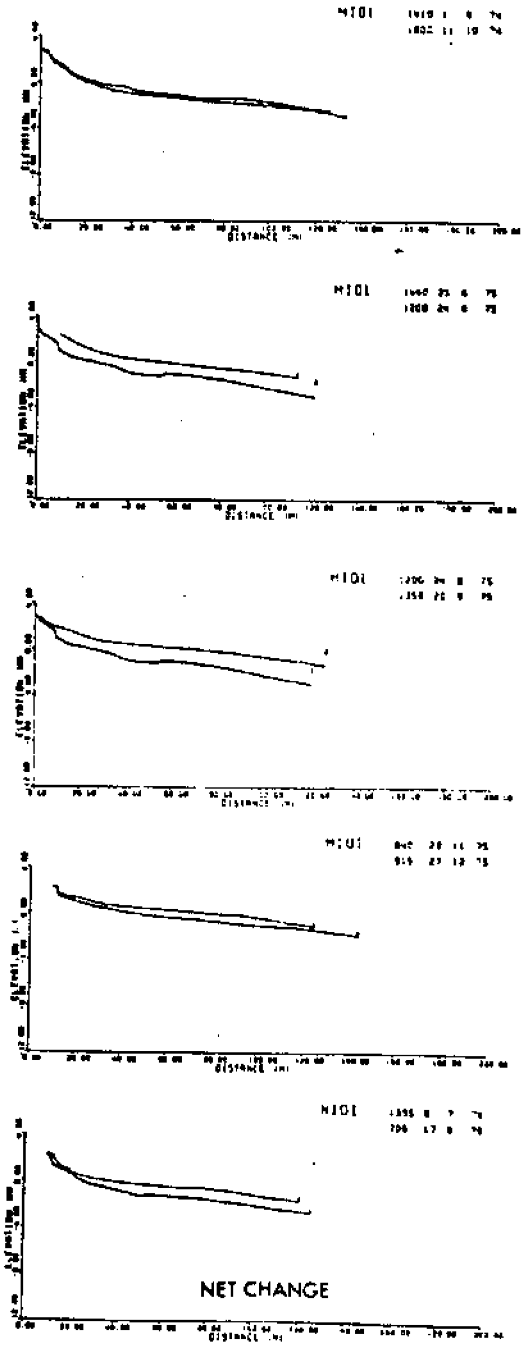


Figure A-8 Comparison of beach profiles from selected dates between August, 1974 and August, 1976 at station HI01. Net change is shown in lower plot.

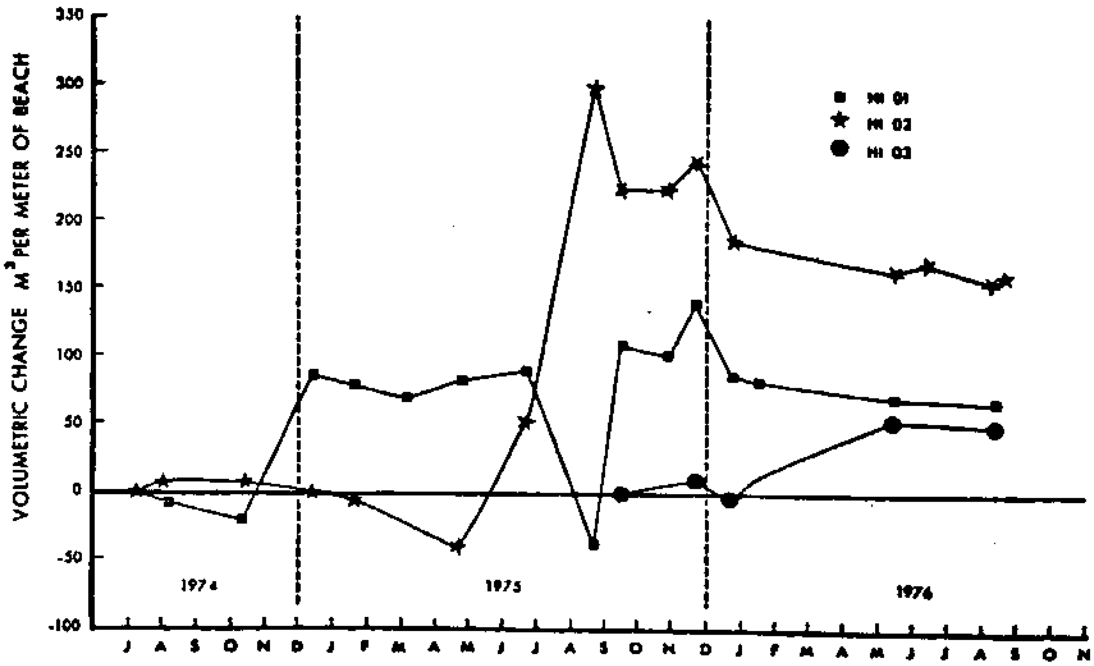


Figure A-9 Volumetric change in cubic meters per meter of beach between survey dates at Hunting Island profile stations HI01, HI02, and HI03.

backed by a steep dune scarp that underwent episodic retreat (Fig. A-10). The net gain of sand at profile HI02 over the study period is the result of the beach nourishment project in 1975. Seasonal trends are masked in part by the artificial fill at profile HI02, but significant decreases in sediment volume during the winter months of 1975 and 1976 may be natural seasonal trends (Fig. A-9).

After completion of the beach nourishment at this profile, a distinct berm developed. A moderately-erosional trend continued until the end of the study period as the berm crest migrated approximately 45 meters landward.

Profile HI03, surveyed only after completion of the nourishment project, maintained a more consistent ridge and runnel topography compared with the other two profiles (Fig. A-11). This profile tended to be accretional during the post-nourishment period; whereas HI01 and HI02 underwent net erosion during this time (Fig. A-9). Because of the proximity of this profile to Johnson Creek, deposition-erosional trends and beach morphology are, in part, controlled by sediment transport and morphologic changes around the associated ebb-tidal delta.

II <u>Hunting Island beach profiles: 1979-1980.</u> - Five new profile stations were established in November, 1979 as part of a year-long study of recent beach erosion problems on Hunting Island (Fig. A-7). Cumulative volumetric changes between November, 1979 and July, 1980 at each profile location are shown in Figure A-12. Similar to the 1974-76 set of profiles, part of the natural depositional-erosional trends are masked by a beach nourishment project completed between January and April, 1980.

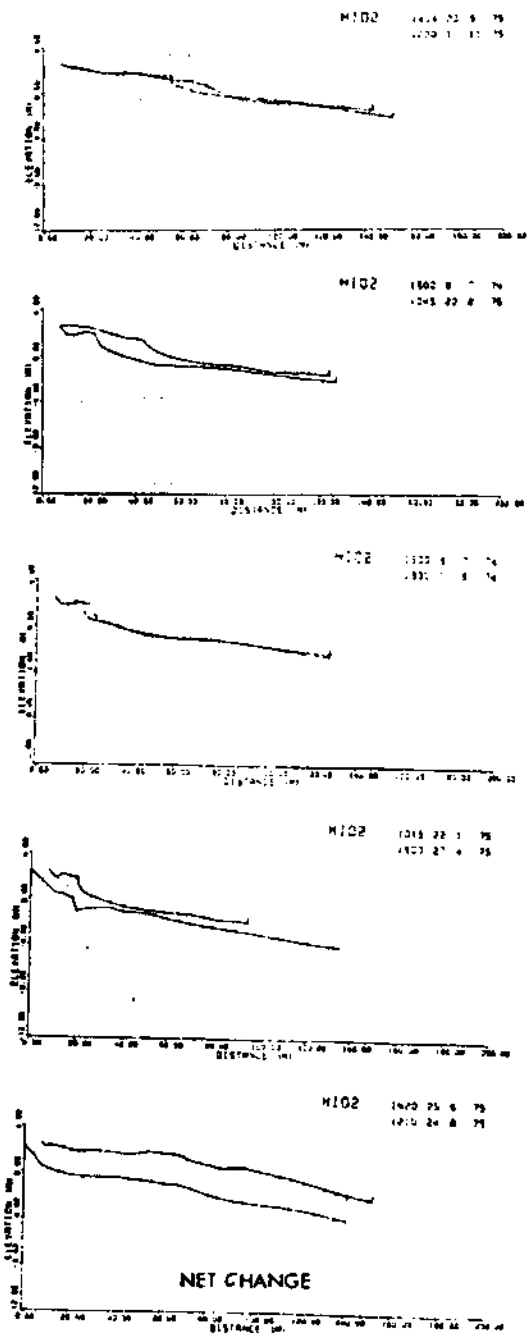


Figure A-10 Comparison of beach profiles from selected dates at station HI02.

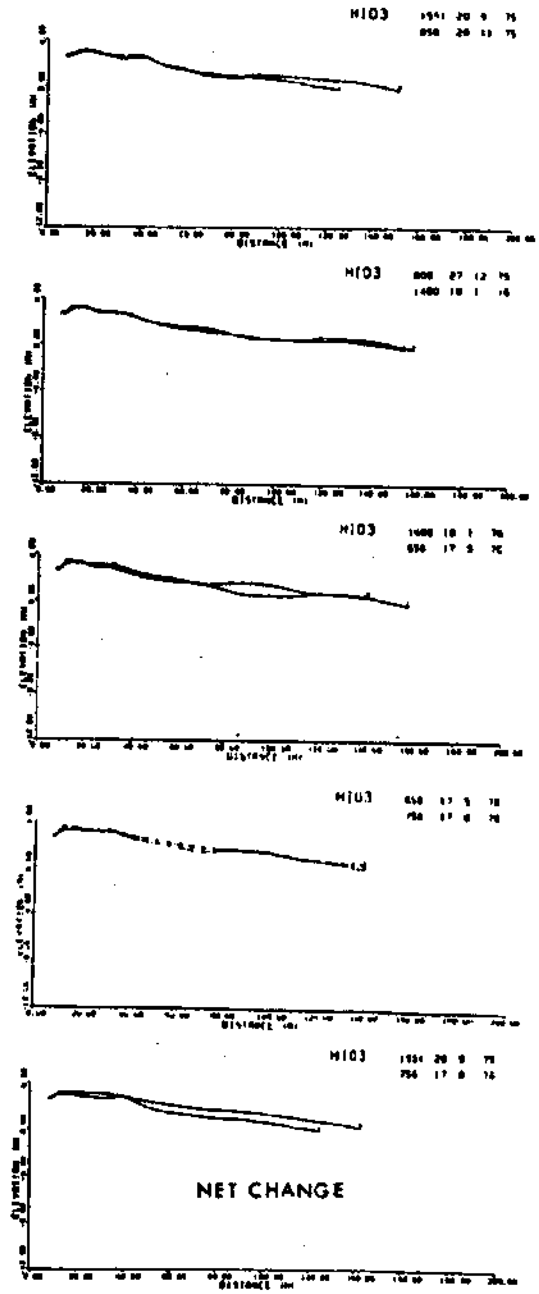


Figure A-11 Comparison of beach profiles from selected dates at station HI03.

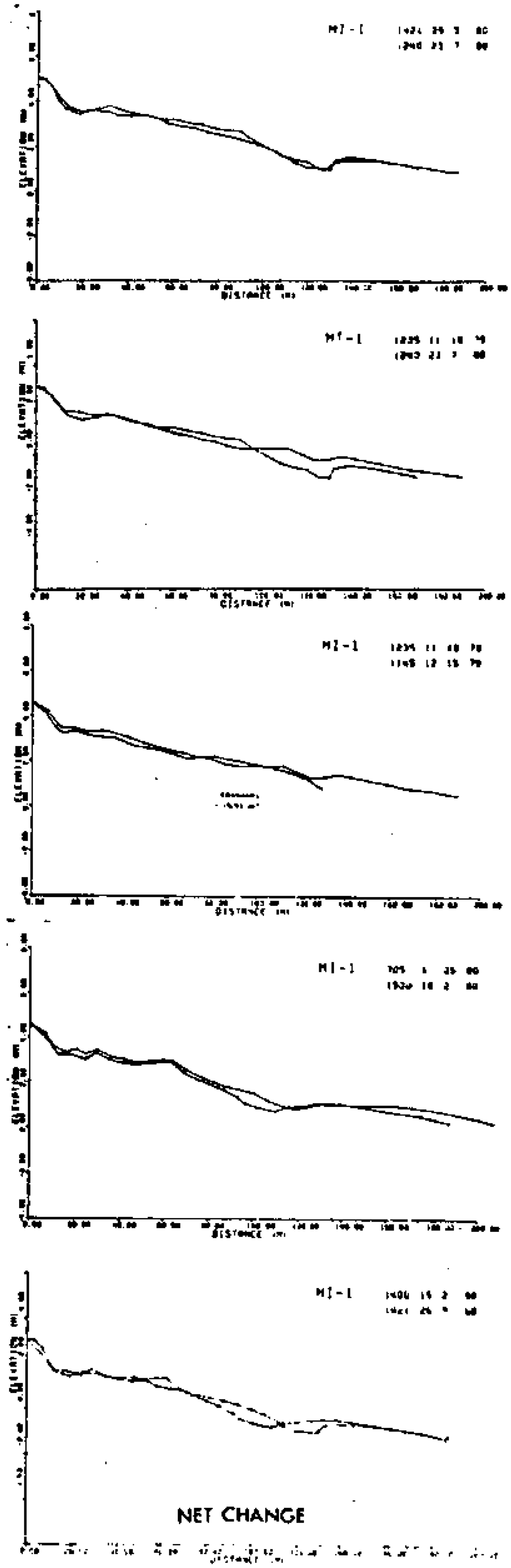


Figure A-12 Comparison of beach profiles from selected dates between November, 1979 and July, 1980 at station HI-1. Net change is shown in lower plot.

Profile station Hl-1, at the north end of Hunting Island, consistently showed ridge and runnel topography through the study period. Similar to station HI03, the morphology of this profile is strongly influenced by the morphology of the Johnson Creek ebb-tidal delta. At low water, this profile station may be up to 200 meters wide (Fig. A-12), but during some tidal cycles, large runnels do not completely drain isolating an outer sand ridge from the beach. The primary dunes at this profile are low and do not exceed 2 meters in relief. A distinct berm is usually present, dividing the beach into a flat backshore and an upper foreshore dipping seaward at a slope of 1.5 to 2 degrees. This section of beach, although subject to frequent morphologic changes, remained relatively stable with respect to volumetric changes (Fig. A-13). A net volumetric loss occurred between November and July. Most of the loss took place during January and February, possibly a seasonal change.

Profile station HI-3 is at the north limit of the most recent beach nourishment project (Fig.A-13). Here, a 2 meter high scarp has been cut into the primary dunes. No permanent berm is developed, and ridge and runnel topography is low in relief or absent during surveys prior to beach nourishment (Fig. A-14). The nourishment project added approximately 100 cubic meters of sediment per meter of beach (Fig. A-14). Morphology of the post-nourishment beach included a berm crest and a foreshore zone dipping at 1.5 to 2 degrees (Fig.A-11). Ridge and runnel topography was persistent on the post-nourishment beach. The July, 1980 profile at station HI-3 is comparable in morphology to the

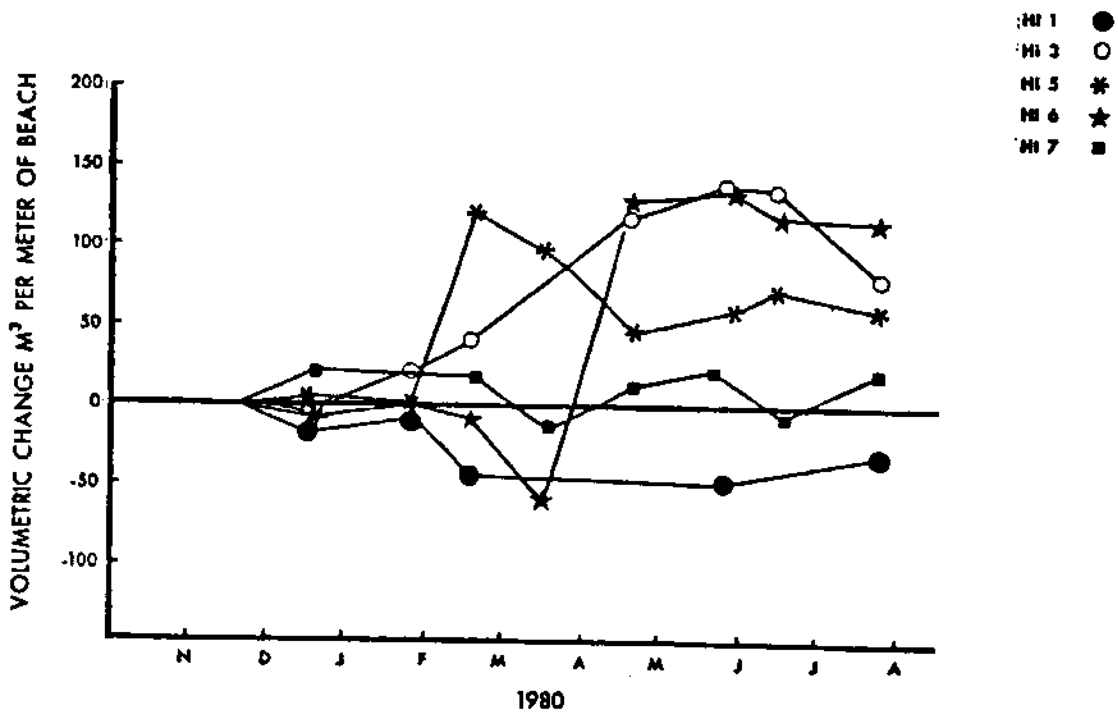


Figure A-13 Volumetric change in cubic meters per meter of beach at five Hunting Island profile stations, November 1979 to July 1980.

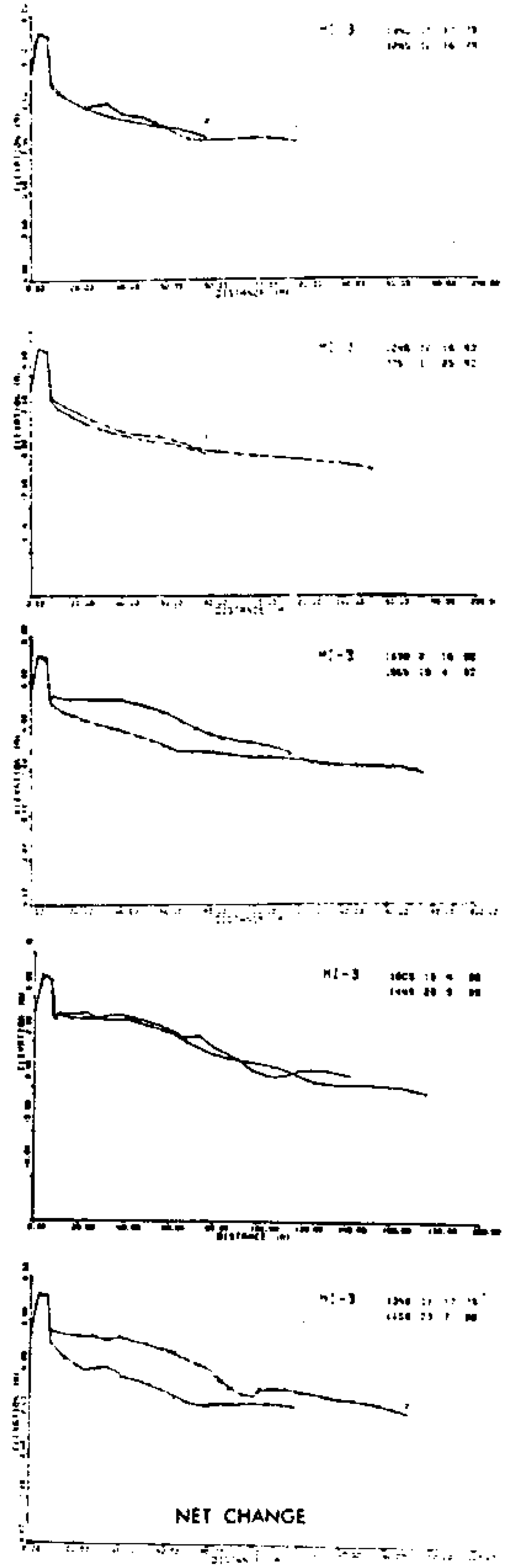


Figure A-14 Comparison of beach profiles from selected dates at station HI-3.

July profile at HI-1. Net accretion at HI-3 between November and July is due largely to the nourishment project, masking any seasonal trends.

The beach profile at station HI-5, November through January, consisted of a gently-sloping foreshore and low relief ridge and runnel topography (Fig. A-15). Dunes are low along this section of Hunting Island not exceeding 1 meter in relief. A low artificial dune was created at HI-5 during February, 1980' when the nourishment project began. Similar to profile HI-3, beach morphology elements at HI-5, after the nourishment project, included a flat backshore area separated from the foreshore by a berm. In the post-project period, ridge and runnel topography has more relief, and the overall morphology of the beach changed considerably as the berm crest retreated landward (Fig. A-15). Net gain of sediment volume at this profile is the result of beach nourishment (Fig. A-13). A significant loss of the artificial fill took place during a two-month long erosional trend lasting from February to April, 1980. This loss may have been a seasonal effect and was matched, in part, by erosion at profiles HI-6 and HI-7.

Profile HI-6 is at the south limit of the 1980 beach nourishment project (Fig. A-7). The most outstanding feature at this location is a 3 meter high dune scarp below which the pre-nourishment beach sloped seaward at a low angle (Fig. A-16). Relief features on the beach included low-amplitude ridge and runnel topography and no berm or backshore and foreshore zones that underwent little change through the last survey in July. An erosional episode between late January and mid-March may have been a seasonal trend but was interrupted by artificial filling

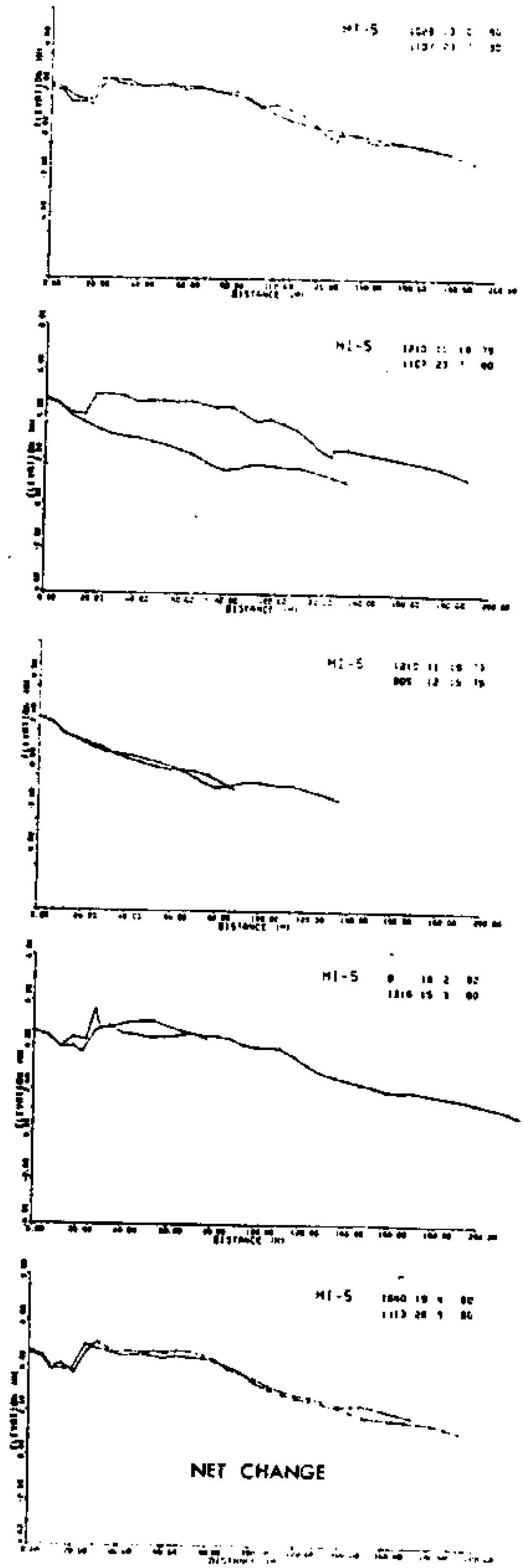


Figure A-15 Comparison of beach profiles from selected dates at station HI-5.

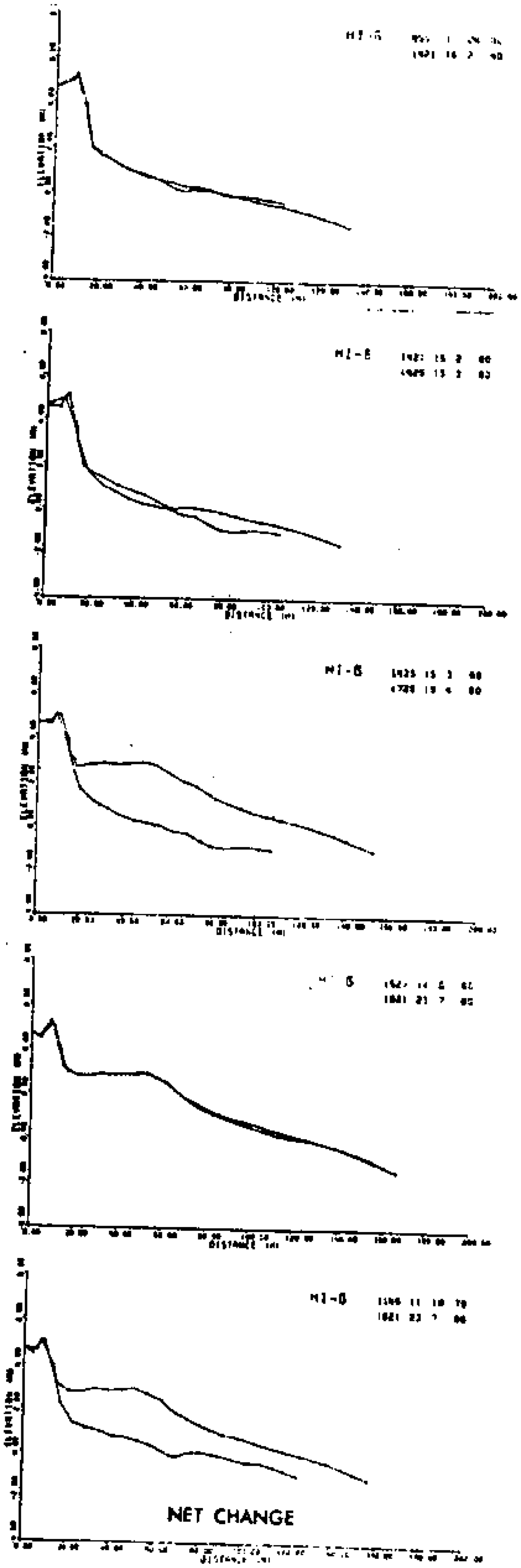


Figure A-16 Comparison of beach profiles from selected dates at station HI-6.

in late March (Fig. A-13).

Station HI-7 is well south of the nourishment project and, as at station HI-1, reflects more natural depositional-erosional trends. At low water in this location, one or more ridge and runnel sets may be exposed (Fig. A-17). These formations are associated with tidal deposits around Fripp Inlet. Flood oriented bedforms superimposed on sand ridges at the base of HI-7 indicate that this areas is adjacent to a flood-dominated marginal tidal channel. The beach is somewhat protected from wave attack by the shoals around Fripp Inlet and, at the present time, has an adequate sand supply through exchange with tidal-delta deposits. Profile HI-7 fluctuated between erosion and deposition over the eight month study (Fig. A-13). The net result was a small volumetric gain by the end of the study. Profile HI-7 compares with profile HI-1 at the north end of Hunting Island in that both are influenced by the morphotogy and sediment budget of an adjacent tidal inlet.

Engineering Solutions

In past years, the response to Hunting Island's erosion problem (Shoreline retreat of about (28 ft per year) 8.5m per year has been large scale beach nourishment. In simple terms, beach nourishment replaces e-roaded sand with material borrowed from a nearby source. Ideally, the source should be the deposition zone of the erosion process, but, alter-native sources can be used if the material is similar to the native beach sand. Four nourishment projects have been completed at Hunting Island to date, (Table A-4).

In addition to the beach fill, a terminal groin was built in 1969 ($179,000) to assist in fill retention. The following assesments of

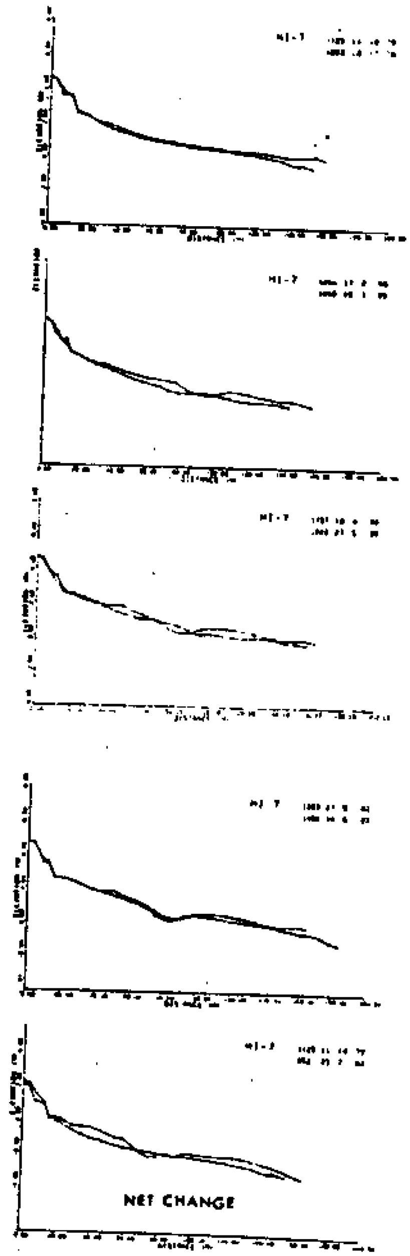


Figure A-17 Comparison of beach profiles from selected dates at station HI-7.

TABLE A-4

Historic Project Costs for Beach Nourishment at Hunting Island.

TABLE A-4

Date Accomplished	Cubic Meters* Placed (yd^3)	Limits of Placement	Unit Cost** \$1m^3 (\$/yd^3)	Total*** Project Cost
2/27/68 - 12/5/68	573,416 (750,000)	50 + 00N to 50 + 00S	N/A	$435,178
5/6/71 - 12/18/71	582,074 (761,324)	50 + 00N to 50 + 00N	N/A	$534,000
4/5/75 - 6/5/75	468,652 (612,974)	60 + 00N to 30 + 00S	2.45 (1.88)	$971,540
1/16/80 - 5/1/80	1,080,080 (1,412,692)	24 + 60N to 97 + 00S	3.21 (2.45)	$2,267,201

* Includes overfill

** Unit cost to payline

*** Cost data based upon project specifications, not the actual volume of sand placed.

future projects was prepared by the Corps in 1977.

> "The initial work was completed in the fiscal year ending 30 June 1969. Federal participation was supposed to end 10 years thereafter--June 1979. The actual language in the authorizing document (House Document 323, 88th Congress, 2nd Session) was to the effect that local interests would be required to: contribute 30 percent of the first cost of the project construction, a sum currently estimated at $136,000, and agree that during the 10-year period following initial construction they also will contribute to the periodic nourishment work 30 percent of the costs thereof, a sum estimated at $29,500 annually."
>
> This 10-year limitation on Federal participation was extended to 15 years by Section 156 of the Water Resource Development Act of 1976. This 15-year limit would expire 30 June 1984 in the case of Hunting Island. In addition to the nourishment in FY 1977, there could be nourishments in FY 1980 and FY 1983. These changes could increase the project costs (Federal and non-Federal) by about $3,420,200, which, if added to recent 10-year (PB-3) cost estimates of $3,830,000, would make a total present estimated 15-year cost of $7,250,200."

The 1977 fill was delayed until January - May of 1980 at a cost of $2,267,201. This recent fill was considerably larger than the previous projects, probably due in part to the delay from its scheduled 1977 completion. (Figure A-18).

The recent beach nourishment project is typical of possible future plans for Hunting Island. With the possible inclusion of a groin field, there will be a comparable renourishment every three years. It is the intent of the present PRT research project to determine if this nourishment could be made more effective and if additional structure should be considered. In addition, PRT is interested in the probable consequence of no future beach fill, that is, a do nothing alternative.

The past fill projects offer the best guidelines to future costs at Hunting Island. The volumes and frequency of fill appear to be

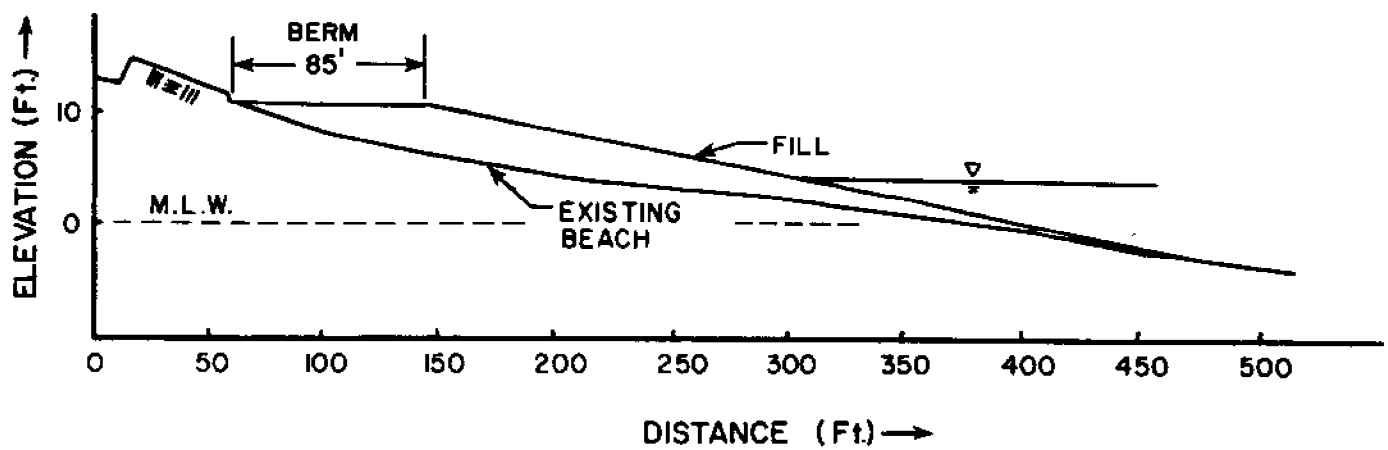


Fig. A-18. Hunting Island Nourishment Profile reasonable, and have a favorable benefit cost ratio according to the Corps analysis. There is no reason to believe that this solution could not be continued indifinitely from an engineering perspective.

Benefit-Cost Analyses

The principle benefits accruing from erosion control measures taken at Hunting Island stem from: 1) the prevention of property loss and 2) the prevention of recreational loss. The following section estimates values for these potential benefits and compares them with the estimated costs of further beach nourishment at Hunting Island.

Property Loss

The potential loss to be prevented is a function of the rate of erosion anticipated over the planning horizon. As Hunting Island has been highly erosional over recent history, two scenarios were projected using alternate erosion rates. Annual erosion rates observed over the past 25 years and the past 100 years were projected forward over a 50 year planning interval. Although conditions affecting shoreline formation over the recent past may not exist in the projection period, the estimates assume that long-term erosional trends are captured and that these trends will continue.

Because Hunting Island is a state park left predominantly in a natural state, the value of its structures is considerably less than at the other three sites considered. The location of the existing structures is shown in Figure A-19. Based upon erosional/accretional trends observed over the past 25 and 100 year periods, potential property loss and expected lifetime of the structure are calculated for both public and private facilities on the island. The present value of the property loss is then

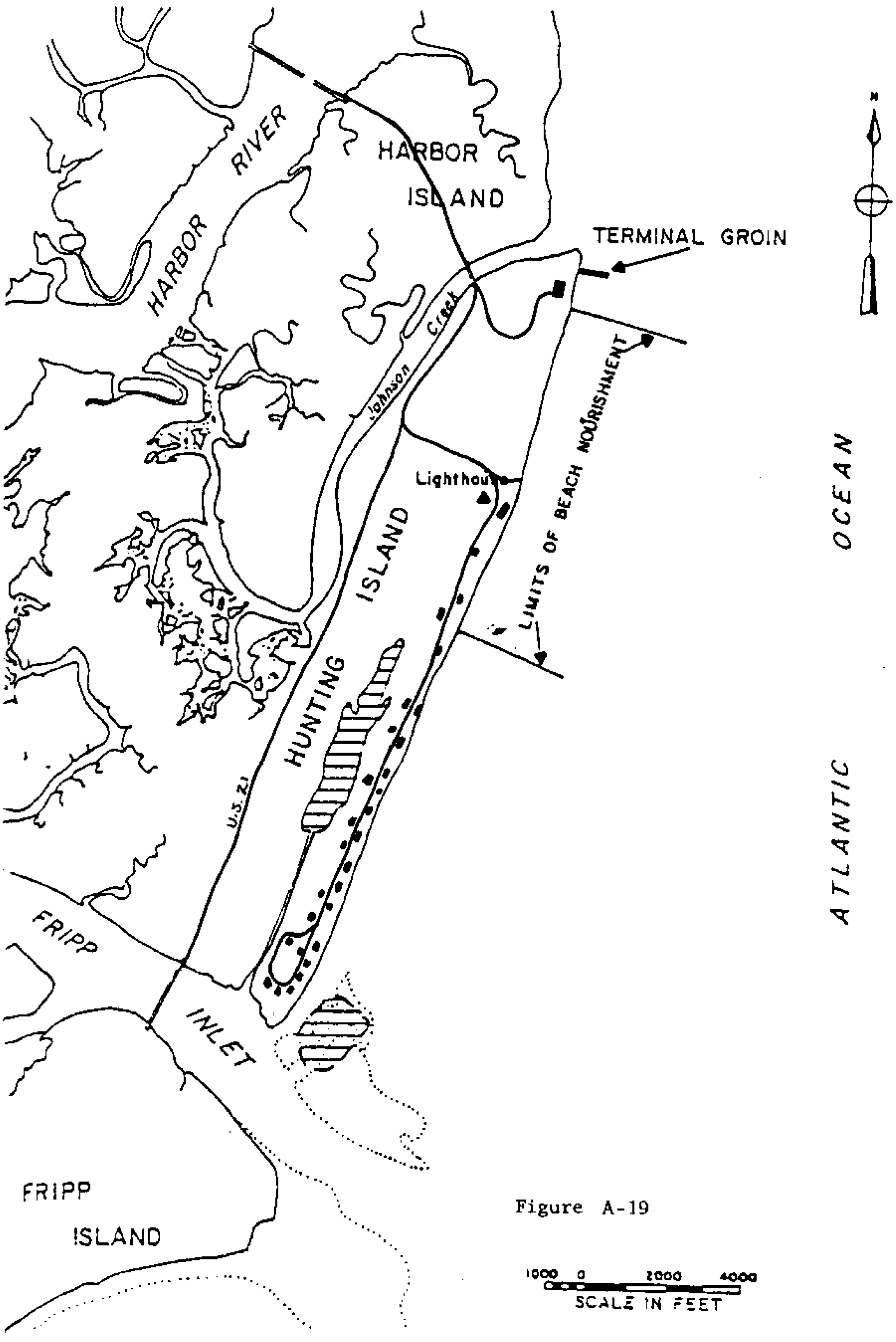

HARBOR RIVER
HARBOR ISLAND
TERMINAL GROIN
Johnson Creek
Lighthouse
LIMITS OF BEACH NOURISHMENT
HUNTING ISLAND
U.S. 21
FRIPP INLET
FRIPP ISLAND
ATLANTIC OCEAN
N
1000 0 2000 4000
SCALE IN FEET

Figure A-19

computed using constant dollars for property value and a 4 percent discount rate (for reasons discussed previously p. 105). The estimated property loss accruing under each of the erosion scenarios is presented in Table A-5.

It should be noted that neither of the above scenarios result in loss to the historic lighthouse or surrounding buildings which represent the most important development on the island. Neither of the scenarios considers the relocation of strucutes which has been employed in the past to reduce damages on Hunting Island. Theis overstatement of damages appears less important when considered relative to the substantial recreational benefits that accrue at Hunting Island.

Recreational Benefits

The recreational benefits accruing from erosion control reflect the value of visitor occasions saved as a result of the project. In 1980, visitation at Hunting Island was estimated to be 1,102,696. Projections for the remainder of the 50 year planning period are based upon an earlier study of recreation in South Carolina by Hartzog, Lader, and Richards (1974). Visitation projections are based on population projections as well as proximity and accessibility to each of the state beaches. Table A- 6 lists average annual visitation for each the 5 decades during the planning period. Listed below is the distribution of visitor demand according to day of the week for the 86 day summer season.

With periodic beach nourishment it is estimated that an average of 195 feet of dry sand can be maintained along the 10,000 feet feeder beach. Based upon a required area of 100 square feet per person, the estimated capacity of the replenished beach is 19,500 users/day. At present, only

TABLE A-5

Value of Property Loss on Hunting Island
Under Alternate Erosion Scenarios

Scenario I 25 Year Erosion Rate

	Value	Lifetime	Present Value at 4% Discount
Public Property			
Concession	$ 20,000	25 years	$ 7,500
Cabins: #2	37,500	35 years	9,487
#3	37,500	35 years	9,487
#14	45,000	40 years	9,360
#15	45,000	40 years	9,360
Private Property			
10 Cabins at	13,240 each	2 @ 25 years	9,930
		3 @ 30 years	12,231
		4 @ 35 years	13,396
		1 @ 40 years	2,753
TOTAL	$315,240		83,504

Scenario II 100 Year Erosion Rate

	Value	Lifetime	Present Value at 4% Discount
Public Property			
Recreation Building	$ 50,000	25 years	$18,750
Cabins: #10	37,500	25 years	14,062
#11	37,500	25 years	14,062
Private Property			
7 Cabins at	13,240	25 years	4,965
		2 @ 30 years	8,154
		2 @ 40 years	5,506
		2 @ 45 years	4,528
TOTAL	$217,680		$70,027

TABLE A-6

Projected Visitation and Recreational Value Accruing for Periodic Beach Nourishment at Hunting Island.

	1980-90	1990-2000	2000-10	2010-20	2020-30
1. Visitation	1,168,857	1,309,120	1,466,214	1,642,159	1,839,219
2. Weekdays (60)	11,239	12,588	14,098	15,790	17,685
Sats (12)	16,859	18,882	21,147	23,685	26,527
Suns (12)	19,668	22,028	24,672	27,632	30,948
Peak (2)	28,098	31,469	35,246	39,475	44,212
3. Annual Visitation with project	1,149,648	1,254,864	1,352,880	1,454,400	1,568,100
4. Annual Visitation without project	994,074	838,500	838,500	838,500	838,500
5. Differential	115,574	416,364	514,380	615,900	729,600
6. Erosion Control Benefit for 10 Year Period	2,311,480	8,327,280	10,287,600	12,318,000	14,592,000
7. Present Value	1,900,037	4,621,640	3,857,850	3,116,454	2,495,232
8. Sum of Present Values					$15,991,213

peak day activity exceeds capacity, but over the planning period, it is estimated that weekend activity will become constrained even with the project and that weekday activity will approach capacity. Assuming a daily constraint of 19,500 visitors, therefore, annual visitation with the project is listed as item 3 in Table A-6.

Without the project, it is estimated that the beach will significantly deteriorate after the first 5 years of the recently completed nourishment project. After that time, the beach and dune system will migrate, in some cases, with the high water mark meeting or exceeding the tree line. As a result, the available dry beach area will be reduced significantly during the adjustment process. Eventually, when temporary stability is achieved, the beach width will again broaden allowing greater recreational capacity. It is important to note, however, that the island will continue to have recreational potential during such a transitional period as erosion rates will vary along the breadth of the beach area. For purposes of the present study, it is estimated that beyond the first 5 years of the planning period, beach capacity without renourishment will average 50 percent of capacity with periodic nourishment. Item 4 in the table lists the projected annual visitation without the project.

The recreational benefit is found then as the differential between values accruing with and without the project. Item 5 in the table represents differential usage for each of the ensuing decades. The differential is small in the first time period as the recently completed nourishment project continues to produce benefit. As erosion occurs without renourishment and weekday capacity is approached with the project, the difference widens.

Corresponding erosion control benefits in current dollars are given in Item 6. User occasions are accessed a value of $2 per day (as previously noted). The dollar value of benefits for the ten year period is found then by multiplying the average differential by $2 by 10 years. The present value of recreational benefits is derived by discounting the ensuing stream of benefits at a 4 percent discount rate. As benefit streams are estimated in current dollars, it is appropriate to use an inflation free discount rate, i.e., the market rate of interest with price expectations deducted. This concept has been discussed previously by Hanke (1975) and Stepp, et al., (1975).

Project Costs

According to estimates by the Corps of Engineers, the cost of the 1980 nourishment project at Hunting Island amounted to $2,267,201. Because of the delay between nourishment projects, a larger than normal amount of fill was required. Therefore, tow cost scenarios are estimated. The high-cost scenario assumes that renourishment costs occuring every 3 years will continue at the 1980 level. The low-cost scenario assumes that renourishment costs will amount to 60 percent of the initial cost if maintained every 3 years. The project costs over a 50 year planning horizon are given in Table A-7 under both of these assumptions. Present values based upon the 4 percent discount rate are also given. It is estimated that the present value of future expenditures may vary between $8.4 and $14 million. It is recommended that the high-cost scenario be used for present planning purposes given past cost overruns.

Benefit-Cost Summary

Table A-8 presents a summary of benefits and costs of periodic re-

TABLE A-7

Costs of Beach Nourishment at Hunting Island

A. Low-Cost Scenario

Year	Cost	Present Value
3	$ 1,360,321	$ 1,209,325
6	1,360,321	1,074,653
48		12,152
TOTAL	21,686,270	8,267,666

B. High-Cost Scenario

Year	Cost	Present Value
3	$ 2,267,201	$ 2,015,542
6	2,267,201	1,791,088
48	1,533,333	20,253
TOTAL	36,143,783	13,779,443

TABLE A-8

Summary of Costs and Benefits of Beach Nourishment at Hunting Island in Present Dollar Values.

Item	Benefit	Cost
Property Loss (Table VI - 6)	$ 83,504[1]	
Recreational Value (Table VI - 7)	15,991,213	
Beach Nourishment		$13,779,443[2]
TOTALS	16,074,716	13,779,443
Benefit/Cost Ratio	1.167	

[1]Based on 100 year erosion rates.

[2]Based on high-cost renourishment scenario.

nourishment at Hunting Island. The only option considered is periodic renourishment of the beach under the high-cost scenario. As previous nourishment projects have influenced recent erosion rates, only the 100 year rate is applied to property loss. Under the assumptions that have been made, the benefit-cost ratio for a continuation of the project is estimated to be 1.167.

From the state perspective, the federal/state distribution of costs for future nourishment cycles will be an important determining factor. In addition, closer examination of shoreline retreat and carrying capacity of the island without the project should be given as the major justification for the project rests with the recreational value of the island to beach users.

CASE B: HILTON HEAD

Beach Morphology

Hilton Head Island is the largest beach ridge-type barrier on the South Carolina coast, originally formed by a series of prograding beach ridges. On the present-day island, this complex development pattern is indicated by beach-ridge sets that trend in several directions. Most recent sets of beach ridges are parallel to the present shoreline along the southern half of Hilton Head. Along the northern section of the island, beach ridges are truncated and oblique to the shoreline, indicating a zone of erosion.

In addition to larger dimensions, Hilton Head also differs from most other beach-ridge barriers in that it is bordered by large estuary systems rather than a tidal river - salt marsh system connected with the ocean by a relatively narrow tidal inlet. The effects of tidal inlet - tidal delta systems on the stability and sediment budget of adjacent barriers has been well studied (FitzGerald et al., 1978; Hubbard et al., 1977; Nummedal and Humphries, 1977). Port Royal Sound to the north of Hilton Head and Calibogue Sound to the south have associated with them linear sand bodies and shallow marginal channel systems that are continously shifting position. Larger main tidal channels also exist, having evolved morphologically with time, although significant shift has not occurred. A study of the effects of these changes on the littoral sand budget of adjacent sections of Hilton Head beach has not been conducted at this time.

The data base that presently exists on trends of shoreline change along Hilton Head consists of the five sets of aerial photographs at five to seven year intervals between 1951 and 1972, six editions of nautical charts published between 1898 and 1978 and a two-year beach profile study at four locations on Hilton Head conducted from 1974 to 1975.

Changes in Shoreline Position 1898 - 1979

Long-term changes in shoreline position along Hilton Head Beach alternate between zones of accretion and zones of erosion (Fig. B-1). As suggested by truncated beach ridges, the section of shoreline between Forest Beach and a point 7 km north of Folly Creek has undergone significant erosion between 1898 and the present (Fig. B-1). Net changes north of Forest Beach were erosional from 1898 to 1979 ranging from 200 to 500 m of shoreline retreat. Maximum shoreline retreat occurred along an 8 km section of beach immediately south of Folly Creek. Net migration 1000 m to the south by the small tidal inlet associated with Folly Creek over the past 80 years indicates net sand transport southward at least along this section of beach.

Depositional-erosional trends along the southern half of Hilton Head Island have varied considerably in space and time (Fig. B-1). The section of shoreline extending from the north end of Forest Beach to a point 9 km to the south accreted seaward by up to 500 m from 1898 to 1922 (Fig. B-1). Since 1972, however, the section of shoreline along Forest Beach has retreated significantly. Maximum net erosion of approximately 200 m has taken place near the center of the Forest Beach section between 1922 and the present.

The beach along the Sea Pines Plantation section of Hilton Head eroded significantly between 1898 and 1922. This zone has been more or less stable since 1922, however, undergoing either slight net erosion or slight net accretion. The southwest end of Hilton Head has developed by build-up and

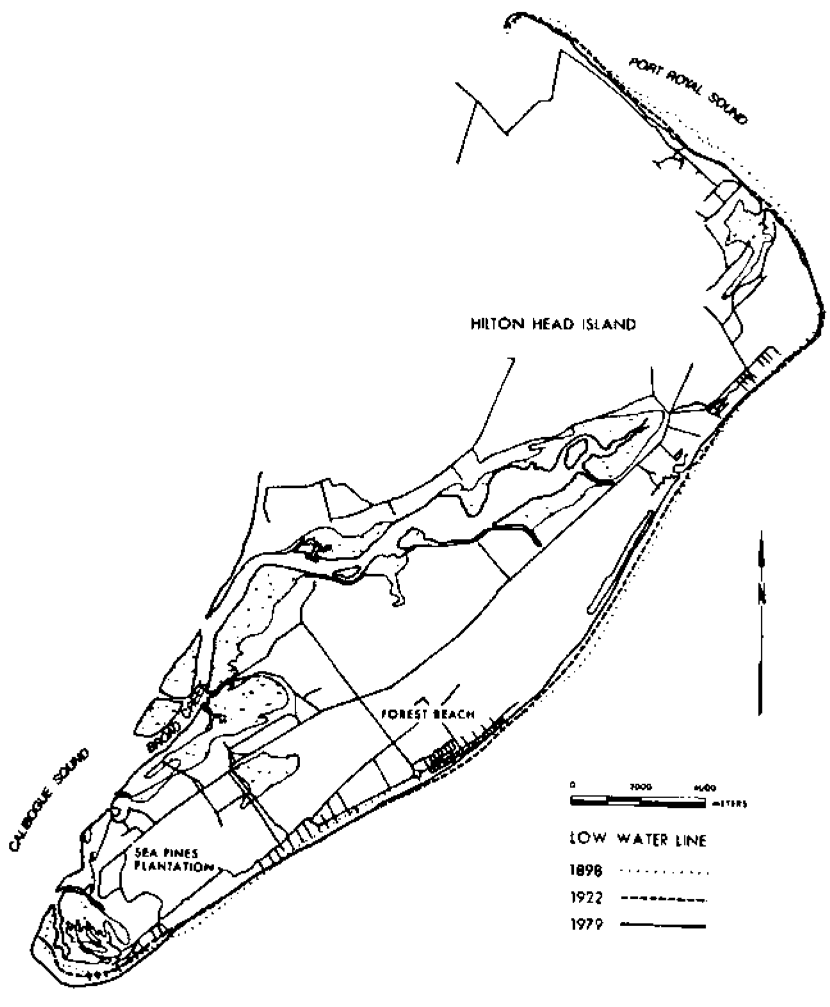


Figure B-1 Long-term changes on Hilton Head Island compiled from nautical charts between 1898 and 1979.

extension of a recurved spit. Morphology and depositional-erosional trends in this area are controlled by tidal circulation, sediment supply from shoals associated with the entrance of Calibogue Sound and sediment supply from updrift, erosional areas of Hilton Head Beach. Patterns of shoreline change along the recurved, distal end of Hilton Head were irregular between 1898 and 1922. Zones of erosion alternated with zones of deposition and overall net changes were small. Between 1922 and 1979, this area was strongly depositional (Fig. B-1) and extended 200 to 600 m toward the entrance of Calibogue Sound. In contrast, the shoreline at the northeast end of Hilton Head on Port Royal Sound has been cut back extensively over the past 80 years.

The overall trend of shoreline change on Hilton Head Island has been significant, with long-term net erosion along the northern half and a relatively stable to strong accretional trend along the southern half. Erosion along the southern portion of the island has been only local and of short-term duration. This pattern lends support to the idea that beach erosion at the north end of Hilton Head is serving as a sand source for depositional trends at the south end of the island. Direction and rates of longshore sediment transport on Hilton Head Island have not been well investigated as yet, however. Related wave energy flux on the beach and shoreface of Hilton Head is also largely uninvestigated, but the effect of waves can be qualitatively seen in refraction diagrams of monochromatic waves over the present day bathymetry. Orthogonals of hypothetical waves approaching Hilton Head from the east, southeast and south tend to converge on the Forest Beach area and the northern half of the island (Fig. B-2 and B-3). Convergence on Forest Beach seems to be, in part, a function of wave

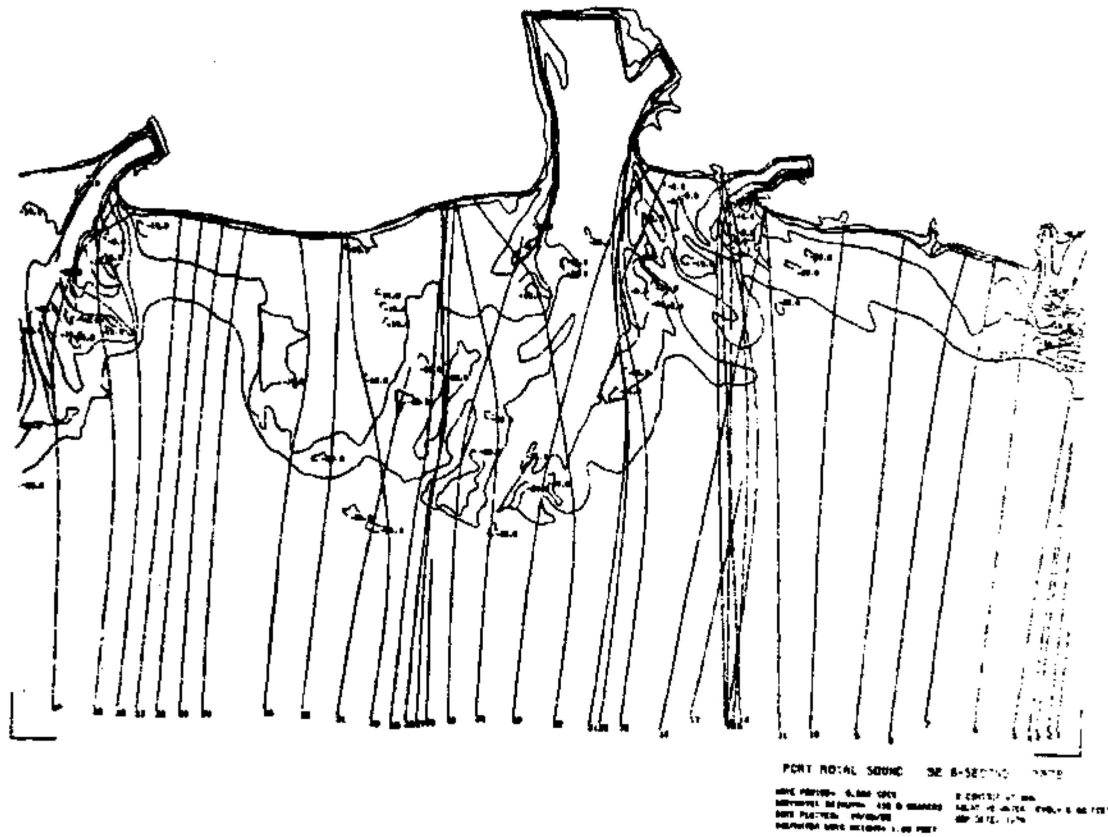


Figure B-2 Refraction of 6-second waves from the southeast over 1979 bathymetry in the vicinity of Hilton Head Island.

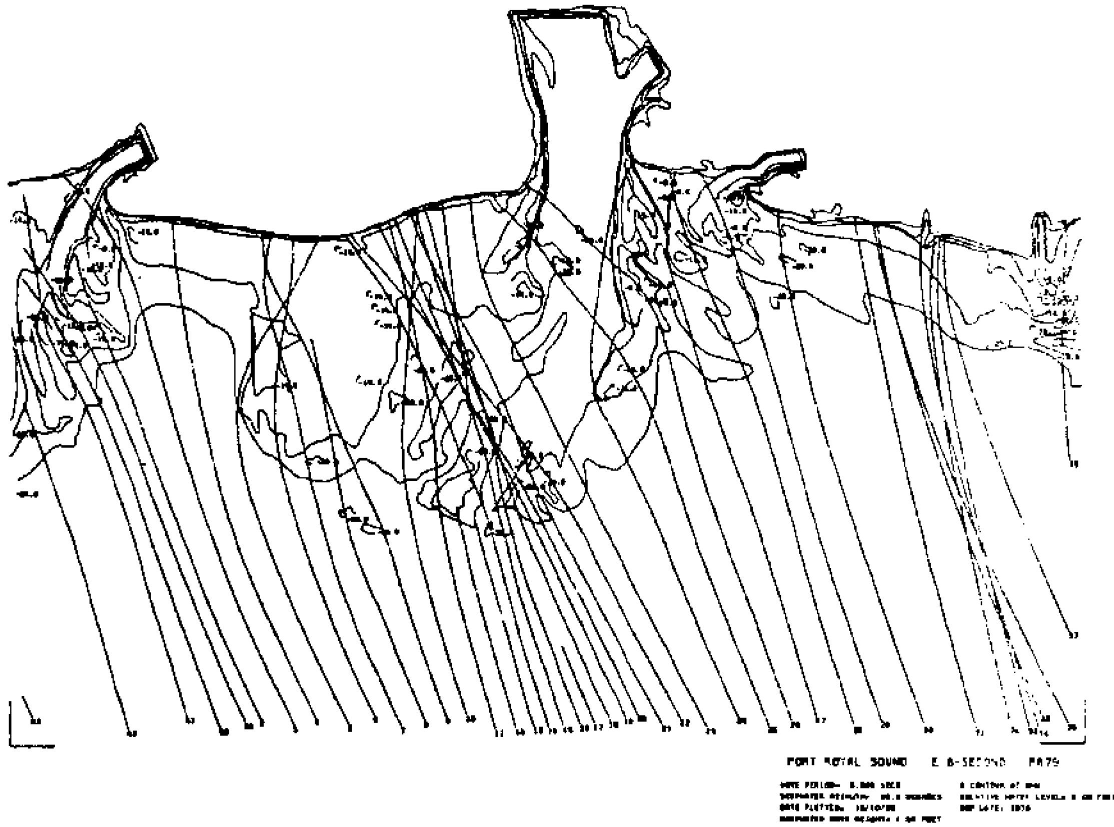


Figure B-3 Refraction of 8-second waves from the east over 1979 bathymetry.

refraction over the offshore shoal known as Gaskin Bank.

Shoreline Changes 1951 to 1973: Aerial Photographs

Intermediate-term trends of shoreline change have been documented from five aerial photographic surveys of Hilton Head Island, completed between 1951 and 1973. Changes in shoreline position between each aerial survey date were measured at thirteen points spaced 1500 to 2000 m apart. Analysis methods were similar to those described for the Hunting Island aerial survey, consisting of determining the high water line relative to fixed control points on scale corrected aerial photos.

Results of the aerial photo analysis indicate trends similar to longer-term shoreline changes (Table B-1). The most persistently erosional sections of Hilton Head beach are along the northern half; whereas, the southern section has been stable to moderately accretional (Fig. B -4). The area of greatest erosion during the twenty-two year period of aerial photo surveys was the section of shoreline enclosed by photo-control points J5, J6 and J7 (Table B-1 Fig. B-4) north of Forest Beach. Only one control point was established in the Forest Beach section of Hilton Head which has been retreating over the last sixty years. Intermediate-term rates of erosion for this highly-developed area, therefore, are not well known. South of Forest Beach, shoreline changes were either strongly accretional between photo survey dates or stable and no measurable change recorded. The only exception to this trend was a significant loss of beach along the recurved spit that underwent an episode of erosion between 1951 and 1955 (Table B-2, Fig. B-4). Between 1955 and 1972, this area resumed the long-term stable to accretional trend.

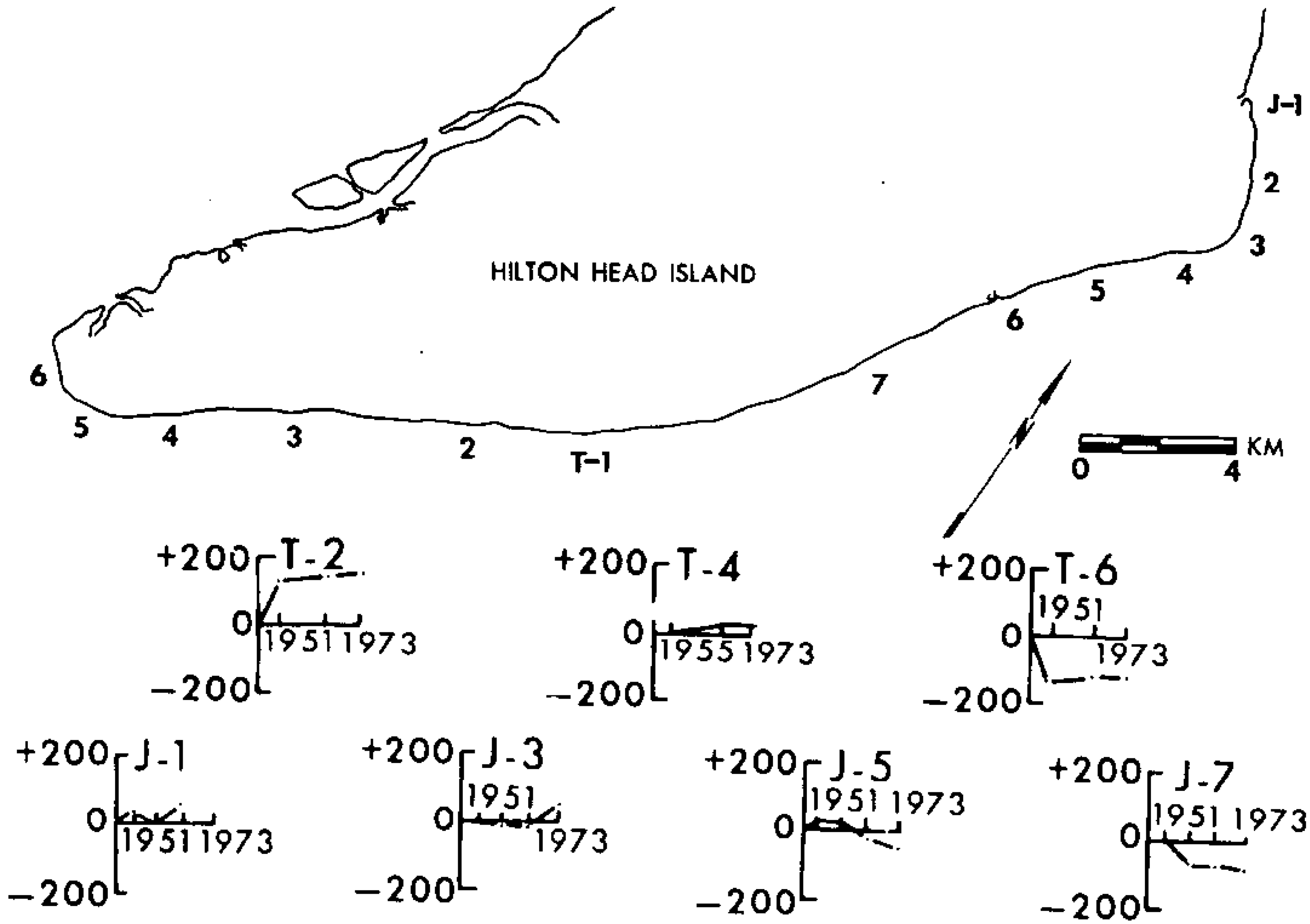


Figure B-4 Depositional-erosional trends along Hunting Island compiled from vertical aerial photographs.

TABLE B-1

North Hilton Head Island

Reference Point	Change 1951-55	Change 1955-60	Change 1960-66	Change 1966-73
J 1	15	-17	30	ND
J 2	0	-16	0	1
J 3	0	- 4	-6	36
J 4	31	0	0	10
J 5	11	0	-23	-15
J 6	-10	-11	-12	-34
J 7	ND	-36	0	- 9

TABLE B-2

South Hilton Head Island

	Change 1951-55	Change 1955-66	Change 1966-73
T 1	53	0	0
T 2	62	9	6
T 3	57	27	0
T 4	0	11	0
T 5	-66	9	14
T 6	-66	10	0

Short-Term Changes: Beach Profiles

Morphologic and volumetric beach changes along Hilton Head were recorded at four profile stations between September, 1974 and August, 1976. The profile locations (Fig. B-4a) were not meant to be representative of the entire island, but were systematically placed within zones that have historically been both erosional and depositional. Profiles were surveyed a total of seventeen times over the two-year study period at intervals of one or two months.

Through the two-year study period, the beach at all four profile locations was subject to large volumetric changes (Fig. B-5) which correlate, to some degree, with morphologic changes from profile to profile. Particularly well correlated were changes among profiles HH3, HH4 and HH5. An accretional period in August, 1975 (profile 3) and September, 1975 (profile 5) was followed by an erosional episode in October, 1975. A smaller, but still significant depositional-erosional period at these profiles followed in December, 1975 - January, 1976. Large positive changes in beach volume may correlate with the practice of beach scraping. Overall, little net volumetric change took place at any of the profile stations during the survey period. No seasonal trends in morphology or volume changes were rated. Seasonal changes may have been masked by the effects of beach scraping.

Profile station HH2 at the north end of Hilton Head (Fig. B-4a) is located in one of the more stable sections of the island (Fig. B-1). The beach profile at this location was composed of a low well vegetated dune and a flat beach with superimposed ridge and runnel topography during the time of the study (Fig. B-6). The one or two ridge and runnel systems that were nearly always present at this location were usually low

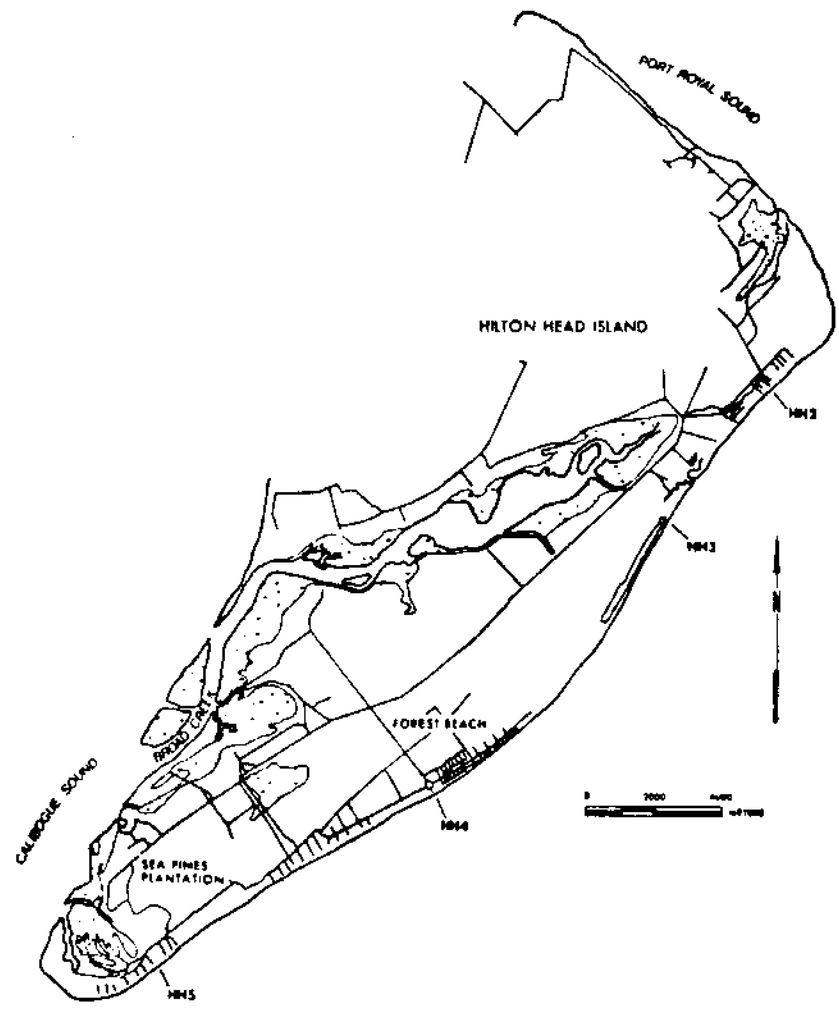


Figure B-4a. Location of Hilton Head beach profile stations, 1974-76.

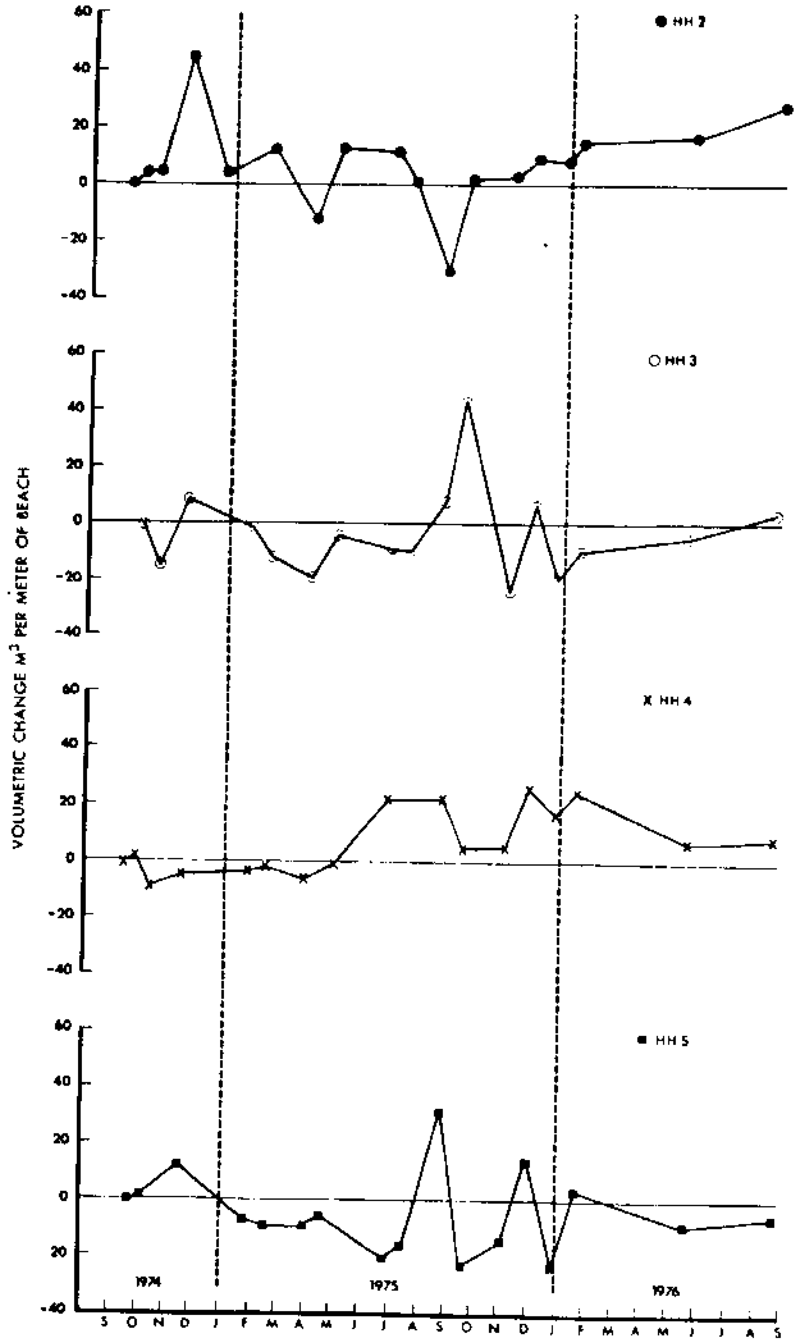


Figure B-5 Volumetric change in cubic meters per meter of beach between survey dates at Hilton Head profile stations HH2, HH3, HH4 and HH5.

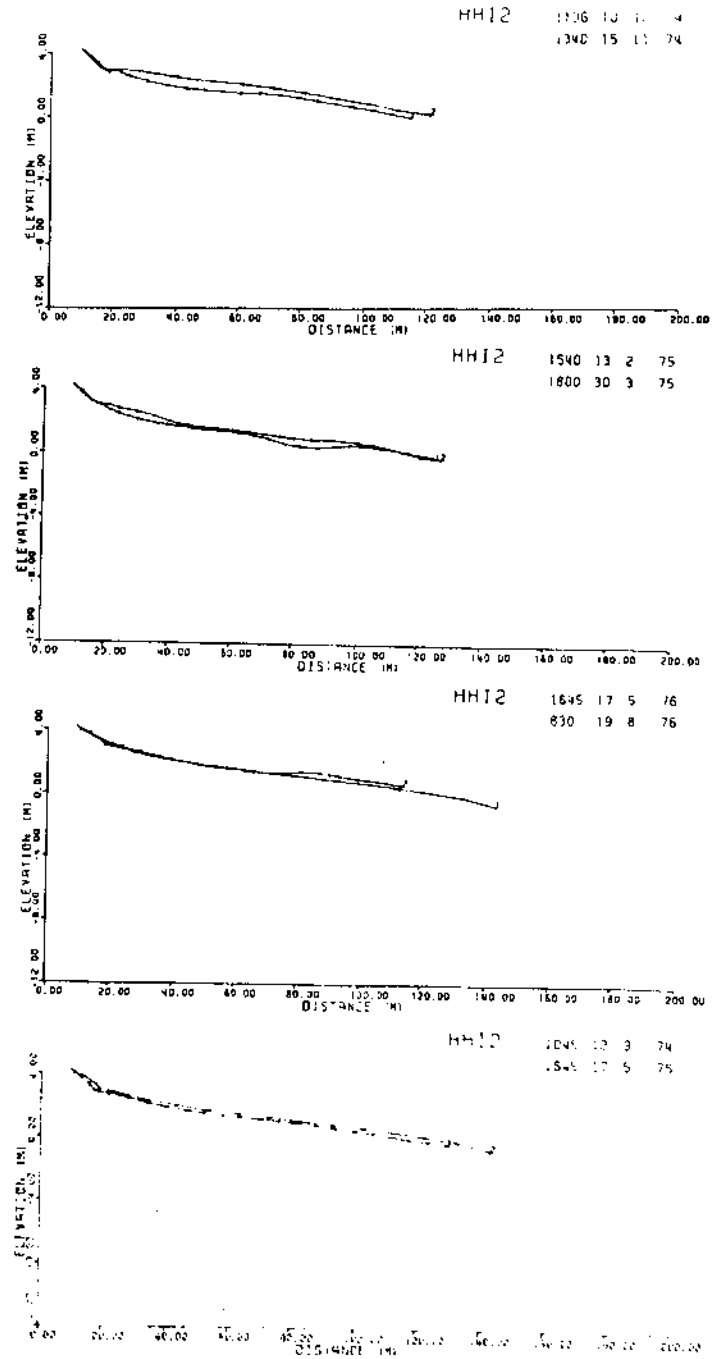


Figure B-6 Comparison of beach profiles from selected dates between September, 1974 and August, 1976 at station HH2. Net change is shown in lower plot.

relief features, but, during spring and summer months, sand ridges occasionally attained amplitudes of 50 cm or more.

The beach at HH2 was relatively wide compared with beaches more centrally located along Hilton Head. Three large fluctuations in beach volume took place compared with the first survey of the study (Fig. B-5). These changes occurred during 1974 and 1975; whereas, changes during the second half of the study were positive, but not large. The abrupt, large fluctuation may be related to periodic beach scraping, but no records are avaliable to support this conclusion.

Profile station HH3 is located approximately 4 km south of HH2 in a zone that has historically undergone significant erosion (Fig. B-1). The beach at this station is the narrowest of the four profiles measured, averaging 110 m wide at low water. The dune ridge at this location is approximately 2 m high and was artificially constructed from dredge material. This man-made dune was subject to frequent truncation by wave attack over the study period and apparently has been repaired during beach scraping exercises (Fig. B-7).

The most significant feature of the volume change plot (Fig. B-5) based on beach profile data is a large positive change between the August 23 and September 19, 1980 surveys. The sediment fill resulted in a flat beach relative to the ridge and runnel system present during the previous survey (Fig. B-7). A large net loss of sediment was recorded at the next survey (November 2, 1975) followed by a partial rebound in beach volume by November, 1975 (Fig. B-5). Rather than a natural depositional-erosional episode, these abrupt changes seem to be related to the beach scraping practice. Such large, rapid changes and flat accretional beach profiles

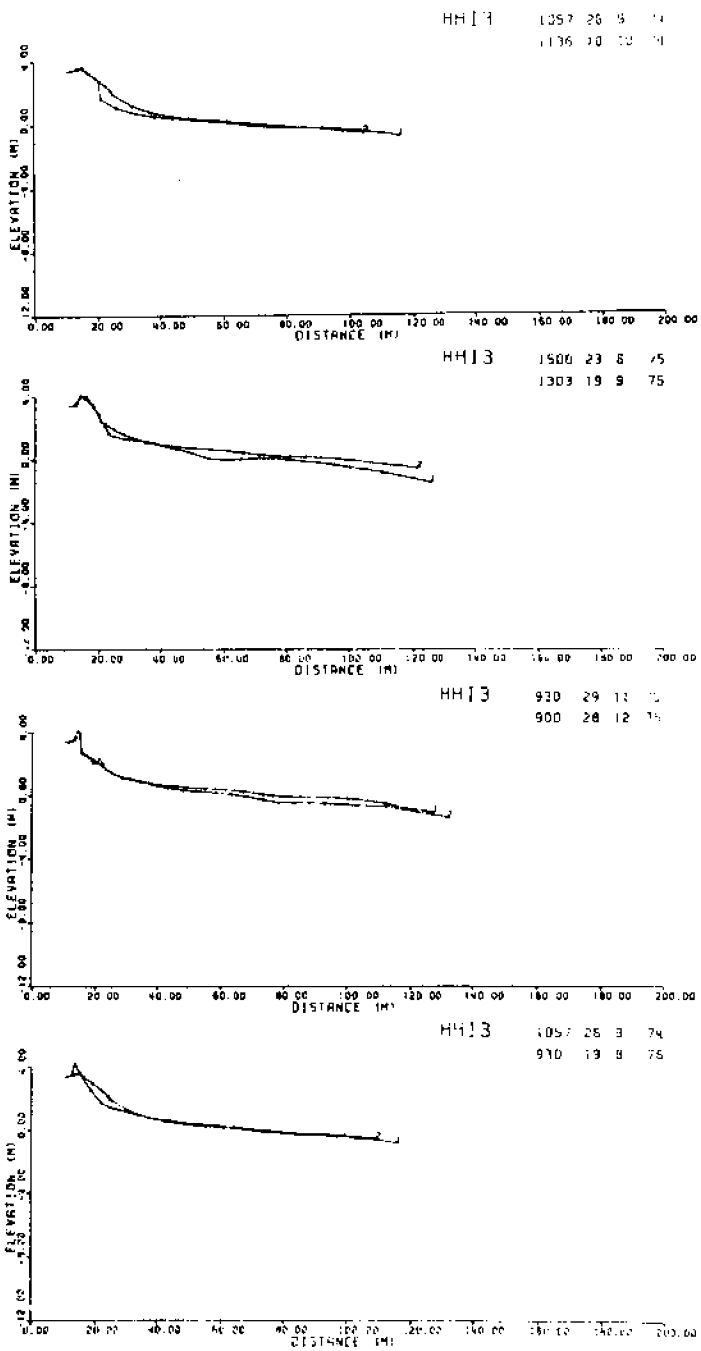


Figure B-7 Comparison of beach profiles from selected dates at station HH3. Net change is shown in lower plot.

are not common under normal conditions. An alternate explanation might be the effects of a storm or storms or an unusual set of wave conditions. The correlation of abrupt depositional-erosional changes among the Hilton Head profiles during this part of the study could be explained by storm effects. Similar to profile HH2, the beach at HH3 underwent a period of slow net accretion over that latter part of the study, but, overall, the beach at profile HH3 showed nearly zero net change over a two-year period (Fig. B-5).

The profile designated HH4 was positioned near Forest Beach, an area that has been moderately erosional since 1898 (Fig. B-1). The beach here was backed by a low natural dune covered with sea oats (Uniola) at the time of the study. Ridge and runnel topography was persistent throughout most of the two-year study (Fig. B-8). Periodically, a distinct spring tide berm developed 15 to 20 m seaward of the dunes, particularly associated with periods of ridge and runnel activity. Trends of volumetric change generally correlate with changes in profiles HH3 and HH5, but depositional-erosional patterns were not as large or as abrupt. The large volumetric changes spanning August, September and October, 1975, at other profile stations were represented at profile HH4 by a moderate erosional period (Fig. B-5).

A period of significant deposition between the beginning and end of November, 1975, followed by erosion during December was similar to changes at the other Hilton Head profiles during this time. The beach at HH4 seemed relatively stable between January and August, 1976, but only four surveys were completed over this period, and large fluctuations may have been overlooked. At the end of the two-year study, a small net accretion

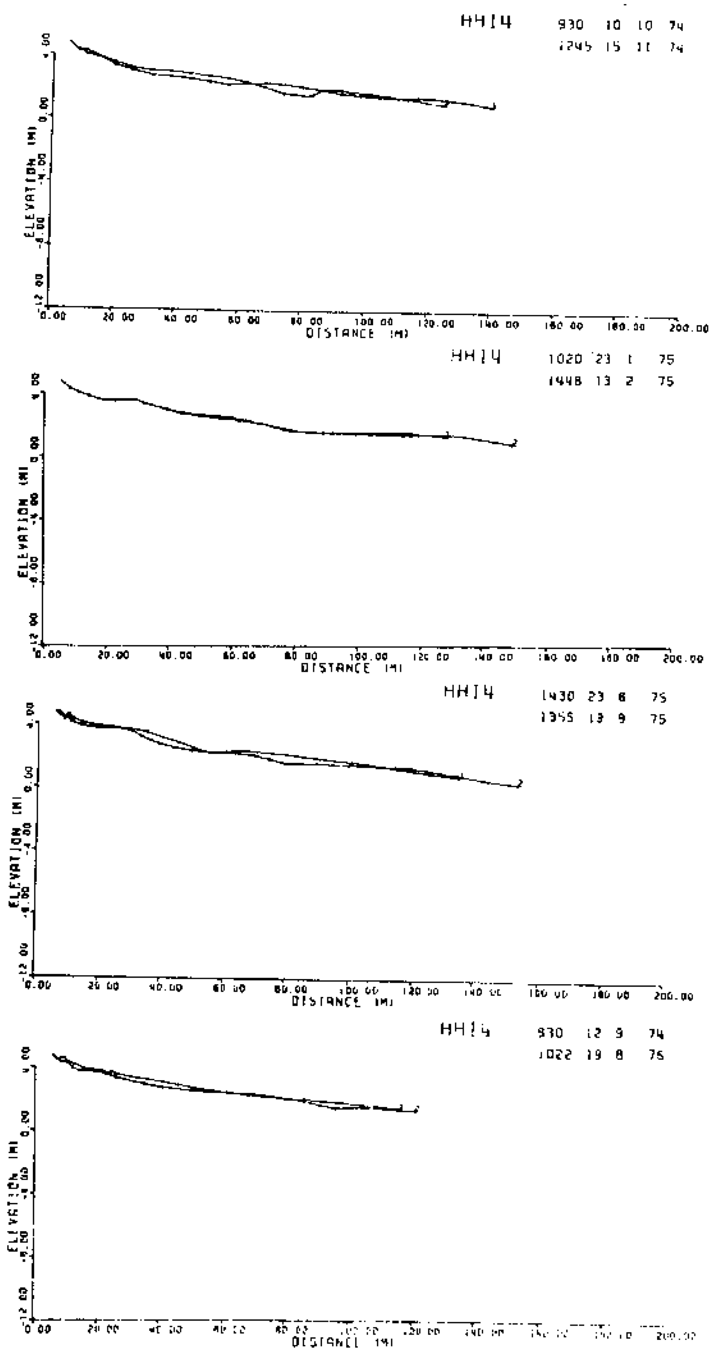


Figure B-8. Comparison of beach profiles from selected dates at station HH4. Net change is shown in lower plot.

of sand was recorded at HH4. The beach was morphologically similar at the time of the final survey compared with the initial survey.

Profile HH5 is near the southern end of Hilton Head just within the recurved spit section. Here, the beach is under the influence of the tide-dominated shoals marginal to Calibogue Sound. The beach is wide, averaging 150 m from the dunes to the low water line and frequently has one or more high amplitude ridge and runnel systems moving across the beach (Fig. B-9). The 2 m high dune ridge at this location is artificial, well vegetated and was not subject to erosion through the two-year study.

A low spring tide berm was frequently present at HH5 and usually associated with ridge and runnel activity. Similar to profile HH3, the beach at HH5 was subject to large volumetric changes between August and September, 1975. The pattern here was nearly identical to station HH3 except that the maximum volumetric peak occurred in August rather than September (Fig. B-5). Another volumetric peak was recorded in November followed by significant erosion in December, 1975. Again, it is not certain whether these abrupt changes are related to beach scraping or storm effects. The general pattern at profile HH5 included large, possibly man-made depositional-erosional cycles, but nearly zero net change through the two-year study.

Engineering Solutions

As discussed in the preceding section, Hilton Head has a relatively stable shoreline. Some erosion is taking place; the trend being moderate retreat along the northern half and accretion along the southern end. Most of this erosion appears to correlate with individual storm periods. At the present, individual property owners are using a wide variety of

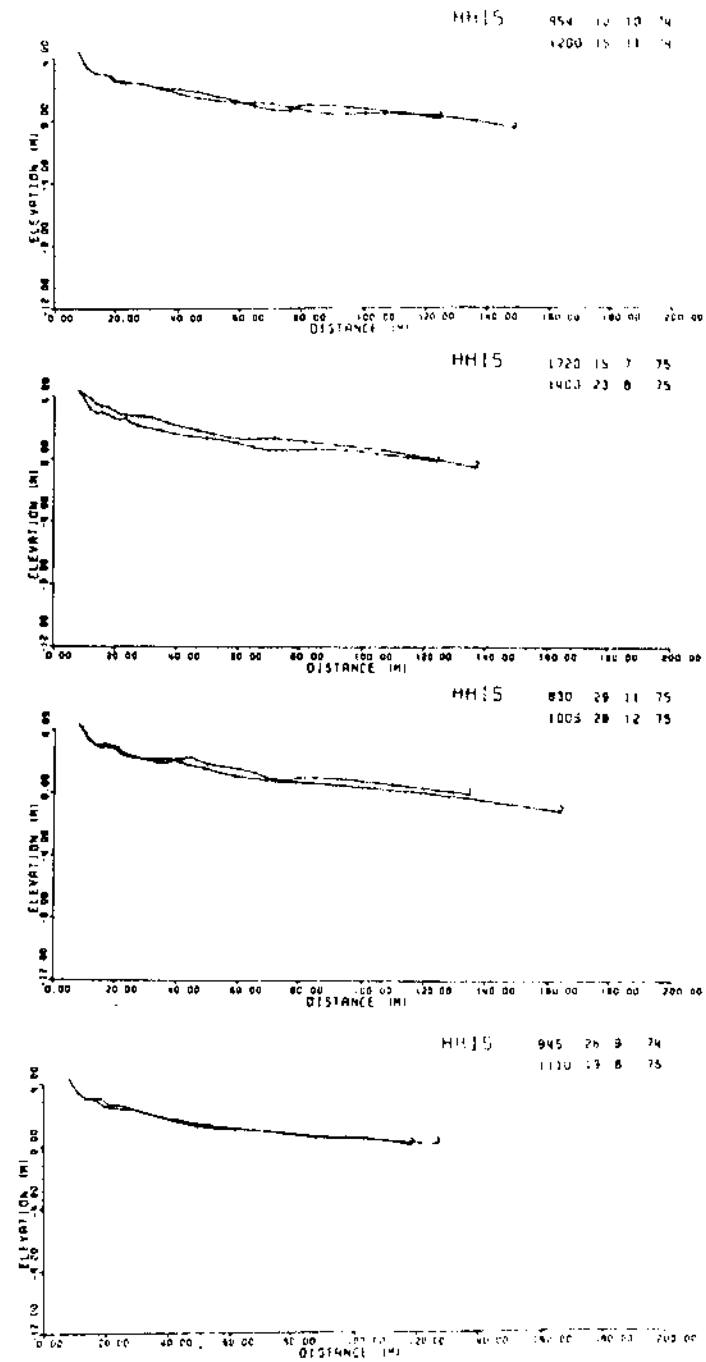


Figure B-9 Comparison of beach profiles from selected dates at station HH5. Net change is shown in lower plot.

erosion control techniques including beach scraping (from foreshore to backshore), beach nourishment, dune restoration, bulkheads (sandbags) and riprap. Many of these techniques have had unsatisfactory results.

Beach scraping has become a popular erosion control prodecure in South Carolina, particularly after severe storms. Although no documented evidence exists that it is a viable engineering plan, there is some data that suggest that the net effect of removing sand from the foreshore accelerates erosion. A comprehensive study of this practice should be made before it is adopted as an erosion control alternative.

The use of sanbags for bulkhead construction has met with only limited success in areas exposed to direct attack by ocean storm waves. Individual property owners in the North Forest Beach area have used sandbags, but they failed during Hurricane David. Alternative materials for bulkhead construction and riprap has also been used, generally in a discontinuous, non-uniform manner, resulting in increased erosion due to the presence of a bulkhead on the adjacent shoreline. This problem underscores the need for comprehensive shoreline protection, as opposed to fragmented solutions.

Beach nourishment has been used at North Forest Beach to control erosion and more recently at Palmetto Dunes. Sand was borrowed from a site on the marsh side of the island, an area where a marina is under construction. Nourishment provides both a recreational beach as well as a defense from storm waves and tides; thus, for this area, it seems to be the most reasonable erosion control alternative.

Beach Nourishment

Two exemplary projects are considered to illustrate the feasibility of beach nourishment at Hilton Head. The first alternative considers nourishment for 25,700 feet of feeder beach near Folly Inlet; while the second alternative considers nourishment for a 3,000 foot stretch at North Forest Beach. Figure B-10 shows a typical cross-section for the Hilton Head shoreline in the North Forest Beach region. The fill design includes a 50 ft (15 m) berm at an elevation of 10 ft (3 m) above MLW. Because no data was available to evaluate potential borrow areas, a range of unit costs have been used to estimate total costs. Based upon the fill profile, the volume requirements were estimated at 67 yd^3/ft (52 m^3/m).

TABLE B-3

Nourishment (3000 ft., 915 m)

Sand/yd^3	Total
\$3	\$ 603,000
\$4	804,000
\$5	1,005,000
\$6	1,206,000

Benefit-Cost Analysis

Hilton Head Island has developed over the past two decades into one of the most exclusive beach resorts in the country. While most of the island is relatively stable and the individual plantations generally have followed sound building patterns, the location of expensive dwellings on or near the oceanfront poses a potential for property loss. Presently, severe erosional problems are being observed at the North Forest Beach section of the island. To alleviate present and potential loss, beach nourishment has been considered as an alternative in the past (Corps of

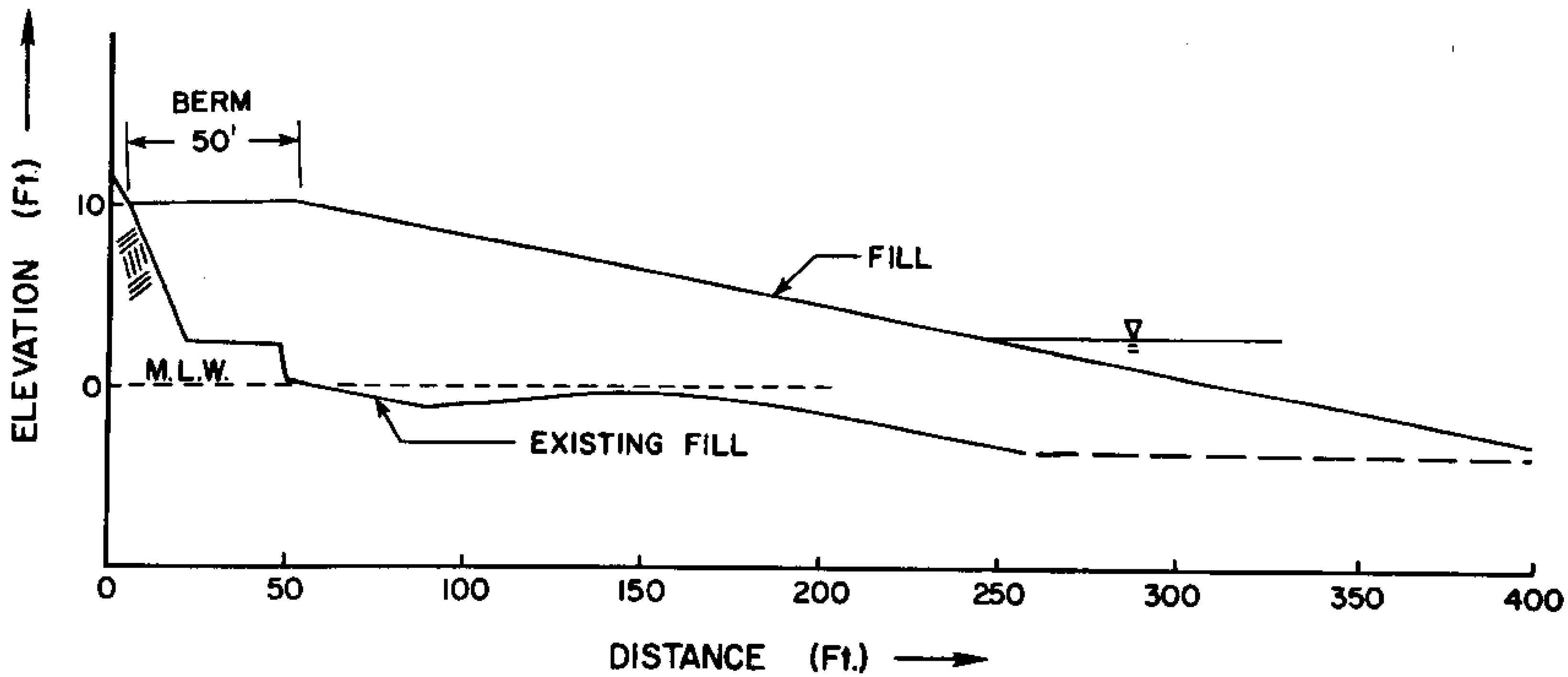


Fig. B-10 - Proposed Nourishment - Hilton Head

Engineers, 1974). The Corps considered beach nourishment alone and in conjunction with structural solutions. Nourishment was considered for 10.4 and 6 mile sections with unjustifiable returns in both cases. The following analysis will provide an update and reconsideration of the earlier study.

Prevention of Property Loss

Property values at Hilton Head are based upon the 1978 tax assessment for Beaufort County. Current market values were estimated by calculating monthly appreciation on subsequent market sales and extra polating property values forward to July, 1980. It was found that properties appreciated at a 28 percent annual rate between 1978 and 1980. As the remaining oceanfront properties are developed and value due to scarcity becomes still more significant, it can be assumed that properties at Hilton Head will appreciate at a faster rate than the real estate market as a whole. For this reason, property loss estimates at Hilton Head may be slightly conservative when discounting future property values.

As incremental property loss is realized throughout the erosion process, properties are divided into segments to reflect partial loss at designated time intervals. Figure B-11 depicts components contributing to property loss, the concept being similar to a property loss model employed previously in Michigan (Armstrong, et al., 1979). Potential land loss can be disaggregated into amenity and risk components. The former component includes the public beach from which amenity value is derived; the latter component begins as private property is eroded and is assumed to be most significant in the first two quadrants. Table B-4 presents proportiate land values derived for beachfront and second row lots. The difference between the two results as second row land does not include amenity value. The percentages reflect relative weights derived from a sample of property values for lots at Myrtle Beach in Case D.

The distribution of building values in Item C of Table B-4 is based upon an observation of construction patterns on the island. No formal sample was conducted as was done at Myrtle Beach, but in general, buildings at Hilton Head are setback from the beach and most often located in the third quarter of the lot.

Because recent erosion rates at Hilton Head are more reliable than longer-term estimates, 25 year rates are projected to determine potential property loss under the full beach nourishment alternative. For the 3,000 feet nourishment project at North Forest Beach, a 1.0 meter/year erosion rate is assumed to better approximate more recent trends. Both alternatives are considered in Table B-5. To reflect time preference, potential loss is estimated in 10 year intervals as indicated in Table B-5. The value of property loss for each of these intervals appears in column 2, while the final column represents the present value of this loss discounted at a 4 percent rate. The present value of property loss at Hilton Head is calculated to be $20.5 million under the first alternative and $1.0 million under the second alternative. It should be noted that in the first case almost half of this loss will occur even with beach nourishment as stabilization will occur only on the middle third of the beach while property losses are also calculated at the far northern and southern portions of the island. For this reason, the property benefits accruing under the first alternative are generous.

Figure B-11. ZONES EMPLOYED FOR ASSESSING BEACH PROPERTY LOSS

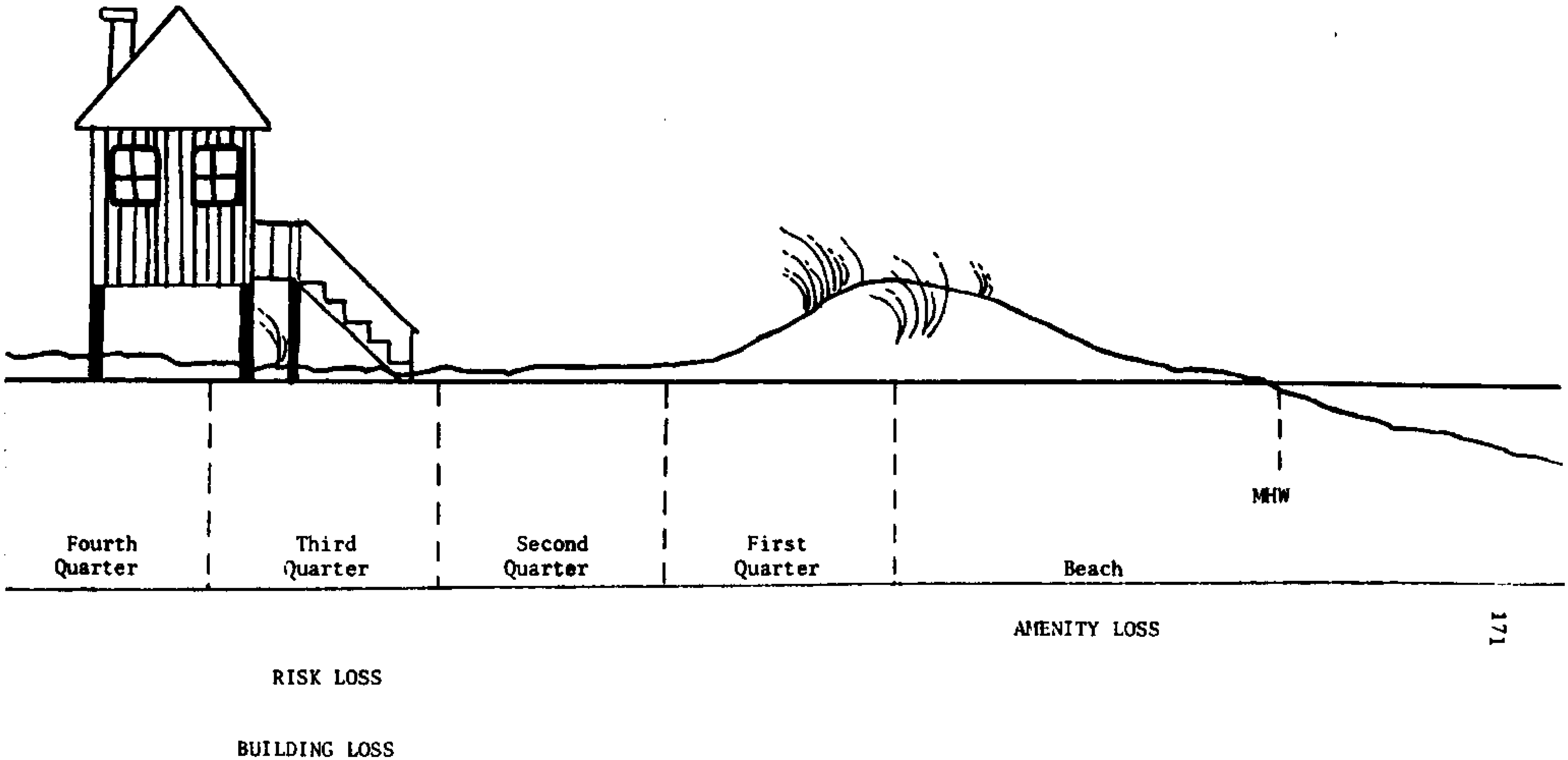


TABLE B-4

Distribution of Value on Lots - Hilton Head Island by Quarters of Lot*

A. Value of Beach-Front Property (Land Value)

Beach To Property Edge	.150
1st Quarter of Lot	.317
2nd Quarter of Lot	.333
3rd Quarter of Lot	.167
4th Quarter of Lot	.033

B. Value of Non-Beach-Front Property (Land Value)

1st Quarter of Lot	.357
2nd Quarter of Lot	.373
3rd Quarter of Lot	.207
4th Quarter of Lot	.063

C. Value of Buildings (By Quarter Lot)

1st Quarter of Lot	.150
2nd Quarter of Lot	.250
3rd Quarter of Lot	.400
4th Quarter of Lot	.200

*All quarters numbered from the beach.

TABLE B-5

Value of Property Loss on Hilton Head at Ten Year Intervals

Interval In Years	11.4 Mile Project		.57 Mile Project	
	Value of Property Loss	Present Value of Loss	Value of Property Loss	Present Value of Loss
0-10	$ 6,875,357	$ 5,651,543	$ 342,392	$ 281,446
11-20	10,392,712	5,767,956	517,557	287,244
21-30	11,745,727	4,403,898	584,937	219,314
31-40	11,774,722	2,979,006	586,381	148,354
41-50	9,714,739	1,661,221	483,794	82,728
TOTAL	$50,501,257	$20,463,624	$2,514,962	$1,019,088

Recreational Benefit

Visitation at Hilton Head is estimated by Claude Terry and Associates (1980) to be 834,500, while growth rates are based on estimates by the Corps of Engineers (1974). Average visitor days per year for 10 year intervals are projected based upon these figures (Table B-6). Annual visitation is translated to daily visitation on the same basis employed for Hunting Island. Peak day visitation is assumed to be 2.5 times weekday visitation, while Saturday and Sunday visitation are 1.5 and 1.75, respectively, times weekday activity.

Carrying capacity at Hilton Head is estimated to be 90,288 users per day based upon an average beach width of 150 feet and a beach length of 11.4 miles. With such a physical capacity, peak visitation is not expected to approach capacity during the projection period. If past erosion rates continue, 5 of the 13 sections (stations) of the beach are expected to be affected by erosion. If all of these areas are completely removed from recreational potential, the remaining carrying capacity of the island would still accomodate 55,562 visitors per day double the highest peak visitation estimate for the planning period. It seems unreasonable therefore, to justify beach nourishment in terms of recreational demand for either of the project alternatives.

The Costs of Beach Stabilization

The cost of beach nourishment at Hilton Head is based on the supply of 25,700 feet of feeder beach near Folly Inlet. Two sets of costs are considered. The lower cost estimate uses a $3 per cubic yard cost for the initial nourishment; the higher cost estimate uses a $6 per cubic yard initial cost. Both costs scenarios assume a 5 yar renourishment cycle at 60 percent of the initial cost. Based upon the cost estimates total cost and present value of that cost are estimated for the 50 year planning period (Table B-8). The present value of costs is expected to range from $16.8

TABLE B-6

Projected Visitation and Recreational Value Accruing For Periodic Beach Nourishment at Hilton Head.

	1980-90	1990-2000	2000-10	2010-20	2020-30
1. Visitation	883,750	982,400	1,052,300	1,092,950	1,145,800
2. Daily Visitation					
Weekdays (60)	8,498	9,446	10,118	10,509	11,017
Sats (12)	12,747	14,169	15,177	15,764	16,526
Suns (12)	14,872	16,530	17,707	18,391	19,280
Peak (2)	21,245	23,615	25,295	26,273	27,543
3. Annual Visitation with project	883,750	982,400	1,052,300	1,092,950	1,145,800
4. Annual Visitation without project	883,750	982,400	1,052,300	1,092,950	1,145,800
5. Differential	0	0	0	0	0
6. Erosion Control Benefit	0	0	0	0	0
7. Total Benefit					0

TABLE B-7

Costs of Beach Nourishment at Hilton Head Island

Year	25,700 foot Project At $3/yd^3	25,700 foot Project At $6/yd^3	3,000 foot Project At $3/yd^3	3,000 foot Project At $6/yd^3
0	5,165,700	10,331,400	603,000	1,206,000
5	3,099,400	6,198,800	361,800	723,600
10	3,099,400	6,198,800	361,800	723,600
15	3,099,400	6,198,800	361,800	723,600
45	3,099,400	6,198,800	361,800	723,600
TOTAL	32,950,015	65,900,030	3,859,152	7,718,305
Present Value of Costs	16,843,668	33,678,336	1,972,754	3,945,508

to $33.4 million for the 25,700 foot project. For the 3,000 foot project the present value of costs is expected to range from $2.0 to $3.9 million. It is expected, at this time, that the lower cost scenario is more appropriate in both cases given sand availability and transport requirements.

Summary of Benefits and Costs

Estimates of future benefit streams under both project alternatives are compared with both low cost and high cost scenarios to access the feasibility of beach nourishment at Hilton Head. For the 25,700 foot alternative a favorable benefit/cost ration of 1.215 is found based upon the low cost scenario, while a ratio of 0.607 is found under the high cost assumption. It should be recalled that property estimates are slightly inflated as they reflect some areas at both ends of the island outside of the project area. Nevertheless, nourishment may be feasible along the middle third of Hilton Head Island if: 1) sand can be found and transported at a low cost and 2) development pressures continue to increase property values in this area.

For the 3,000 foot project considered at North Forest Beach, unfavorable benefit/cost ratios of 0.517 and 0.258 are estimated. Given the value of properties in this stretch of the beach, beach nourishment does not seem to be a reasonable alternative.

Should beach nourishment be considered at Hilton Head, the distribution of costs among public and private parties will be an important consideration. The principle criteria for justifying such a project must rest with property values in the affected area as no recreational benefit is anticipated due to an excess of capacity forecast over the project period. Although much of the area has been developed to date, new development and reconstruction should attempt to locate in such a way as to minimize the potential loss

TABLE B-8

Summary of Benefits and Costs of Beach Nourishment at Hilton Head Island in Present Dollar Values

Alternative I: 25,700 foot Project

Item	Benefit	Low Cost	High Cost
Property Loss	$20,463,624		
Recreational Value	0		
Project Cost		$16,843,668	$33,687,336
TOTALS	$20,463,624	$16,843,668	$33,687,336
Benefit/Cost Ratio		1.215	0.607

Alternative II: 3,000 foot Project

Item	Benefit	Low Cost	High Cost
Property Loss	$ 1,019,088		
Recreational Value	0		
Project Cost		$ 1,972,754	$ 3,945,508
TOTALS	$ 1,019,088	$ 1,972,754	$ 3,945,508
Benefit/Cost Ratio		0.517	0.258

due to long-term erosional trends. The most effective way of limiting loss potential is to insist upon reasonable setback lines, therefore allowing for long-run shifts in the beach profile.

CASE C: PAWLEYS ISLAND

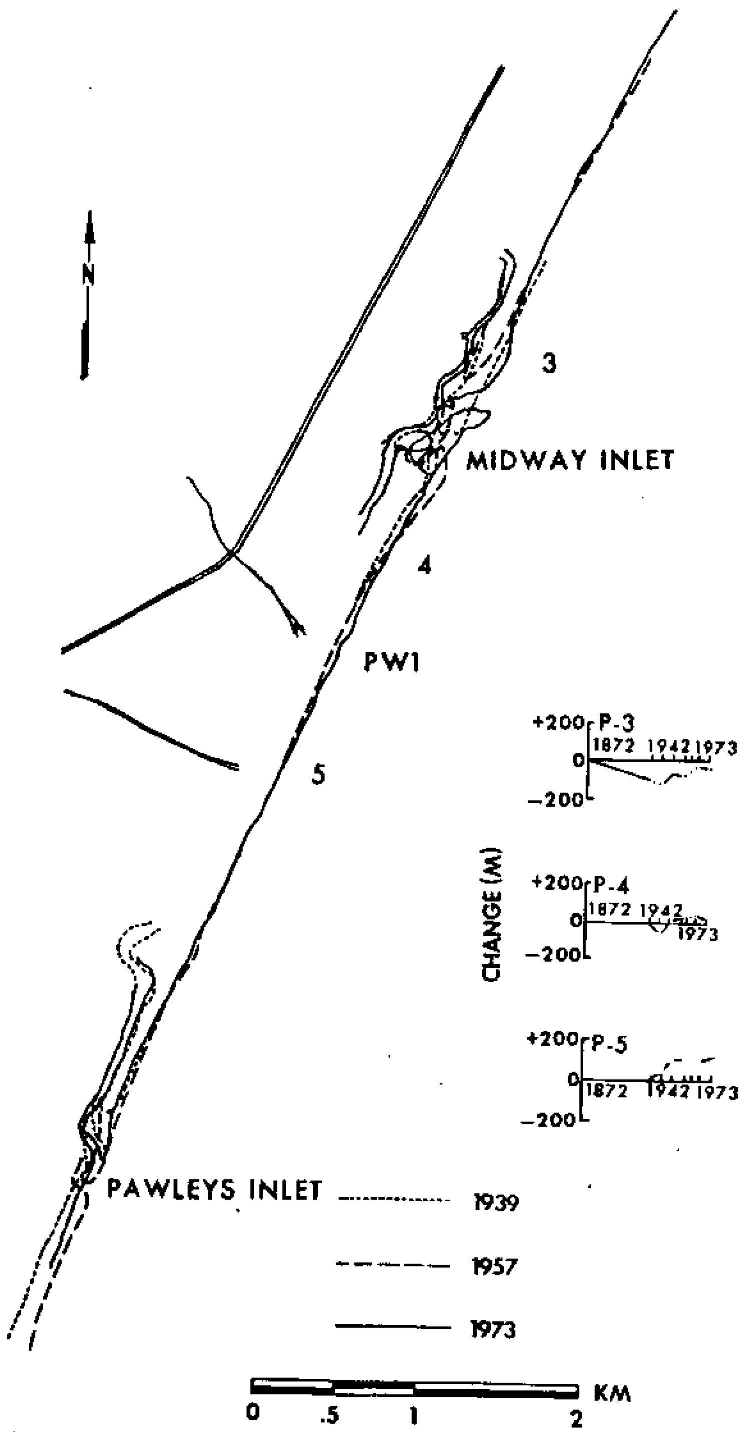
Beach Morphology

Pawleys Island is located at the southern end of arcuate strand and is separated from Pleistocene shoreline deposits by a narrow marsh system. The inlets that border Pawleys are small, shallow, and transitional, showing the effects of both wave and tidal processes. The spring tidal range and high energy wave climate tend to keep sand shoals associated with Pawleys and Midway Inlets close to the inlet throat where they undergo sediment exchange with adjacent beaches.

Long-Term Beach Changes

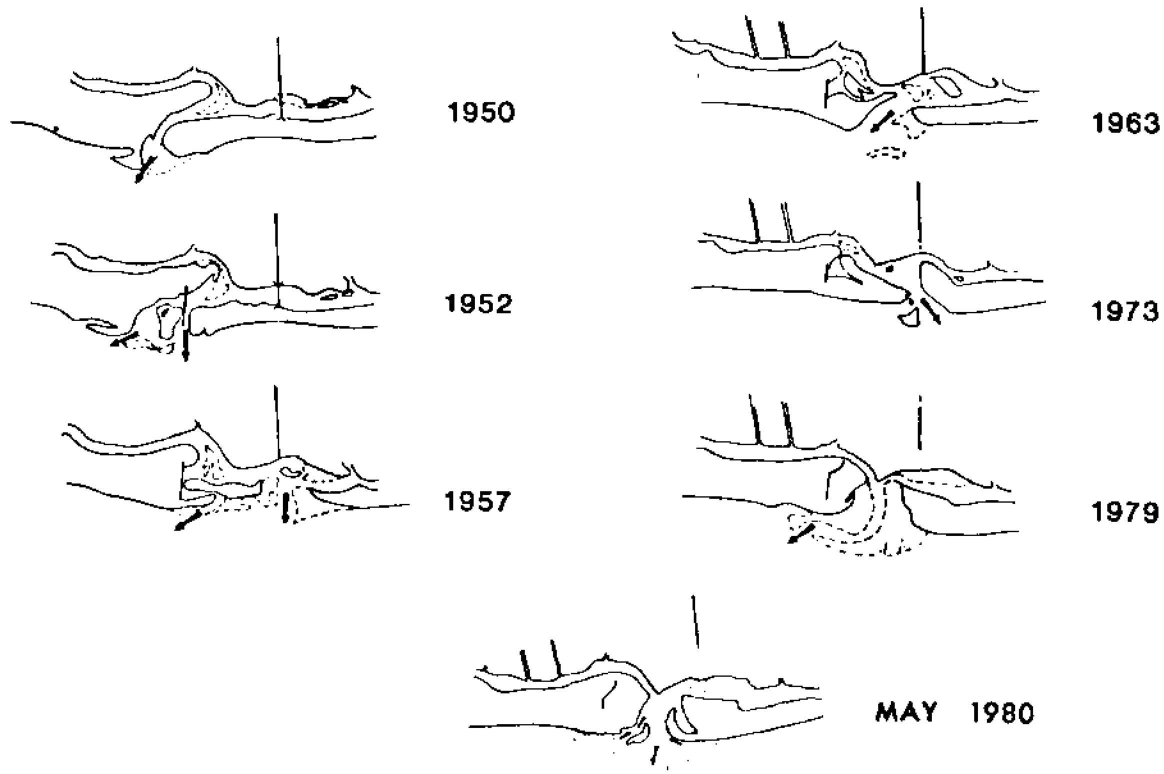
Shoreline configurations compiled from the 1937, 1957 and 1973 aerial photo sets show that Pawleys Island has been relatively stable along the central section over the past 40 years (Fig. C-1). Maximum change in shoreline position recorded from aerial photos and historical charts at fixed reference points is on the order of ± 100 meters (Fig. C-1). The general trend along the northern half of the island is depositional. The southern half of the island has been stable to moderately erosional. These trends are subject to inlet fluctuation.

The island is relatively small (5-6 km.) and the small bordering inlets are subject to abrupt and rapid morphologic change due to wave and storm effects. Therefore, it is probable that depositional - erosional trends are controlled, in large part, by sand bypassing processes at Midway and Pawleys Inlets. Inlet - related changes are most apparent immediately adjacent to the inlets, but changes along the control part of the island are likely to be a function of addition or removal of sand from the littoral system by inlet sand bypassing.



FigurеC-1, Changes in shoreline position on Pawleys Island based on aerial photo surveys from 1939 to 1973. Numbers (3, 4 and 5) indicate fixed reference points for graphed shoreline data. PWI indicates location of single beach profile.

The area of concentration for this study has been Midway Inlet, because changes there, though paralleling the evolution of Pawleys Inlet, have been more complex. Change is, in part, related to man-made alterations of the back-barrier salt-marsh system. Two causeways built across the marsh to Pawleys Island have divided the once continuous tidal drainage network between Pawleys Inlet and Midway Inlet into nearby separate systems (Domeracki et al., 1980). Drainage to both systems has been reduced, but the larger part of the tidal prism is exchanged through Midway Inlet. Between 1939 and 1950, Midway Inlet migrated 400 m to the south causing severe erosion of beach property at the north end of Pawleys Island. A stone jetty was constructed in 1952 in an attempt to stabilize the inlet and prevent further beach loss (Fig. C-2). The position of Midway Inlet shifted north by 1957, an apparent result of spit breaching during Hurricane Hazel. The north end of Pawleys Island began an accretional episode, whereas beaches north of the inlet were eroded significantly (Figs. C-1 and C-2). From 1957 to 1963, Midway cut a more southerly route through the inlet shoal system, and the north end of Pawleys Island continued in a depositional trend, probably through swash-bar accretion around the stone jetty. By 1973, Midway Inlet was forced into a more northerly position by a spit-like extension at the north end of Pawleys Island. The north end of the island was cut back significantly by 1979. As a result of Hurricane David in September, 1979, the main ebb channel broke through surrounding shoals along a curved route toward the beach and the north end of the island suffered abrupt and severe erosion (Fig. C-2). This erosional trend began to reverse by May, 1980, when the inlet channel breached the shoals along a more seaward route (Fig. C-2). The results of this more normal configuration include



FigureC-2 Geomorphic changes at Midway Inlet since 1950 (after Domeracki et al., 1980).

the apparent onshore migration of swash-bar type sand bodies at the north end of Pawleys Island, at least partially restoring lost beach property.

Short-Term Changes in Beach Morphology

Profile data is presently available for only one station on Pawleys Island (Fig. C-1). The profile measured at monthly intervals over a two-year period shows beach morphology and volumetric changes typical of the central part of Pawleys Island. Overall beach morphology is similar to other arcuate strand beaches. The beach profile is concave up (Fig. C-3) and the beachface dips seaward at 1 to 1.5M, which is slightly steeper than on beaches south of the arcuate strand. This slope is a function of coarser sands available from nearby Pleistocene sources.

No distinct seasonal trends in beach morphology (Figs. C-3 and C-4) or volumetric changes were seen among the data collected during the two-year survey at the single profile station on Pawleys Island. Net volumetric change at this station was slightly erosional, but no definite trend can be assumed from the data (Fig. C-4). Several of the recorded monthly changes in beach volume were equal to or greater in magnitude than the two-year volumetric change.

Alternative Solutions

The specific concentration of alternative solutions for Pawleys Island has been the north end of the island, adjacent to Midway Inlet, due to the complexity of the problems of inlet stabilization. In addition to a no action response, inlet stabilization and engineering alternatives of using a bulkhead, revetment, or terminal groin have been considered.

No Action

If no action is taken, the present erosion/accretion cycle will repeat itself periodically. In addition to this response of inlet

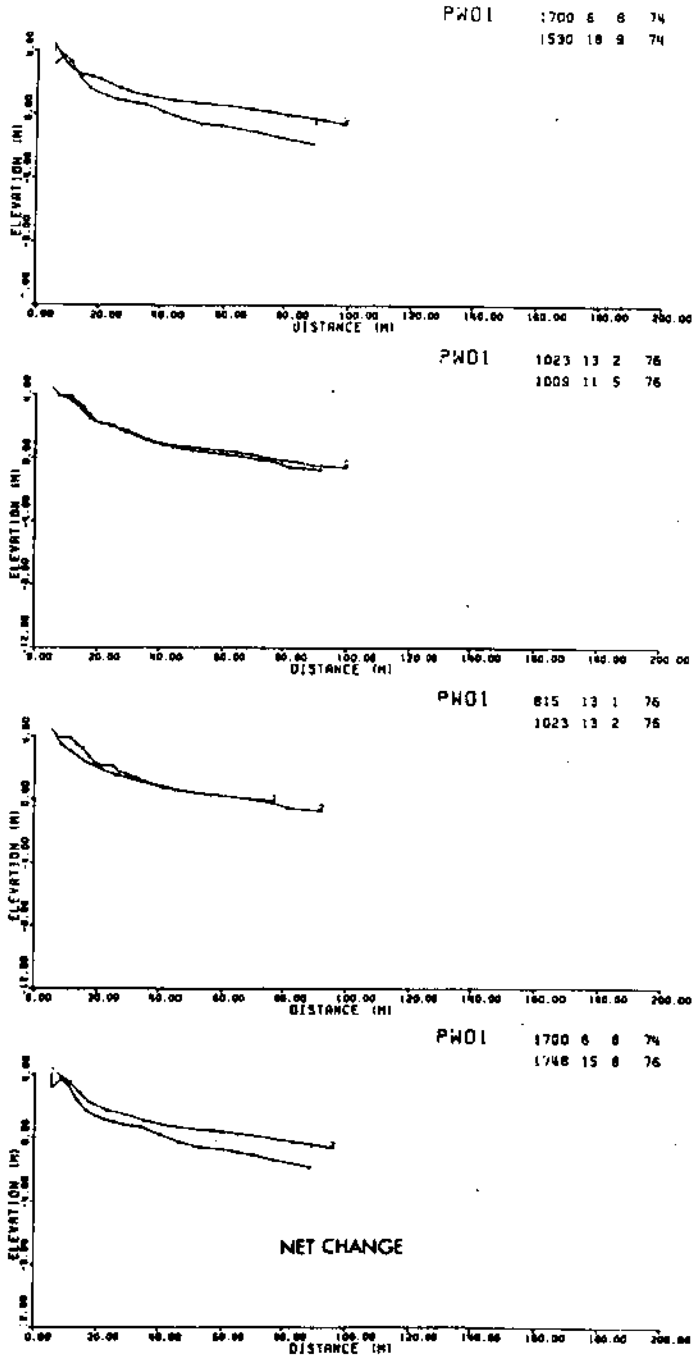


Figure C-3.Comparison of selected beach profiles between 1974 and 1976 at Pawleys Island beach profile station PWI.

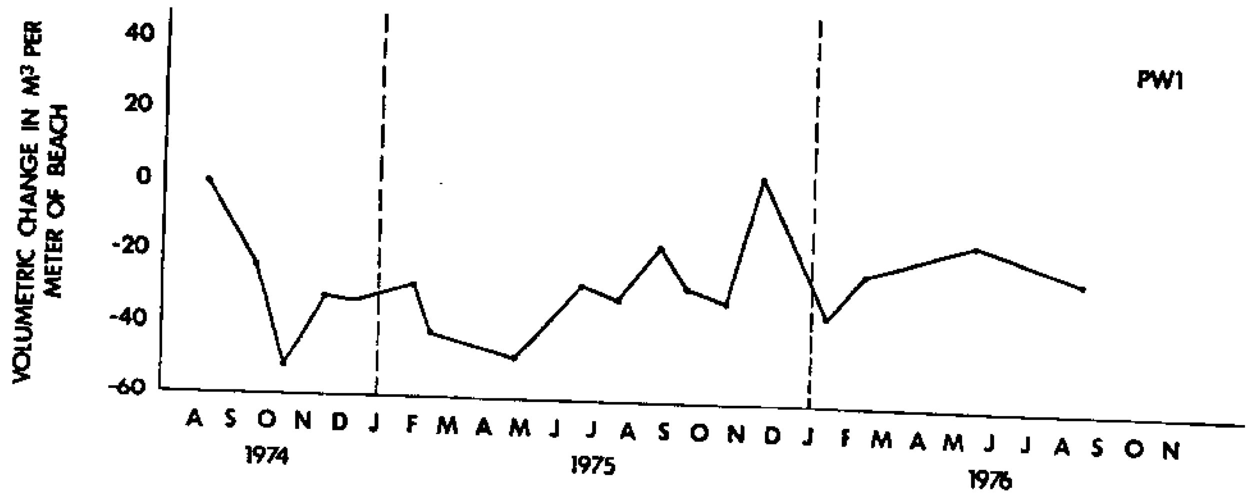


Figure C-4.Volumetric change in cubic meters per meter of beach at beach profile station PWI.

availability the beach is also affected by severe storms and to a lesser extent sea level rise, both causing erosion. Beach scrarping and dune destruction will occur as well as potential property damage in particularly vulnerable areas due to shallow setbacks and positions relative to Midway Inlet. The costs of the no action alternative would be limited to the value of beach, dunes and homes in the immediate area.

Bulkhead

A distance of 1000 feet (305 m) has been selected as the project length, providing limited protection to the most seriously threatened property. A bulkhead will prevent shoreline retreat as long as it is designed t9 withstand storm attack. It is recognized, however, that these walls may result in accelerated scour on the beach during storms and, thus, may tend to reduce beach width.

The proposed unit would be of precast, steel reinforced concrete, tongue and grooved. Each panel measures 3 in. x 12 x 4.5 ft (.076 x 3.7 x 1.4 m) and would be driven 8 ft (2.4 m) into the ground. Tie backs on 9 ft (2.7 m) centers would be anchored in a backfilled dune landward of the bulkhead. After the structure is in place, a continuous concrete cap would be constructed on top. Filter cloth would be used at each of the panel joints to limit washout during periods of seaward drainage. Toe protection using stone is placed in front to an elevation of 2 ft (.61 m) on a 1 to 2 slope (Fig. C-5).

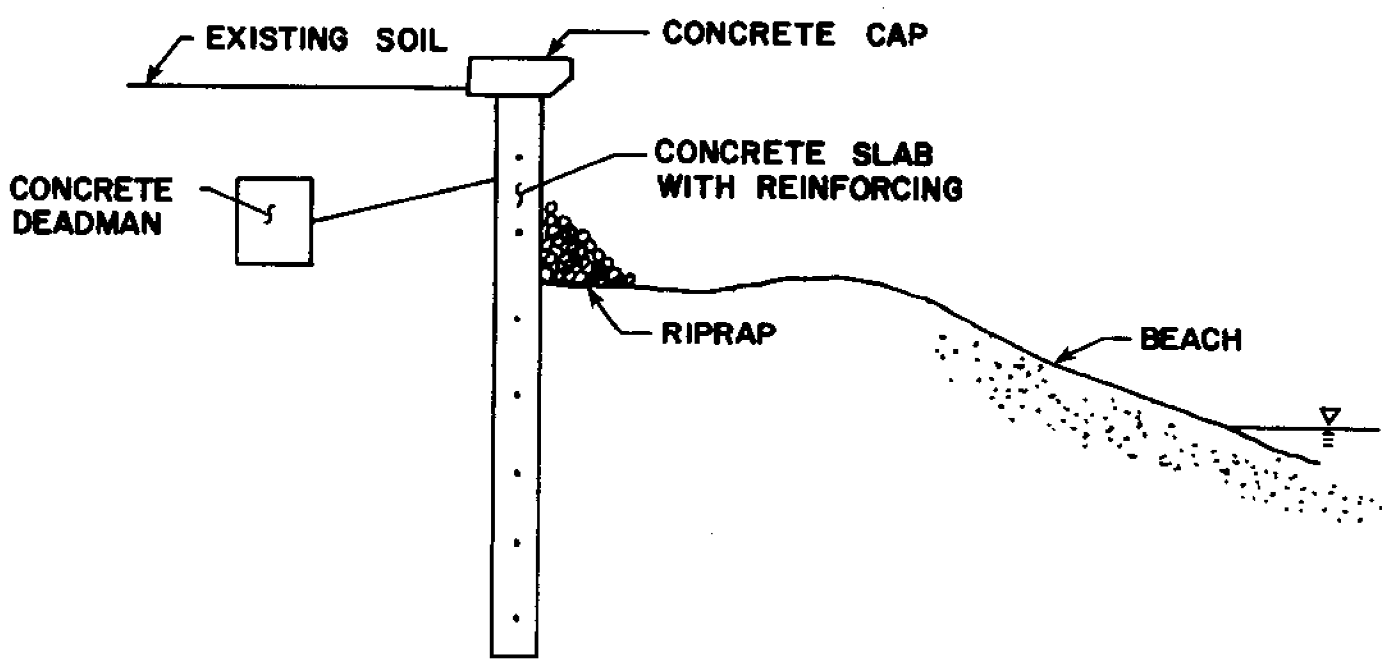


Fig. C-5. Proposed Bulkhead -
Pawleys Island

TABLE C-1 - Bulkhead Cost

a.	bulkhead	
	1100 ft. (including 100 ft. flanks)	
	at $65 per feet	$71,500
b.	riprap stone, 180 tons	8,100
c.	engineering, supervision	7,310
	Total	$86,910

This form of shoreline stabilization is semi-permanent, subject to failure from severe storm attack or extreme shoreline retreat.

Riprap

An alternative to the bulkhead is stone or rubble placed at the base of the dune line,(Fig. C-6). If necessary, the dune is first rebuilt and then graded to a 1 on 2 slope. Large coarse stone is placed on a bed of finer material. As in the case of bulkheads, riprap is designed as a barrier to hold a reach of shoreline. Erosion seaward is not controlled by this scheme, and, in fact, may be accelerated due to a lack of beach replenishment from dune erosion. As with the bulkhead this approach is a semi-permanent solution.

TABLE C-2 - Riprap Cost

a.	1000 ft @2.5 ton/ft, $45/ton	$112,500
b.	engineering, supervision	11,250
	Total	$123,750

Terminal Groin

A terminal groin at the extreme north end of the study area (adjacent to the inlet) would reduce the impact of inlet migration on the beach. The groin would act as a large sediment trap, collecting the

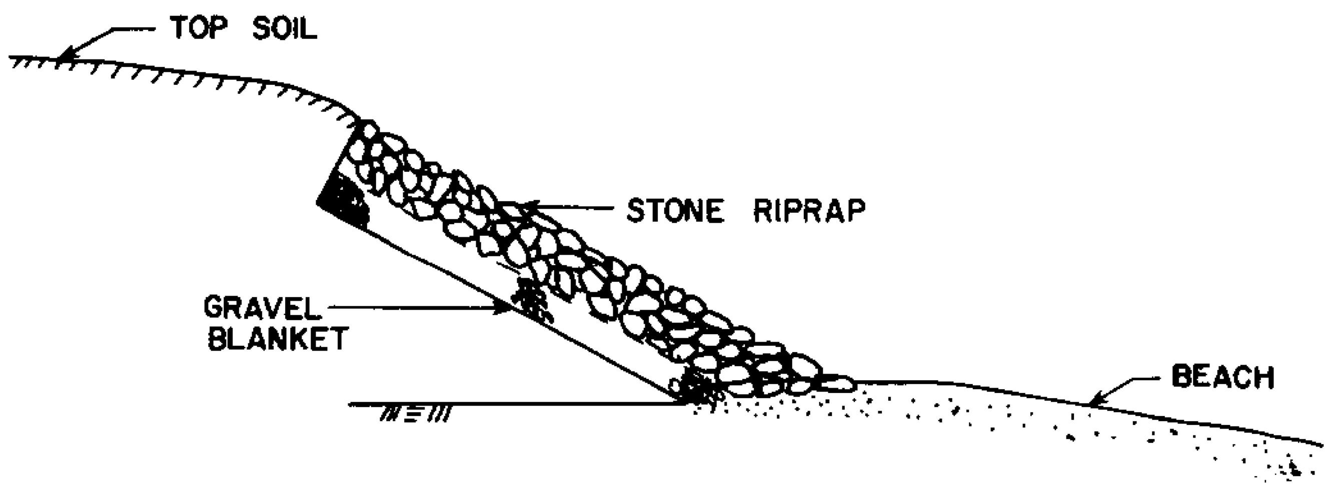


Fig.C-6. Proposed Riprap Profile - Pawleys Island sand which tends to be carried north into the inlet. The groin would also serve to control the inlet, reducing its tendency to change alignment. It should be noted that a terminal groin, while similar to regular groins in that it is perpendicular to the beach face, is both longer and more massive than the former. Figure C-7 illustrates the position and dimensions of the proposed groin. The unit would be constructed of large stone rubble with a 5 ft (1.5 m) width at the top.

TABLE C-3 - Terminal Groin Cost

a.	stone (estimate 13,900 tons)	$625,500
b.	engineering, supervision and contingencies	165,757
	Total	$791,257

Inlet Stabilization

Periodic dredging of Midway Inlet can be used as a shoreline protection alternative. Dredging could be undertaken whenever the main axis has shifted to the south and erosion is taking place in the project area. This alternative would yield two positive results:

1. the main axis of the inlet would be returned to a central location, reducing the erosion at the adjacent shoreline, and
2. the dredged material could serve as beach nourishment to fill the eroded section.

Such dredging would be a temporary solution. The frequency required would depend upon the occurrence of large storms, changes on the shoreline north of the inlet, and changes in the interior estuary.

TABLE C-4 - Dredging Cost

Note: Total volume for a single dredging operation was assumed to be 35,000 cu yds (27 km^3). Unit costs ranged from $2.50 to $4.00 per yard, and engineering, supervision and contingencies were added at

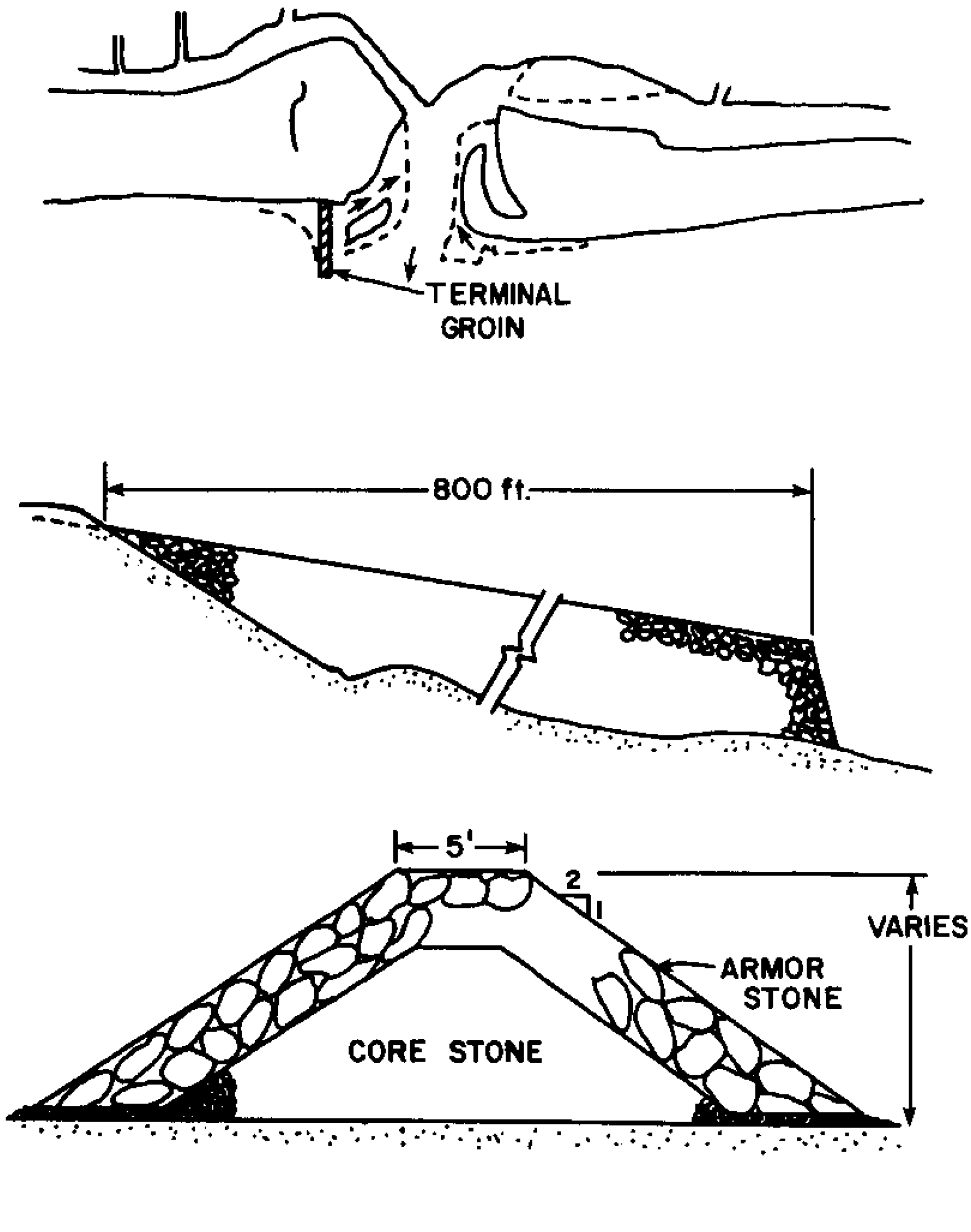


Fig. C-7- Proposed Terminal Groin
and Position - Pawleys Island

10 percent and 15 percent, respectively.

Dredging $110,700 - $117,100

Cost-Benefit Analysis

Of the sites considered, Pawleys Island most clearly typifies the traditional family resort with rustic beach houses reflecting its historic past. Although an 54 unit condominium complex was completed in 1972, the beaches at Pawleys remain less crowded than beaches further north along the Grand Strand. Under present land-use conditions, the more immediate erosion-related problem at Pawleys Island appears to be the potential for property loss. Short-term erosional trends have caused considerable concern among property owners for which various solutions have been suggested. The analysis that follows considers the feasibility of employing the aforementioned options to alleviate potential loss of recreation and property.

Property Loss

Although the older residences at Pawleys Island are generally built well behind the dune line, continued erosional trends could result in property loss particularly at the north end of the island. To estimate the potential for such loss, county appraisals completed in 1973 were gathered for all properties on the island. Based upon recoreded market sales since that time, a yearly appreciation rate of 13 percent was estimated to derive a 1980 estimate. As most of this property had been developed previously, land and building values were difficult to separate. Therefore, land and building estimates were combined, and lot values were disaggregated in the manner indicated in Table C-5 as follows.

TABLE C-5

Distribution of Property Values at Pawleys Island by Lot Section.

Section	Percentage of Total
First Quarter	.200
Second Quarter	.325
Third Quarter	.383
Fourth Quarter	.092
TOTAL	1.000

The allocation of land value differs slightly from that used at Hilton Head and Myrtle Beach as private property lines at Pawleys are drawn from the mean high water mark. Therefore, the beach area with its amenity value lies within the first quarter. Building values are distributed as determined by the location of structures on oceanfront lots. Once again building value is assumed to be lost when the high water mark surpasses the foundation of the structure.

The estimated loss and time interval at which portions of the property are lost is based upon historical erosion rates along the island as discussed above. Table C-6 lists the total amount of property to be lost if 100 year erosional trends continue. As the potential loss prevented by erosion control occurs as a benefit stream over time, the value of loss in constant dollars is discounted at a 4 percent rate. It is estimated that the present value in terms of property loss prevented by effective erosion control measures will be $2,332,342.

TABLE C-6

Projected property loss and present value of property loss resulting from beach erosion at Pawleys Island.*

Section	Total Property Loss	Present Value Of Property Loss
First Quarter	$5,025,889	$1,822,259
Second Quarter	2,954,098	446,595
Third Quarter	376,176	60,900
Fourth Quarter	18,357	2,588
Total Present Value	$8,374,520	$2,332,342

*For Pawley's Island, property lines extend down to the High Water Mark--for this reason, the first quarter at Pawley's Island incorporates the beach area, unlike the Hilton Head Island and Myrtle Beach studies.

Recreational Benefit

Figures by the Waccamaw Regional Planning Commission (1978) and projections by Hartzog, Lader, and Richards (1974) estimated peak visitation at Pawleys Island to be 4,500 and 4,430, respectively in 1977. The mean for these two studies projected a growth rate in visitation of 10 percent per decade through the end of the century. Applying this rate of growth to the approximate peak visitation for 1980 as estimated by the Waccamaw Regional Planning Commission, peak visitation is projected for the planning period (Table C-7). As only peak visitation is projected, weekday and weekend activity is estimated using the same weights employed at Hunting Island. Peak usage is assumed to be 2.5 times weekday usage, while Saturday and Sunday usage is assumed to be 1.5 and 1.75 times weekday activity, respectively. Seasonal visitation disagregated in this manner is shown in Item 2 of Table C-7.

The average dry sand beach at Pawleys Island is estimated to be 40 m wide (MHW) and 2.5 miles in length. Based upon an average space requirement of 100 square feet and a turnover rate of one, the present carrying capacity of the beach is 17,318 users per day. If recent erosional trends continue, the maximum loss of dry beach area would be 664,187 sq. ft. The remaining beach would still provide a carrying capacity of 10,677 users per day, sufficient to accomodate peak use over the planning period. As a result, no recreational benefit is estimated for any of the measures taken to stabilize the beach.

The Cost of Alternatives

With the exception of the no action solution, the alternatives proposed involve an initial outlay during project construction. It is difficult to

TABLE C-7

Projected Visitation and Recreational Value Accruing For Periodic Beach Nourishment at Pawleys Island.

	1980-90	1990-1000	2000-10	2010-20	2020-30
1. Visitation	$204,256	$224,640	$247,104	$271,572	$299,000
2. Daily Visitation					
Weekdays (60)	1,964	2,160	2,376	2,613	2,875
Sats (12)	2,946	3,240	3,564	3,920	4,313
Suns (12)	3,437	3,780	4,158	4,573	5,031
Peak (2)	4,909	5,399	5,939	6,533	7,187
3. Annual Visitation with project	204,256	224,640	247,104	271,572	299,000
4. Annual Visitation without project	204,256	224,640	247,104	271,572	299,000
5. Differential	0	0	0	0	0
6. Erosion Control Benefit	0	0	0	0	0
7. Total Benefit					$ 0

predict life expectency of any of these alternatives without further information, yet it is known that none of these solutions will be permanent. A reasonable assumption is that the structural solutions will require replacement every 20 years. As inlet stabilization will be required each time a storm breaches the inlet significantly altering sediment transport to the north end of the island, it is assumed that the stabilization of Midway Inlet will be required every 10 years. Based on these assumptions, the cost projections are made for each of the alternatives (Table C-8). The terminal groin is estimated by the most expensive alternative, costing considerably more than the other solutions at present value terms.

Summary of Benefits and Costs

Based on the estimated present value of costs and benefits accruing over the project period, each of the alternatives offers a favorable benefit per cost ratio with the construction of a terminal groin appearing to offer only marginally favorable conditions (Table C-9). The construction of a 1000 foot bulkhead to maintain property appears to offer the most favorable alternative, yet these figures require some clarification as the relative effectiveness of each of these alternatives cannot adequately be determined given present information.

Without inlet stabilization, localized erosion may shift as the inlet changes direction and sand transport patterns are altered. Both the bulkhead and riprap would require extension or construction at another location. Wrap around effects on adjacent properties might cause a leapfrogging effect along the beach. Finally, although beach capacity has not been reached, accelerated erosion of public beaches which might result with either of the retainer structures would not be without cost in terms of both recreation and amenity.

TABLE C-8

Projected Costs and Present Values of These Costs for Each of Four Erosion Control Alternatives for Pawleys Island.

Alternative 1: Bulkhead

Year	Cost	Present Value of Cost
0	$ 80,410	$ 80,410
10		
20	80,410	36,667
30		
40	40,205	5,709
50		
		$122,786

Alternative 2: Riprap

Year	Cost	Present Value of Cost
0	$123,750	$123,750
10		
20	123,750	56,430
30		
40	61,875	8,786
50		
		$188,966

TABLE 8 Con't.

Alternative 3: Terminal Groin

Year	Cost	Present Value of Cost
0	$791,257	$ 791,257
10		
20	791,257	360,813
30		
40	395,629	56,179
50		
		$1,208,249

Alternative 4: Inlet Stabilization

Year	Cost	Present Value of Cost
0	$117,100	117,100
10	117,100	79,160
20	117,100	53,398
30	117,100	36,067
40	117,100	16,628
50		
		$ 301,353

TABLE C-9

Summary of Benefits and Costs of Shoreline Protection Alternatives at Pawleys Island.

	Property Benefit	Recreation Benefit	Cost	Benefit Cost Ratio
Bulkhead	$2,332,342	0	$ 122,786	18.99
Riprap	2,332,342	0	188,966	12.34
Terminal Groin	2,332,342	0	$1,208,249	1.93
Inlet Stabilization	2,332,342	0	301,353	7.73

CASE D: Myrtle Beach

Beach Morphology

Myrtle Beach is the only mainland-type beach among the four areas considered in this survey. The tidal range is significantly lower than along the barrier island section to the south, averaging 170 cm at spring tide. The section of South Carolina that includes Myrtle Beach is similar to other microtidal shorelines tending to be wave-dominated and cut by few major inlets.

Similar to other sections of the arcuate strand, sands along Myrtle Beach are somewhat coarser in mean grain size than along barrier island sections and finer than beach sands of the cuspate delta zone. It is likely that erosion of Pleistocene beach-ridge sands of the Myrtle Beach Formation just landward of the active modern beach serves as a source for the coarser material. In addition to erosion of Pleistocene beach-ridge sands, outcropping of loosely consolidated, calcareous sandstone at several locations also effects the stability of the Myrtle Beach shoreline (Dunbar, 1964).

The existing data base for shoreline changes along Myrtle Beach includes sets of low level aerial photographs, hydrographic surveys and short-term beach profile surveys. Aerial photo sets from which shoreline positions can be determined are available from 1948, 1952, 1958, 1965, and 1973. Longer term data at more widely-spaced intervals are available from hydrographic surveys completed for the Myrtle Beach area in 1878, 1925 and 1972. The resulting nautical charts include the position of the low water shoreline. Data concerning short-term changes in beach morphology and short-term depositional-erosional cycles are available from four beach profile stations within Myrtle Beach proper.

Long-Term Trends

Analysis of shoreline changes for a six kilometer section of Myrtle Beach proper is based on the hydrographic and aerial photo surveys between 1878 and 1973 relative to six controlled points (Fig. D-1; Table D-1), indicating a distinct erosional trend from 1878 through 1940. Myrtle Beach was not uniformly erosional, however. Erosion rates increased to the south (Fig. D-1; Table D-1) and zero net change was recorded relative to the two northernmost control points (Table D-1). From 1948 through 1973, erosional rates slowed or reversed (Fig. D-1). The shoreline was most stable between 1958 and 1973 compared with earlier periods. During this time, the shoreline at all six control points underwent zero net change or was moderately accretional (Table D-1).

Overall, the northern half of Myrtle Beach seems to be more resistant to erosional episodes. This trend holds true for both shorter-term and longer-term data. Similar to Pawleys Island, net change and rates of change in shoreline position along Myrtle Beach are an order of magnitude less than changes evident from the case studies of Hilton Head Island and Hunting Island. The relative stability of arcuate strand beaches is, in part, related to proximity of Pleistocene sediment sources and outcropping of resistant units along the beach. Lower rates of change are also related to the lack of large inlet complexes within the arcuate strand. The abrupt and large volumetric changes common to beaches in the barrier island sections of South Carolina where sand exchange takes place between inlet shoals and adjacent beaches are not to be expected where large inlet complexes do not exist.

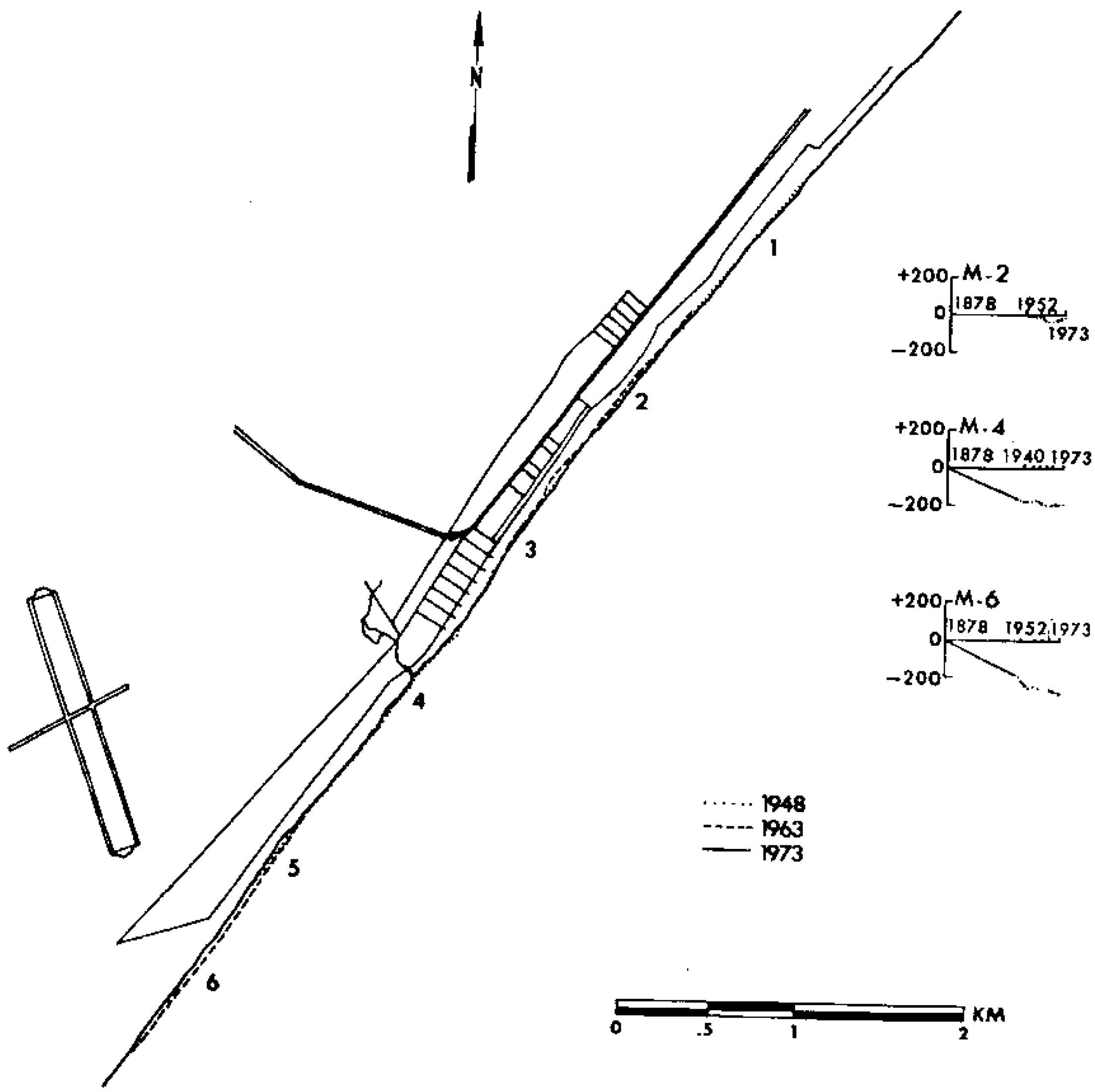


Figure D-1. Depositional-erosional trends along Myrtle Beach compiled from vertical aerial photographs and historical charts.

TABLE D-1 Beach Profiles at Myrtle Beach, 1878-1973.

Reference Point	Change 1878-1940	Change 1940-48	Change 1948-52	Change 1952-58	Change 1958-63	Change 1963-73
M 1	0	- 6	- 7	-11	0	34
M 2	0	-10	10	-29	0	21
M 3	- 57	0	0	-17	0	0
M 4	-169	0	11	-29	0	0
M 5	- 80	-30	- 7	0	14	0
M 6	-195	-50	9	-10	0	0

Short-Term Shoreline Changes

The four profile stations along Myrtle Beach are spaced 1.5 to 2.5 km apart and provide a survey of morphology variation within this area (Fig. D-2). Profiles measured along Myrtle Beach differ somewhat than the convave-upward profile typical of (Figs. D-3, D-4, D-5 and D-6) other arcuate strand beaches. Instead, Myrtle Beach is characterized by a relatively straight shoreface that dips seaward at slopes of up to 2 degrees. The steeply-dipping foreshore is a function of the coarser sands found in the beach compared with areas further to the south. Mean sand size ranges from 0.25 to 0.35 mm (medium sand); whereas, mean grain size of beach sands comprising barriers south of the cuspate delta region range from 0.15 to 0.10 mm (fine to very fine sand).

The low tide beach is relatively narrow in the Myrtle Beach vicinity compared with finer grained flatter barrier island beaches. Average width is approximately 100 m. at mean low water. Ridge and runnel topography tends to be of low amplitude and activity is more frequent in the late spring and summer months at the end of erosional and the beginning of depositional beach cycles.

Volumetric changes calculated from profile data show more distinct seasonal trends than beaches in the other case study areas to the south (Fig. D-7). Similar changes in beach profile occurred along the entire 6 km section of Myrtle Beach included within the profile network. This may be due, in part, to the lack of inlet-related changes that mask seasonal or cyclic trends. Depositional cycles occurred from late summer to early winter; whereas, erosional cycles occurred from late winter through spring. Depositional cycles at the southernmost station, SP1 (Fig. D-7) lagged 1

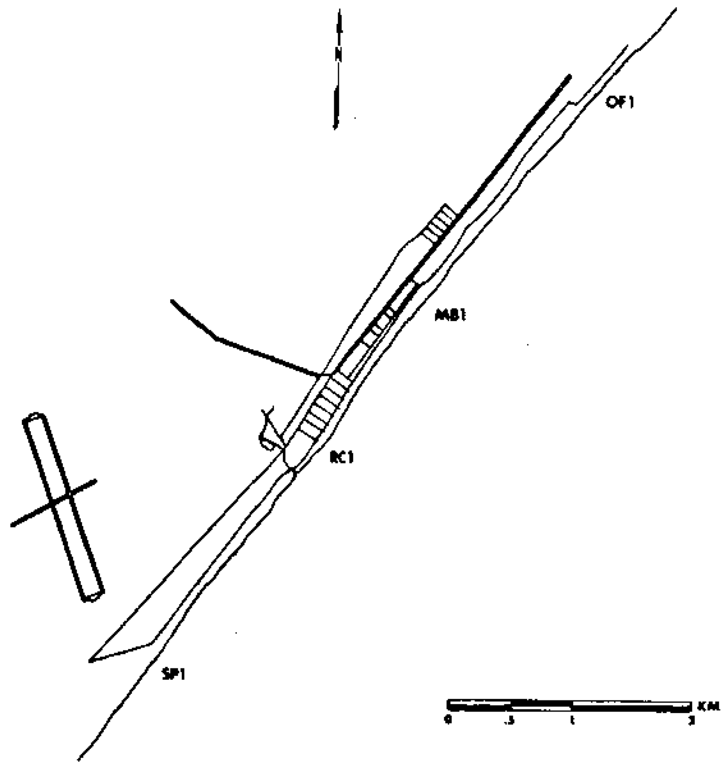


Figure D-2. Location of Myrtle Beach profile stations, 1974 to 1976.

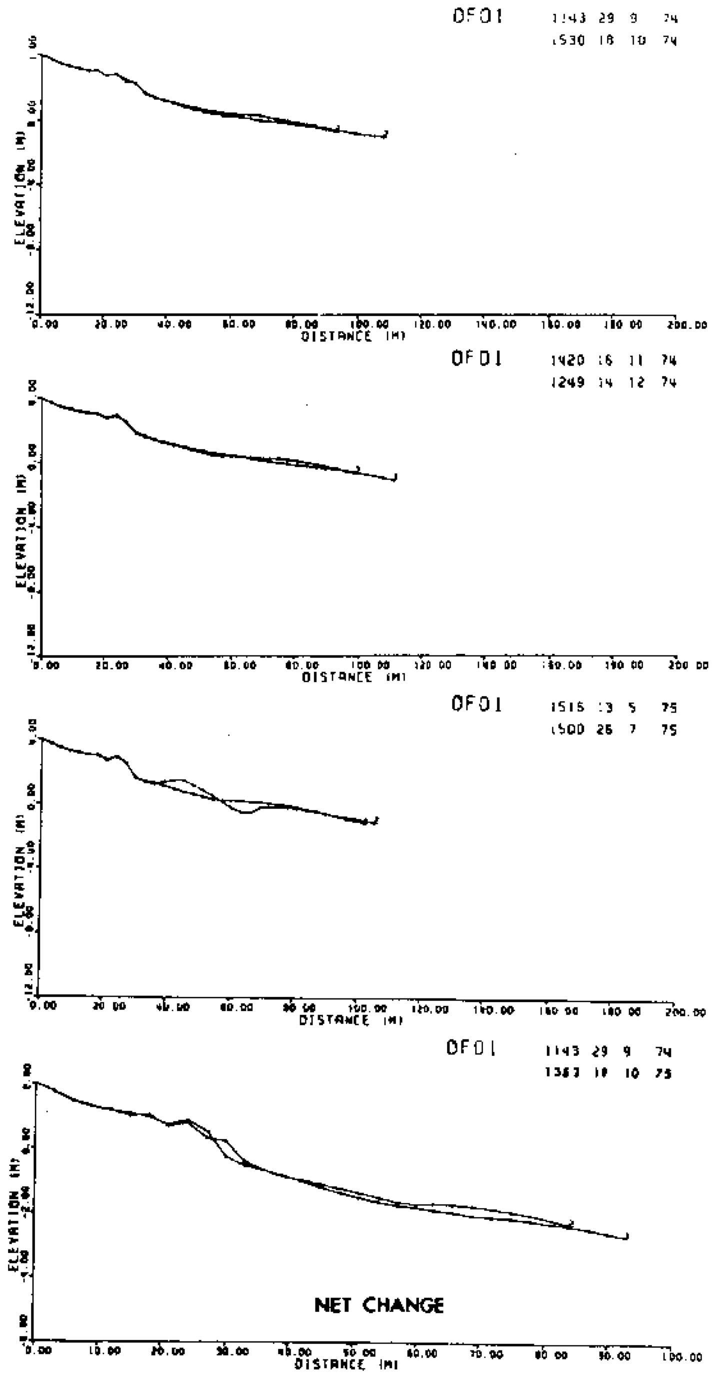


Figure B-3. Comparison of beach profiles from selected dates between September 1974 and October 1975 at station OF-1.

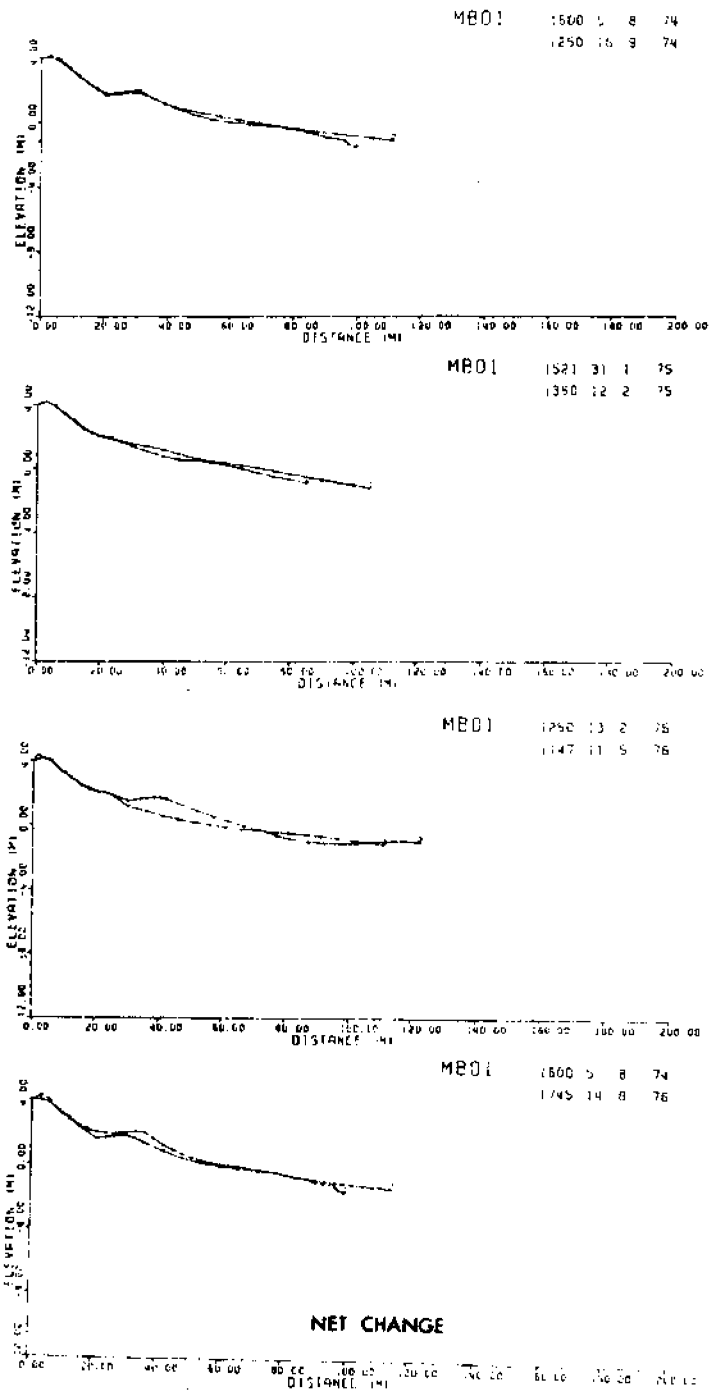


Figure D-4. Comparison of beach profiles from selected dates between August, 1974 and August, 1976 at station MB-1.

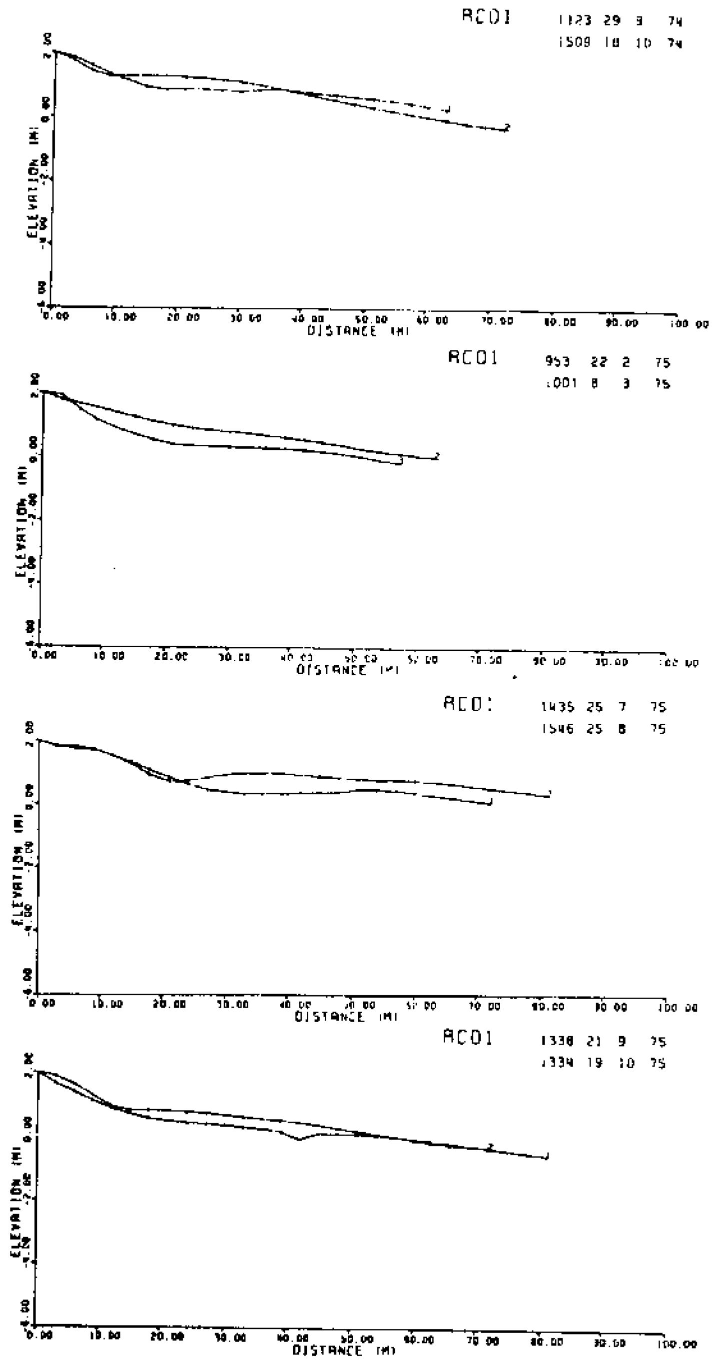


Figure D-5. Comparison of beach profiles from selected dates between September, 1974 and October, 1975 at station RC-1.

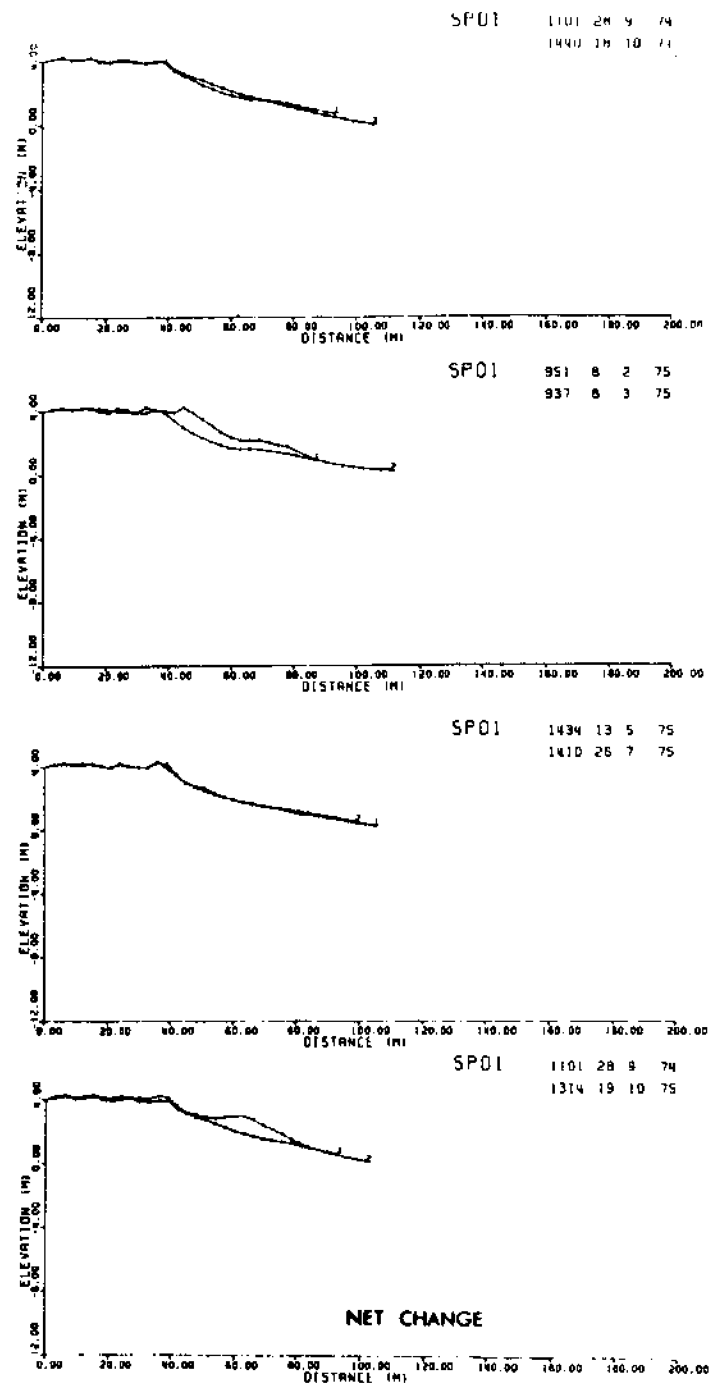


Figure D-6. Comparison of beach profiles from selected dates between September, 1974 and October, 1975 at station SP-1.

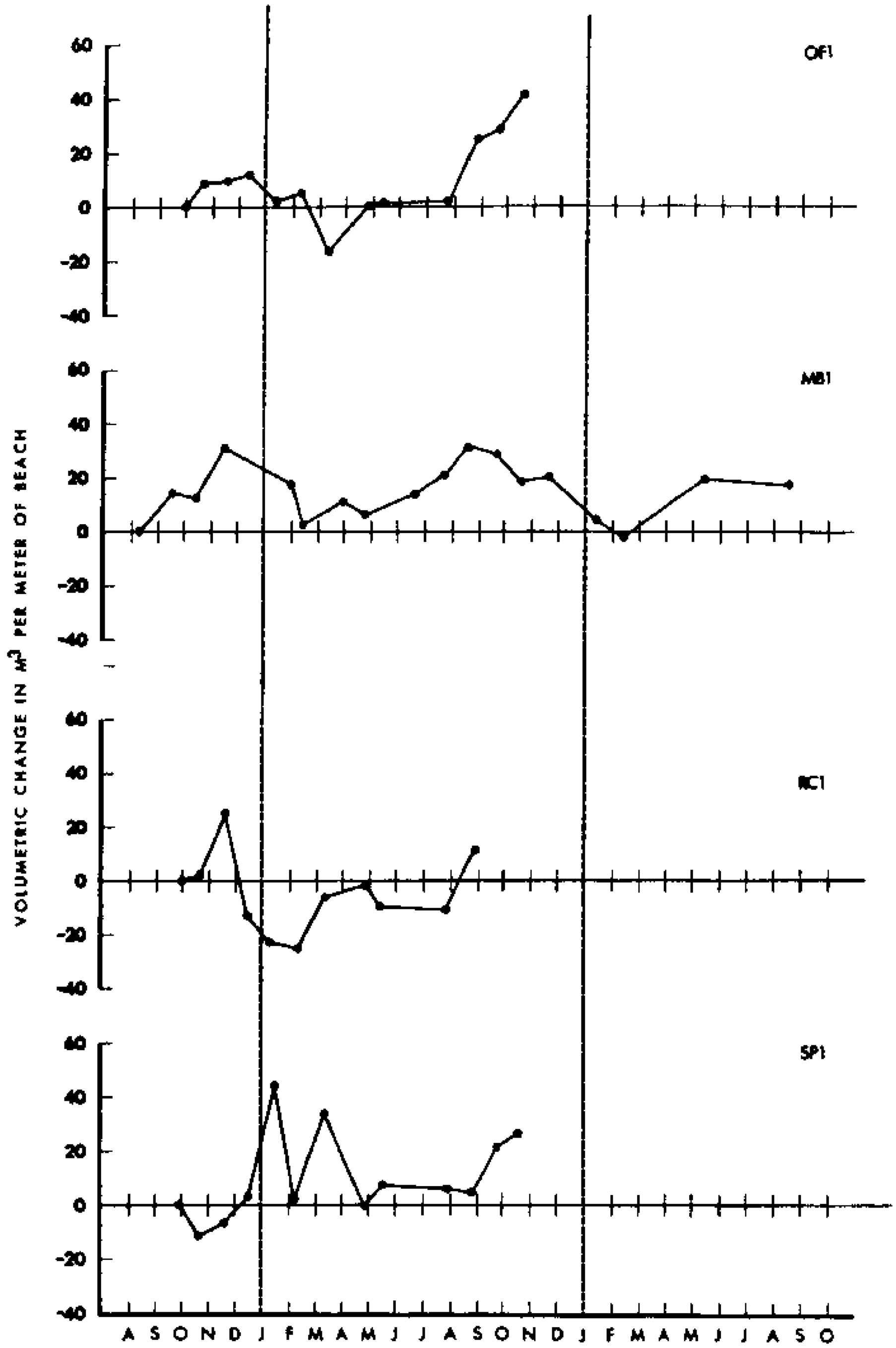


Figure D-7. Volumetric change in cibic meters per meter of beach between survey dates at Myrtle beach stations OF-1, MB-1, RC-1 and SP-1.

to 2 months behind depositional episodes at the three other profile locations to the north. This may have been the result of a packet of sediment moving south within the southerly net littoral drift system in this area.

Volumetric beach changes recorded were smaller and less abrupt than recorded at the other case study sites. This reflects the relative stability and lack of inlet-influenced changes along Myrtle Beach. Net change recorded at all four profile stations over the 1 to 2-year study was depositional. Monthly changes in volume at all four profile locations were similar in magnitude or greater than net change over the entire study period.

It can be concluded that the shoreline position of Myrtle Beach was relatively stable at the time of the 1974-76 profile study. The beach here was not subject to large, abrupt changes, but showed seasonal or at least cyclic depositional-erosional episodes.

Engineering Solutions

Myrtle Beach is a relatively stable region, with beach erosion primarily a result of storms. Hurricane David caused significant erosion, as did a recent extratropical event. During these periods of large storm tides and waves, the beach sand is apparently carried seaward to a depth where post-storm waves are unable to return it to the beach. Erosion protection could require the construction of offshore breakwaters designed to reduce the magnitude of the wave heights reaching the beach. Alternatively, the beach can be resupplied or nourished on a periodic basis as dictated by the magnitude and frequency of storms.

There are two secondary factors which also contribute to the erosion problem at Myrtle Beach. The storm water outfalls on the beach clearly result in local scour during periods of heavy rainfall. In addition, the present pattern of discontinous bulkheads impacts the beach. While neither of these problems are considered in the present review, they are important in understanding the causes of erosion on Myrtle Beach. The outfalls should be removed, and the bulkhead should be a continous, uniform barrier.

Beach Nourishment

The periodic replacement of beach sand by nourishment is a well recognized non-structural erosion control procedure. The rebuilt beach provides both protection (by absorbing wave attack) and recreation. The dimensions of the nourished beach are determined by the degree of protection required, space requirements for bathers, and natural equilibrium contours. Many beach nourishment projects include a barrier dune intended to act as a dike or levee for storm tides. While this barrier dune is a major expense, it is often justified by the reduction in property damage due to such tides.

For the purpose of this study, a minimal beach nourishment dimension is considered without a barrier dune (Fig. D-8). The berm elevation is 10 ft (3m) above MLW and has a width of 50 ft (15 m). The cost of beach nourishment depends primarily on the source of fill material. Idea-ally, sand should be used which has been removed from the beach by the storm waves, i.e., immediately offshore or downdrift. Alternative sources include nearby inlets and landward areas. Due to the absence of data for potential sources, a range of unit costs has been included which may be considered typical for a project of this magnitude; the fill volume was estimated to be 40 cu yd/ft (31 m^3 /m). The analysis that follows considers nourishment of the entire beach length (10 miles, 1km) and a

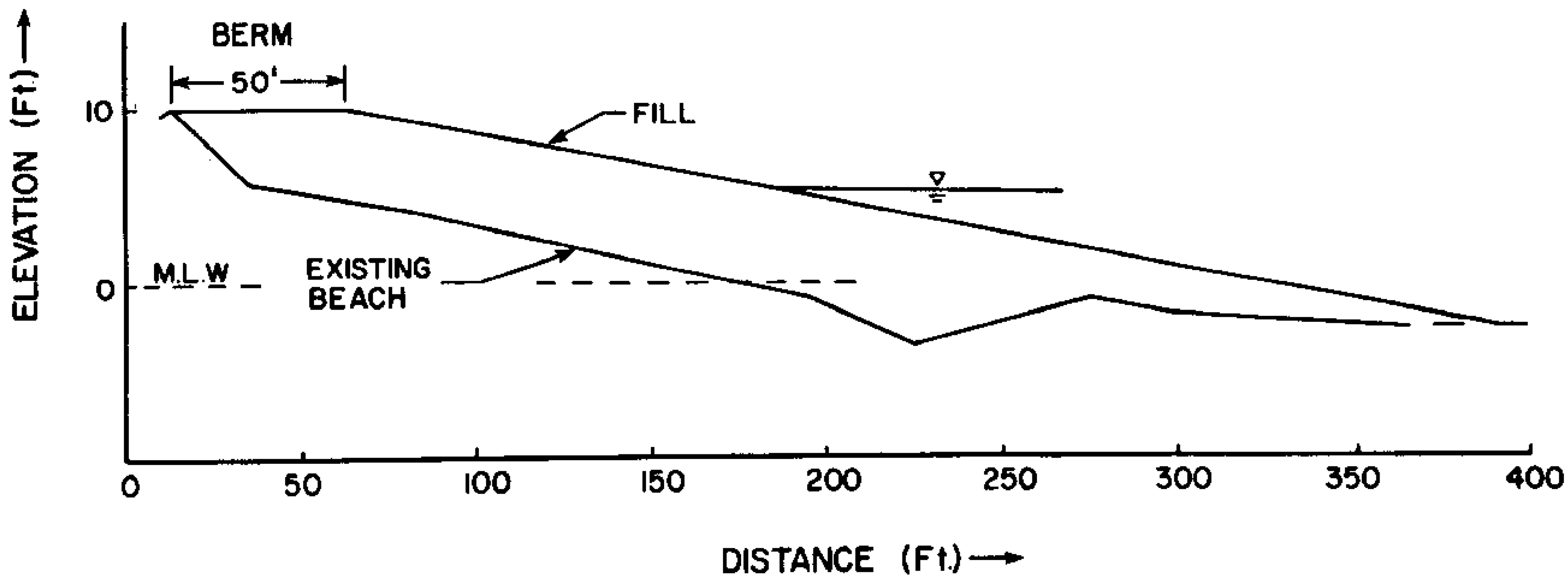


Fig. D-8. Proposed Beach Nourishment - Myrtle Beach smaller project of 3.28 miles (5.2 km) directed at the most severely affected section of the beach.

TABLE D-2

Nourishment Cost

Note: Estimate includes engineering, supervision, etc.

Unit Cost (yd)	Total Cost (in millions)	
	10 mi. project	3.28 mi. project
$5	$10.5	$3.4
$6	$12.7	$4.2
$7	$14.8	$4.9
$8	$16.9	$5.5

Offshore Breakwater

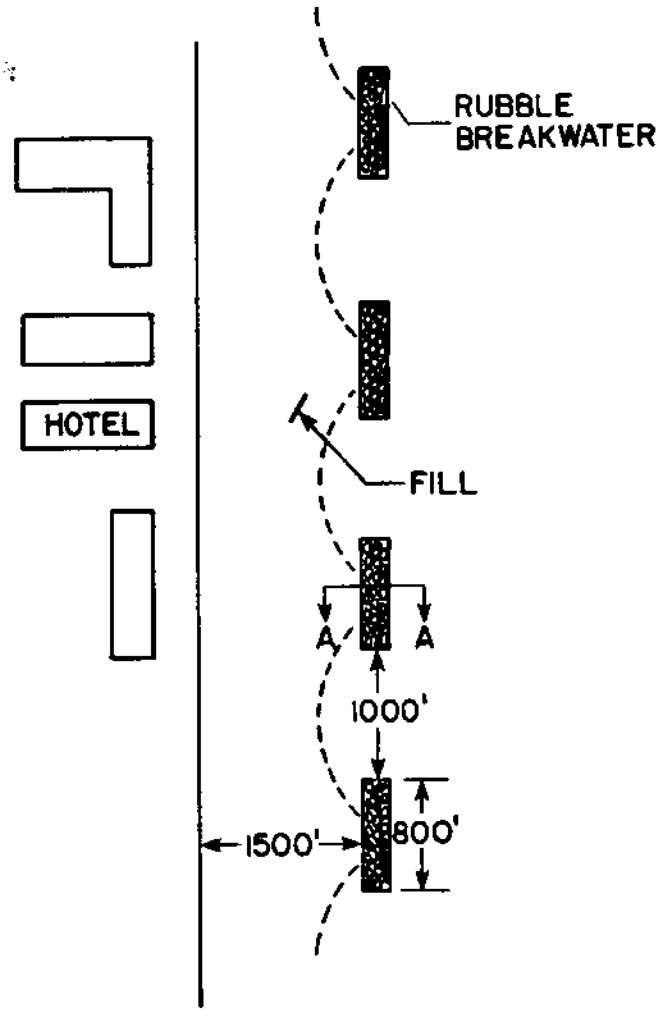
In order to protect the project area from storm waves, large offshore breakwaters are considered. These structures are built parallel to the shoreline at a depth which causes the storm waves to break before reaching the beach. Figure D-9 illustrates one possible design alternative for Myrtle Beach. A series of structures are proposed, each 800 ft (244 m) long, with 1000 ft (305 m) spacings. The breakwaters would be in addition to the beach nourishment outlined in the previous section. These structures would reduce the frequency of beach renourishment by approximately half, as well as reduce the impact of individual large storms.

TABLE D-3

Breakwater Cost (in millions of dollars)

Note: Breakwater is constructed of large stone (12.7 tons/ft.) for the dimensions shown in Figure D-9.

a. stone for 32,440 ft of structure @ $45/ton	$18.6	$6.1
b. stone for 10,640 ft of structure @ $45/ton	1.9	
c. engineering, supervision and contingency		.6
TOTAL	$20.5	$6.7



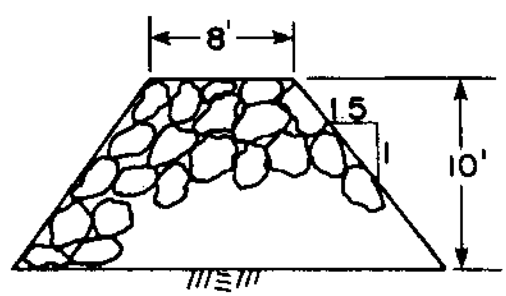


Fig. D-9 Proposed Breakwater and Position – Myrtle Beach

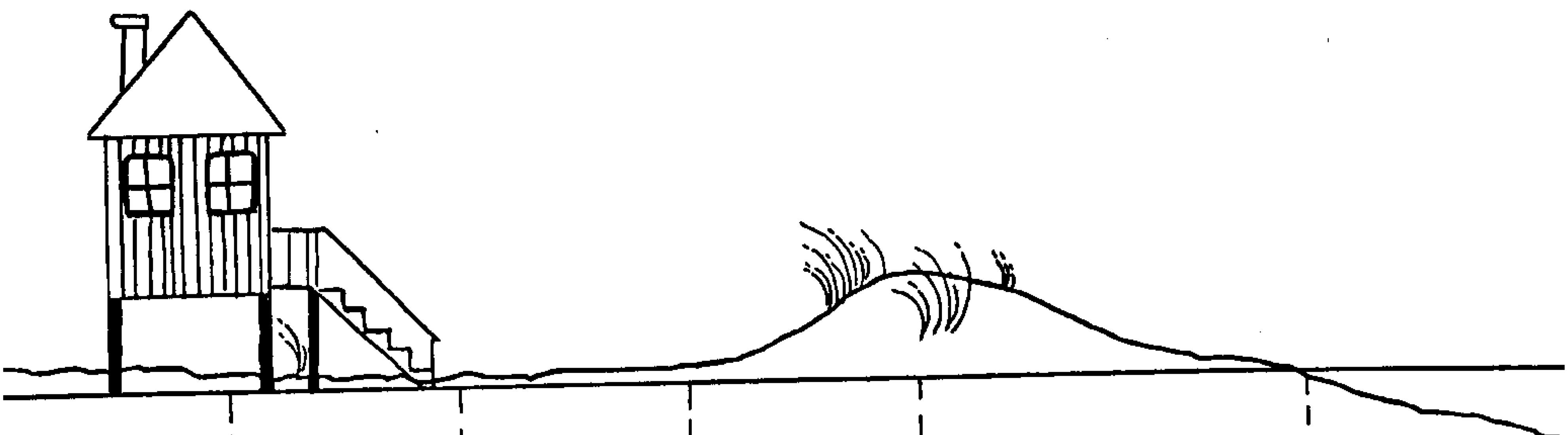
Benefit - Cost Analysis

Myrtle Beach is the most significant commercial development along the South Carolina coast. Although the shoreline is relatively stable, long-term erosional trends at the southern end of the city and short-term recession due largely to storm effects present a potential for serious property loss along the highly developed oceanfornt. In addition, a continued loss of beach area may pose future constraints on the city's important tourist industry. The following section considers the economic feasibility of initiating alternate beach nourishment projects at Myrtle Beact to alleviate damages inflicted by beach erosion. The first alternative considered is a 10 mile project for the entire city; the second alternative is for the more severly affected area bounded by 13th Ave. N. and 29th Ave. S. The latter area includes the principle hotel district and has experienced erosion rates ranging from 0.8 to 2.0 m./yr. Both projects consider beach nourishment and beach nourishment with offshore breakwaters.

Prevention of Property Loss

Property values at Myrtle Beach are based upon the 1979 tax assessment for Horry County. Land and building values were collected for oceanfront as well as second row properties located in areas subject to long-term erosional trends. Property values were then delineated to account the partial loss over the planning period (Figure D-10). Observation of comparable oceanfront and second row properties at Myrtle Beach indicated that oceanfront properties include a 50 percent premium reflecting the additional amenity associated with such location.

Figure D-10 ZONES EMPLOYED FOR ASSESSING BEACH PROPERTY LOSS



Fourth Quarter	Third Quarter	Second Quarter	First Quarter	Beach	Type of Loss
0	0	20%	35%	45%	Amenity Loss
5%	25%	40%	30%	0	Risk Loss
2%	18%	50%	30%	0	Building Loss

For this reason, amenity and risk factors are separated. Amenity stems from the existence of the beach; therefore, it is assumed that the majority of amenity value evolves from the beach and front lot (Figure D-10). Amenity value is fully exhausted when the second quarter of the lot is lost. The risk factor associated with the potential or actual loss of land occurs as open space between the water line and the building is eroded. The risk factor is greatest in the first and second quarters as further erosion presents serious risk and uncertainty to existing or potential buildings (Figure D-10).

Finally, building value is estimated based upon a sampling of building patterns along the oceanfront. It was observed that on average buildings were situated on lots as indicated in Figure D-10; the majority of facilities are located in the first and second quarters of the lots (29.4 and 50.3 percent, respectively). This close proximity of structures to the beachfront without sufficient open space to allow for shifts in the beach system significantly increases the potential for property damage in areas subject to short and long-term erosion.

Historical erosion rates based upon trends over the past 100 years are superimposed on tax maps for the city. By applying past trends to the present shoreline configuration, with an average beach width of 45 meters at mean high tide, the potential for property loss over the 50 year planning horizon is estimated. It is assumed that the application of effective erosion control measures will prevent such a loss; therefore, these figures represent the potential property benefit accuring from shoreline protection. Present values for these benefits are presented in Table D-4 grouped by tax map designation and by section of the lot

TABLE D-4

The Present Value of Property Benefit Accruing From Erosion Control at Myrtle Beach by Area and Lot Section.

Alternative I (10 mile project)

Tax Map-Section*	Beach	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
174-04, 07, 08, 09, 10, 11, 13	$ 240,774	$3,093,390	$12,094,938	$ 834,069	$73,980
181-04	48,154	618,678	618,987	166,813	14,796
181-07	620,604	0	0	0	0
181-10	302,241	1,045,430	1,266,991	740,720	13,826
181-11	152,502	0	0	0	0
181-13	76,768	0	0	0	0
181-14	495,529	1,923,984	2,284,053	130,272	10,508
186-08	233,263	183,471	172,822	55,577	6,388
187-01	1,676,094	1,203,653	0	0	0
Sub-Total	$3,845,929	$8,068,606	$7,437,791	$1,927,451	$119,498
TOTAL					$21,399,275

Alternative II (3.28 mile project)

Tax Map-Section*	Beach	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
181-07 (partial)	$366,307	0	0	0	0
181-10	302,241	$1,045,430	$1,266,991	$740,720	$13,826
181-11	152,502	0	0	0	0
181-13	76,768	0	0	0	0
181-14	495,529	1,923,984	2,284,053	130,272	10,508
186-08 (partial)	193,608	152,280	143,442	46,128	5,302
187-01	1,676,094	1,203,653	0	0	0
Sub-Total	$3,363,049	$4,325,347	$3,694,486	$917,120	$29,636
TOTAL					$12,229,638

*Based on Horry County tax map designations.

eroded; estimates are made for both the 10 and 3.28 mile project dimensions. The total property benefit, in present value terms, resulting from effective erosion control measures is expected to be \$22.3 million in the first case and \$12.2 million in the latter. Yet, the shorter project offers significantly greater benefit on a per mile basis reflecting both the high value of properties and the relatively rapid erosion occuring in this section of the beach.

Recreation Benefit

Peak visitation at Myrtle Beach is estimated to be 107,281 in 1980 (LBC&W, 1979 with Dunes, 501 Corridor, and Southwest deleted). According to the same study, visitation is expected to increase by 26.9 percent between 1980 and 1990 and to increase by 6.5 percent for the remainder of the century as the city seeks to limit further expansion. The present study employs an 18 percent growth projection for the 1980 to 1990 period and a 10 percent increase per decade thereafter. Peak visitation projections averaged for each decade over the planning period are listed in the same manner employed earlier for Pawleys Island (i.e., peak visitation = 2.5 x weekday visitation). (Table D-5, Items 1 and 2).

Present carrying capacity of the sand beach is estimated to be 111,746 visitors/day based upon an average width of 45 meters (MHW) and a beach length of 14.3 miles. The space requirement is estimated to be 100 square feet per user with a turnover rate of one. Based on these estimates, the beach is approaching capacity on peak days at the present time, and capacity will be reached for Sunday visits before the end of the projection period. Constrained visitation given the present

›LE D-5a

jected Visitation and Recreational Value Accruing for Periodic Beach Nourishment
Myrtle Beach-Erosion Scenario I.

	1980-90	1990-2000	2000-10	2010-20	2020-30
Visitation	4,957,168	5,582,515	6,246,038	6,870,656	7,557,786
2. Daily Visitation					
Weekday (60)	47,665	54,598	60,058	66,064	72,671
Sats (12)	71,498	81,897	90,087	99,096	109,007
Suns (12)	83,414	95,547	105,102	115,612	127,174
Peak (2)	119,162	136,495	150,145	165,160	181,677
Alternative I: 10 Mile Project					
3. Annual Visitation with project	4,935,426	5,607,970	6,007,118	6,240,426	6,457,186
4. Visitation without project	4,926,302	5,486,374	5,466,666	4,783,922	3,404,998
5. Differential	9,124	121,596	540,452	1,456,504	3,052,188
6. Erosion Control Benefit	182,480	2,431,920	10,809,040	29,130,080	61,043,760
7. Present Value	149,999	1,349,716	4,053,390	7,369,910	10,438,483
8. Sum of Present Values					$36,284,513
Alternative II: 3.28 Mile Project					
9. Annual Visitation with project	4,931,278	5,595,326	5,790,106	5,862,958	5,330,710
10. Visitation without project	4,926,302	5,486,374	5,466,666	4,783,922	3,404,998
11. Differential	4,976	109,152	2323,440	1,079,036	1,925,712
12. Erosion Control Benefit	99,520	2,183,040	6,468,800	21,580,720	38,514,240
13. Present Value	81,805	1,211,587	2,425,800	5,459,922	6,585,935
14. Sum of Present Values					$15,765,049

TABLE D-5b

Projected Visitation and Recreational Value Accuring for Periodic Beach Nourishment at Myrtle Beach-Erosion Scenario II.

	1980-90	1990-2000	2000-10	2010-20	2020-30
1. Visitation	4,957,168	5,582,515	6,246,038	6,870,656	7,557,786
2. Daily Visitation					
Weekday (60)	47,665	54,598	60,058	66,064	72,671
Saturdays (12)	71,498	81,897	90,087	99,096	109,007
Sundays (12)	83,414	95,547	105,102	115,612	127,174
Peak (2)	119,162	136,495	130,145	165,160	181,677
Alternative I: 10 Mile Project					
3. Annual Visitation with project	4,935,426	5,607,970	6.007,118	6,240,426	6,457,186
4. Visitation without project	4,929,216	5,547,568	5,656,076	5,662,036	4,532,716
5. Differential	6,210	60,402	351,042	579,390	1,924,470
6. Erosion Control Benefit	124,200	1,208,040	7,020,840	11,587,800	38,489,400
7. Present Value	102,092	670,462	2,632,815	2,931,713	6,581,687
8. Sum of Present Value					$19,500,456
Alternative II: 3.28 Mile Project					
9. Annual Visitation with project	4,926,402	5,598,898	5,863,166	5,965,242	5,765,698
10. Annual Visitation without project	4,929,216	5,547,568	5,656,076	5,661,036	4,532,716
11. Differential	3,186	51,330	207,090	304,206	1,233,522
12. Erosion Control Benefit	63,720	1,026,600	4,141,800	6,084,120	24,670,440
13. Present Value	52,378	569,763	1,553,175	1,539.282	4,218,645
14. Sum of Present Values					$7,933,243

beach formation is estimated to average 103,729 daily users in the first decade and 39,593 in the final period a total loss of 69 percent of capacity over the project period. This erosion scenario assumes that historical rates continue and that the shoreline is static with no potential for beach migration.

Annual visitation under both project alternatives then is estimated and compared with the no action solution. Under Alternative I, i.e., the 10 mile project, an annual differential of 3 million visitors is projected resulting in $61 million of erosion control benefits for the decade (benefits are calculated at $2/visitor x 10 years /decade). Under full beach nourishment, therefore, recreational benefits are estimated to be $36.2 million in present value terms.

Alternative II in Table D-5 depicts the same methodology applied to a 3.28 mile project. Because the area of beach fill is substantially less than in the previous example, annual visitation with the project will also be less totaling an average of 5.3 rather than 6.4 million persons during the last decade. As a result, the projected erosion control benefit is also expected to be less amounting to $15.8 million or 44 percent less than with the full nourishment approach.

A second erosion scenario is also employed with the findings depicted in Table D-6. The second scenario assumes that, although erosion rates continue, backward migration of the beach system will decrease net beach loss. Net beach loss is projected to be half of that occuring in Scenario I. As a result, although beach capacity will constrain peak and weekend activity, weekday visitation can be accommodated throughout the period. Annual visitation without the project will be larger reducing erosion control benefits than estimated particularly during the latter years of the planning period. Under Approach I, i.e., with nourishment of the full beach, the sum of present values is expected to $19.5 million compared with the $36.2 million estimated under the first erosion scenario. With the 3.28 mile project the present value of recreational benefits is estimated to be $7.9 million or 50 percent lower than in the more rapid erosion scenario.

The difference between recreational benefits estimated under the two scenarios is substantial. Unfortunately, the state-of-the-art does not allow us to estimate with great precision the effect on beach capacity of erosional trends. Moreover, the introduction of physical structures further complicates prediction. What the figures do suggest is that, the degree to which the beach system is able to absorb and adjust to erosional trends is most important. Although physical barriers designed to prevent property loss may be effective in that regard, the loss of beach capacity during critical erosion periods may be accelerated and may have serious consequences for tourist communities such as Myrtle Beach.

The Cost of Erosion Control Measures

It is anticipated that nourishment costs will range from $5 to $8 per yard under both of the proposed projects. Initial project cost will range from $10.5 to $16.9 million for the 10 mile project and from $3.4 to $5.5 million for the 3.28 mile project. Five-year renourishment cycles are assumed with renourishment costs expected to be 60 percent of initial cost. Under these assumptions, the total cost of maintaining the full 10 mile beach over the 50 year planning period is expected to range from $67 to $108 million, while the present value of these expenditures is expected to range from $35 to $56 million (Table D-7, Section A and B). Costs for the 3.28 mile project are expected to range from $22 to $35 million, while the present value of these expenditures is expected to range from $11 to $18 million (Table D-7, Sections C and D).

With the inclusion of an offshore breakwater to supplement nourishment, initial project costs are expected to rise by $20.4 million under the full nourishment alternative and $6.7 under the partial alternative. It is assumed that replacement will be required every 20 years. The renourishment cycle is extended from 5 to 10 years, however, as wave energy is dissipated along the shoreline. (Table D-8). Although the frequency of nourishment is decreased, total project costs for the 10 mile project are expected to rise to a range of $86 to $109 million, and the present value of costs for the proposed nourishment project in combination with offshore breakwaters is predicted to range from $55 to $69 million (Table D-8, Sections A and B). With the proposed 3.28 mile project, costs are expected to range from $29 to $36 million, and the present value of costs is expected to range from $17 to $21 with the combined nourishment/breakwater solution.

Summary of Benefits and Costs

Given the range of values for both project alternatives under alternate cost and depletion scenarios, the expected feasibility of beach nourishment at Myrtle Beach may vary significantly. Table D-9 summarizes the present value of benefits and costs of the project under each of these scenarios.

TABLE D-7

Estimated Costs and Present Value of Costs for Proposed 10 and 3.28 Mile Beach Nourishment Projects. (in millions of dollars).

	10 Mile Project				3.28 Mile Project			
	@ $5/Yard		@$8/Yard		@$5/Yard		@$8/Yard	
Year	Cost	Pres. Value of Cost	Cost	Pres. Value of Cost	Cost	Pres. Value of Cost	Cost	Pres. Value of Cost
0	$10,500	$10,500	$16,900	$16,900	$3,444	$3,444	$5,543	$5,543
5	6,300	5,179	10,140	8,335	2,066	1,699	3,326	2,734
10	6,300	4,259	10,140	6,855	2,066	1,397	3,326	2,248
15	6,300	3,497	10,140	5,628	2,066	1,147	3,326	1,846
	"	"	"	"	"	"	"	"
	"	"	"	"	"	"	"	"
	"	"	"	"	"	"	"	"
45	6,300	1,077	10,140	1,734	2,066	353	5,543	5,543
TOTAL	$67,200	$34,591	$108,160	$55,675	$22,038	$11,344	$35,477	$18,262

TABLE D-8

Estimated Costs and Present Value of Costs for Proposed 10 and 3.28 Mile Beach Nourishment Projects with Offshore Breakwaters (in millions of dollars).

	10 Mile Project				3.28 Mile Project			
	@ $5/Yard		@ $8/Yard		@ $5/Yard		@ $8/Yard	
Year	Cost	Pres. Value of Cost	Cost	Pres. Value of Cost	Cost	Pres. Value of Cost	Cost	Pres. Value of Cost
0	$30,927	$30,927	$37,327	$37,327	$10,143	$10,143	$12,242	$12,242
10	6,300	4,259	10,140	6,855	2,066	1,397	3,326	2,248
20	26,727	12,188	30,567	13,939	8,765	3,997	10,025	4,571
30	6,300	4,259	10,140	6,855	2,066	636	3,326	1,024
40	16,514	3,435	20,354	4,234	5,916	1,231	6,676	1,389
TOTAL	$86,768	$55,068	$108,528	$69,210	$28,956	$17,404	$35,595	$21,474

TABLE D-9

Summary in Present Value Terms of the Benefits and Costs of Beach Nourishment at Myrtle Beach Under Alternate Project, Cost, and Erosion Scenarios (Figures in thousands of dollars)

Alternative I (10 mile project)

	Low Cost Scenario[1]				High Cost Scenario[2]			
	Rapid Beach Erosion[3]		Gradual Beach Erosion[4]		Rapid Beach Erosion[3]		Gradual Beach Erosion[4]	
	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost
Property Value	$21,399		$21,399		$21,399		$21,399	
Recreation Value	36,295		19,500		36,285		19,500	
Project Cost		$34,591		$34,591		$55,675		$55,657
Total	$57,684	$34,591	$40,899	$34,591	$57,684	$55,675	$40,899	$55,675
Benefit/Cost Ratio		1.67		1.18		1.04		0.73

Alternative II 3.28 mile project)

	Low Cost Scenario[1]				High Cost Scenario[2]			
	Rapid Beach Erosion[3]		Gradual Beach Erosion[4]		Rapid Beach Erosion[3]		Gradual Beach Erosion[4]	
	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost
Property Value	$12,230		$12,230		$12,230		$12,230	
Recreation Value	15,765		7,933		15,765		7,933	
Project Cost		$11,344		$11,344		$18,262		$18,262
Total	$27,995	$11,344	$20,163	$11,344	$27,995	$18,262	$20,163	$18,262
Benefit/Cost Ratio		2.47		1.78		1.53		1.10

[1]Based on a nourishment cost of $5/yd and the construction of an offshore breakwater.

[2]Based on a nourishment cost of $8/yd (no breakwater).

[3]Assumes a potential loss of 69 percent of beach capacity over the project period (50 years).

[4]Assumes a potential loss of 37 percent of beach capacity over the project period.

The use of offshore breakwaters is not considered in the analysis as beach nourishment without breakwaters was deemed a more cost effective solution. Although both gradual and rapid erosion scenarios are used to estimate recreational benefits, it seems more appropriate to estimate benefits on the conservative side using the gradual erosion approach. Finally, the above analysis may represent an overestimate of erosion control benefits as it is assumed that properties maintain values in their present form over the 50-year planning period. In other words, no provision for depreciation of the structure or for redevelopment of the site to allow for erosional trends is made.

Alternative I, i.e. nourishment of the entire beach is estimated to be feasible under the low cost ($5/yd) scenario; yet, as we might expect, the benefit/cost ratio is more favorable under the rapid erosion scenario. (1.67 to 1.18) With high nourishment costs, the project appears to be marginally feasible only under the rapid erosion scenario. We can conclude then that nourishment of the entire beach may be feasible at a low nourishment cost, although the project may not be justified under high cost conditions.

For Alternative II, i.e. for the 3.28 mile project, the expected returns are considerably more favorable. Benefit/cost ratios range from 1.78 to 2.47 under the low cost scenario and from 1.10 to 1.53 under the high cost scenario. These figures suggest that, based upon the assumptions made, beach nourishment in this portion of Myrtle Beach may be justified using both conservative recreational benefits and a high cost construction scenario. Should the city consider nourishment, therefore, it seems appropriate to focus first on the principal hotel district and on adjacent areas where erosion rates have been most severe. The initial cost of such a project is estimated to range from $3.4 to $5.5 million with periodic replenishment required every 5 years. If deemed appropriate, the city should consider the use of a local option sales and/or accommodations tax (pending legislative approval). Otherwise, user charges in combination with property tax increases, particularly in the affected area, might be required to meet the city's bond obligations.

From a long-term perspective, however, and especially if beach nourishment is not pursued, the city should act to restrict construction in erosion prone areas to alleviate losses in the future. This policy would, by itself, reduce the potential property loss accruing from erosion over the 50-year planning period considered. Many of the present problems at Myrtle Beach stem from a failure to anticipate and incorporate potential shifts in beach formation into development practices. As the city continues to develop and redevelop its oceanfront, new structures should be positioned in locations allowing for migration of the beach over the expected lifetime of the structure. It is recommended strongly that the city establish an effective setback law applicable to new structures. Structural solutions to erosion problems should be permitted by both the city and the State Coastal Council regardless of their location on public or private property, as if the structures is needed, it will have a direct effect upon the public beach. Permits for erosion control structures should be limited in time to the depreciation schedule remaining on the building(s) requiring protection. The city must decide if and under what circumstances it will permit erosion control structures for developments occurring after these new policies are enacted.

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CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

The costs associated with coastal erosion have become significant due both to property loss and to the expense of preventative measures employed to minimize further loss. The primary cause of this problem stems from the volatile nature of coastal processes and from building patterns that have proved incompatible with the natural system. Although the options available for controlling nature are limited, coastal development patterns can and should be made consistent with coastal processes.

The state, as trustee of the public beaches and as protector of the public interest, should provide a framework which allows for an optimal use of the state's resources from a long-term standpoint. In its resource management capacity, the primary functions of the state should be:

1) to provide for access and maintenance of the public beach,
2) to develop and disseminate information allowing individuals and communities to make well-informed decisions concerning utilization of the resource, and
3) to institute mechanisms serving to minimize or correct for the external effects of individual actions that adversely affect other individuals or the community as a whole.

Within this framework, individual property owners and local communities should be allowed maximum possible discretion in decisions which are consistent with state policy. At the same time, it clearly is not the responsibility of the state to subsidize risk-taking by individual property owners where appropriate information is provided and individual discretion is allowed.

The recommendations that follow are prefaced by the realization that state policy will continue to be influenced significantly by federal policy with respect to the coastal zone and specifically to erosion control policy. The current reevaluation of federal policy may have considerable impact on state programs; yet, it seems essential that coastal states clearly define appropriate policies in this regard without further delay. The South Carolina Coastal Management Plan and present state enabling legislation provide an institutional basis for doing so. It is recommended, therefore, that the following items be addressed and that the accompanying provisions be given serious consideration to supplement present state policy.

Long-Run State Policy

Recognizing its coastal beaches as among its most valuable resources, the state must commit itself to the management of these resources to provide the greatest possible benefits to its residents. Such an approach must include a long-run perspective recognizing the volatile nature of the coastal system and encouraging building patterns which are compatible rather than at odds with natural processes. The guidelines implemented should be clear and consistent relying on ad hoc decisions for short-term emergency situations rather than as a fundamental long-run approach. Specific attention should be given to the following components in developing such a strategy:

Data Collection

There is a basic need for additional data for both planning and engineering design purposes. A program of permanent wave data collection is needed at a minimum of three points along the coast. These stations should be part of the Federal Wave Data Program of the National Ocean Survey. Information on wave height, period, and direction is necessary in both the analysis of coastal processes and in the design and evaluation of erosion control alternatives.

In addition to wave data, a program should be initiated to monitor and catalogue erosion and accretion at fixed stations along the entire coast. These profile stations should be established with permanent benchmarks using precise surveying techniques. New surveys should be made at least semi-annually, as well as after significant storm periods. This information is essential to accurately assess and accommodate short-term and long-term shoreline erosion or accretion.

Public Awareness

Public awareness of the dynamics of the coastal system should be encouraged through public forums sponsored by the South Carolina Coastal Council and South Carolina Marine Advisory Program. Similarly, information and pertinent state and local policy as well as historical erosion trends should be distributed to prospective buyers of property in hazard areas through the office of the county building inspector. Properties in hazard areas should be so designated as such with the disclaimer that individuals are building at their own risk.

Technical Assistance

It will be necessary for appropriate state agencies and scientists developing coastal process information to work closely with local officials to provide input as well as regulatory and planning support. Technical assistance and financial support to establish and maintain local programs should be provided by the state through its coastal management program.

Building Standards

The construction of both buildings and erosion control structures should be governed by uniform construction codes. Although individual property owners must be encouraged to incorporate risk in their decision-making, the potential for property transfer and high rate of nonowner occupancy suggest that minimum standards should be established to assure reasonable levels of safety. This code should be based upon the unique set of conditions peculiar to areas which experience the direct interaction with storm waves and surge as well as wind and erosion damage. Such a code should be applied on a state-wide basis, although local enforcement may be both necessary and desirable.

Setback Lines

Realizing that its coastal beaches are subject to dynamic conditions and, in some cases, to long-term erosional trends, the state should encourage and give standing to the establishment of a coastal setback line demarcating potential hazard areas to prospective development. By restricting development in hazard areas, setback provisions will lessen the potential for conflict between private property owners and public and adjacent private properties emerging from critically eroding conditions. Building setbacks offer a consistent, institutional mechanism superior to ad hoc solutions development patterns and problems that may ensue. In extreme cases where a setback line may entail a significant taking of property rights, compensation may be required.

A comprehensive setback law should:

1) incorporate site specific scientific data to the extent practical to anticipate and accommodate serious erosion hazards,

2) provide a minimum buffer zone (generally drawn from the mean high water line and/or the crest of the primary dune) from which development would be prohibited,

3) designate particularly volatile areas such as inlets or locations experiencing particularly acute erosional patterns,

4) include provisions for dune protection,

5) allow for local ordinances to reinforce or, in some cases, provide for more restrictive controls as deemed appropriate to the local community and,

6) accommodate periodic revision of the guidelines as physical conditions change as more scientific data is provided.

Specific figures are not presented at this time as they should be determined pending state approval of the concept and a determination of the extent to which site specific scientific data or standard distances are to be used. Setback laws in Florida and New Jersey are typical of the state-of-the-art.

Short-Run State Policy

Past development in coastal areas has been poorly planned in some cases and present plans are made without certainty. For these reasons, the potential loss of property will continue to be of concern and short-term measures will be required. The following recommendations are made concerning such decisions:

Permitting Authority

The principle tool for addressing short-term erosion control problems must continue to be state permitting authority. Guidelines for structural and nonstructural approaches have previously been documented (SCCMP IV

(4) (c)) and new recommendations are being considered at the present time. Requests for permission to construct erosion control structures should be accompanied by:

1) an assessment of the potential impace on adjacent lands and the public beach,
2) a consideration of alternate erosion abatement techniques including where applicable management options, and
3) a reasonable justification indicating that the project may be considered in the best interest of the public.

In general, structures should not be permitted for periods to exceed the remaining depreciation period on the building to be protected. In addition, new structures built in the future should be subject to stringent guidelines and prove that unusual circumstances prevailed before permits for erosion control structures are issued. Permitting authority should apply to all erosion control structures impacting the public beach presently or in the foreseeable future. It can be argued that erosion control structures are unnecessary if they do not potentially affect the beach system.

Broader permitting authority should also be extended to consider the impact of additional development activity on the systems natural and physical carrying capacities. Complementary authority should be considered by localities as a means of augmented state responsibility and assuring that local considerations are met as well.

Relocation

Under some circumstances, it may be more cost effective to relocate structures than to protect them from emminent property loss. The same funding formula in terms of state and federal share applied for engineering solutions should be applied for relocation. Compensation, if paid, should be based upon the depreciated value of the structure and fair market value for the land.

Local Participation

Local discretion should be incorporated in management of erosion control problems to the maximum extent practical as local jurisdictions can achieve maximum responsiveness to local conditions, better accountability, and greater public accessibility. To provide a basis for active local participation, appropriate jurisdictions should be encouraged to develop local coastal erosion programs. Components of the program should include:

1) an identification and evaluation of coastal resources that require management and protection by localities as specified in the Coastal Zone Management Act and the South Carolina Coastal Management Plan,
2) an examination of existing and proposed statutes providing a basis for managing coastal resources,
3) a delineation of areas within the coastal zone and an identification of appropriate uses for these areas, and
4) a description of legal authorities and organizational arrangements needed to implement the program.

Specific components of local programs should include:

1) a description of long-term policy relating to development and to erosion control measures,
2) a provision for and set of guidelines establishing and

providing enforcement for coastal land-use controls - the provisions should include a local setback line, a provision for dune management,

3) a determination of appropriate short-run policies to deal with emergency situations - local permitting authority should be considered, and as suggested previously, technical assistance and financial support to establish and maintain local erosion control programs should be provided by the state through its coastal management program,

4) an identification of funding measures designed to meet the required local share for erosion control measures.

Funding Policy

State funding for erosion control should be based upon policies outlined in SCCMP IV C (4) (a). Priorities and funding formulas should be established for projects based upon the following ranking:

1) state owned public beachfront,
2) municipality owned public beachfront,
3) quasi-public beachfront where public access is provided,
4) privately owned recreational beachfront where public access is provided, and
5) privately owned recreational beachfront.

Project costs should be borne primarily by the beneficiaries of the project. State monies should be made available only to commjnities that have, in force, or in the immediate future to communities developing for approval, a local erosion control program indicating that the jurisdiction is taking a responsible approach to minimize the impact of erosion damage.

It is expected that further bond issues will be required to meet the state share of erosion control projects. The allocation of such funds should be distributed based upon the criteria and formulas suggested previously. In addition, the project must be justified as being in the public interest and as being the most cost effective solution to the problem. To meet local obligations, the adoption of a local option sales tax and/or an accommodations tax offer the potential for tourist communities to support beach maintenance. Communities should also consider user fees administered at public parking areas and local property taxes as local conditions warrant as possible revenue sources.

APPENDIX A

§ 923.25 Shoreline erosion/mitigation planning.

(a) Statutory Citation, Section 305(b)(9):

The management program for each coastal state shall include * * * A planning process for (A) assessing the effects of shoreline erosion (however caused), and (B) studying and evaluating ways to control, or lessen the impact of, such erosion, and to restore areas adversely affected by such erosion.

(b) The basic purpose in developing this planning process is to give special attention to erosion issues. This special management attention may be achieved by designating erosion areas as areas of particular concern pursuant to § 923.21 or as areas for preservation or restoration pursuant to § 923.22.

(c) *Requirements.* (1) The management program must include a method for assessing the effects of shoreline erosion and evaluating techniques for mitigating, controlling or restoring areas adversely affected by erosion.

[*Comment.* In developing assessment and evaluation techniques, states should consider:

(i) loss of land along the shoreline or estuarine banks;

(ii) whether the loss resulted from natural or man induced forces;

(iii) whether the erosion is regularly occurring, cyclical, or a one time event;

(iv) impacts of the erosion on adjacent shorelines, and land and water uses;

(v) probable impacts of mitigation on adjacent shorelines, land and water uses, littoral drift and other natural processes such as accretion; and

(vi) probable impacts of re-establishment of pre-erosion shoreline or rebuilding on wetlands and natural habitat, particularly as the re-establishment or rebuilding might relate to the Executive Orders on Wetlands and Floodplains (see § 923.3(b)(2)(ii)).]

(2) There must be an identification and description of enforceable policies, legal authorities, funding techniques and other techniques that will be used to manage the effects of erosion as the State's planning process indicates is necessary.

[*Comment.* In developing a process to manage the effects of erosion, States should consider:

(i) the extent and location of erosion problems;

(ii) the necessity for control versus noncontrol of erosion;

(iii) whether structural (e.g., groins) or nonstructural controls (e.g., land use setbacks) are appropriate;

(iv) costs of alternative solutions (including operation and maintenance costs); and

(v) the National Flood Insurance Program (24 CFR 1909 et seq.) and regulations of the Federal Insurance Administration on flood-related erosion-prone areas (24 CFR 910.5).]

[*Comment.* Due to restrictions on the use of section 306 funds (see § 923.94), not all means of restoration proposed by States may be eligible for funding under section 306 or other sections of the Act. Accordingly, particular attention should be given to coordination of shoreline erosion management objectives with funding programs pursuant to the U.S. Army Corps of Engineers Beach Erosion Control Program (33 U.S.C. 426 et seq.), the Hurricane Protection Program (33 U.S.C. 701 et seq.) and other programs as may be appropriate.]

APPENDIX B

EROSION CONTROL POLICIES

The Coastal Council will apply the following policies in its review and evaluation of permits for the following erosion control activities:

Seawalls, Bulkheads and Revetments (Riprap)

1) Seawalls, bulkheads and revetments will be considered only as part of a comprehensive erosion control program to insure that these structures do not cause adverse effects to adjoining property owners or appreciably accelerate erosion in the general beach area.

2) These structures must not interfere with existing or planned public access unless other adequate access can be provided.

3) These structures shall not impede public use of beaches below the mean high water line (R.30-13(2)(C).

4) These structures should be sloped seaward or concave with riprap at their bases to reduce the adverse effects of scouring where appropriate.

5) Applications for construction of a seawall in the beach or dune critical areas for the purpose of filling behind these structures to create land for private development shall be denied unless the applicant can clearly demonstrate to the Council that no feasible alternatives exist, that the individual circumstances are extenuating such that they demand an exception to the general policy and that the project would otherwise be consistent with the coastal management program.

6) Except under special circumstances, such as critically eroding shorelines that have a direct measurable effect on the economic well-being of an applicant or are a threat to the public safety, the Council will promote the use of natural features of the dune and beach system rather than artificial protection (R.30-13(2)(a)).

7) Additionally, all other regulations covering bulkheads and seawalls will be applied in the critical areas (R.30-12(C)).

8) Riprap must consist of appropriate materials.

Groins

1) Significant volumes of sand via the littoral transport system should be available.

2) The extent to which the downdrift beach areas will be damaged must be determined before construction.

3) The adequacy of shore anchorage of groins to prevent "flanking" as a result of erosion must be demonstrated.

4) The positive effect and applicability of a groin system in a comprehensive shore protection program must be demonstrated.

5) Care must be taken to insure that groins do not interfere with public access (R.30-13,C(2)(c).

Offshore Breakers and Jetties

1) Since these structures tend to impound littoral drift on their updrift sides, provisions should be made so that sand is pumped at appropriate intervals to downdrift areas so as not to starve these areas of sand thereby creating or worsening an erosion problem.

2) Care must be taken to insure that jetties do not interfere with public access (R.-30-13, C(2)(C)).

3) Where appropriate, jetties should be designed to provide recreational fishing opportunities (R.30-13,C(2)(d)).

4) Construction activities should be scheduled so as not to interfere with nesting and brood-rearing activities of important seabird colonies or other wildlife species (R.-30-13,C(2)(3).

5) These structures should be consistent with other erosion measures being undertaken as part of any comprehensive shoreline protection projects.

Artificial Beach Nourishment

1) A thorough study of littoral transport mechanics as well as beach slope, grain size, and berm geometry should be done before artificial nourishment is attempted.

2) Sand for artificial nourishment should come from offshore deposits or areas of active accretion and from bars or spits only where it can be clearly demonstrated that no negative impacts will result in downshore areas. Fill material should not come from dune fields, adjoining beaches or nearshore bars.

3) Dredging in the borrow areas should not be in conflict with spawning seasons or migratory movements of significant estuarine-marine species.

4) Dredging offshore shall be done in locations and in such a manner so as not to create anoxic sumps or uncover toxic or anoxic deposits.

5) All other policies concerning dredging and filling (R.30-12,G) will be applied to beach nourishment proposals.

6) Careful study must be given to the type (size, quality, etc.) of fill material most suitable for use in a particular beach area.

7) Nourishment of beach areas should be scheduled so as not to interfere with nesting or brood-rearing activities of important seabird colonies or other wildlife species.

8) The recreational and public access requirement of the affected beach area will be a major concern when determining the width of the beach fill.

9) Where possible, inlet stabilization and/or navigation projects shall be done in concert with artificial nourishment projects.

10) Structural control measures should be used, where appropriate and feasible, to complement artificial nourishment projects.

Sand Dune Management

1) Private and public projects to restore and stabilize dunes through non-structural means are encouraged.

2) To the extent possible, the secondary dunes should be kept intact to insure protection of adjoining areas against flooding during storms.

3) Buffer areas should be established, where feasible, to allow for frontal dune growth and movement.

4) All plans for dune restoration, reconstruction or stabilization should be part of a comprehensive shoreline protection program.

5) Dune reconstruction should be done only above the existing berm line or in line with existing frontal dunes. Dunes should be constructed using only native material (sand) of the appropriate grain size and stabilized with native vegetation. Consultation is encouraged with Soil Conservation Service advisory services in determination of plant materials most suitable for dune stabilization.

6) Walkover structures are encouraged over all frontal dunes (R.30-13, B.) However, these walkover structures should not interfere with public access or extend below the mean high water line.

7) Seawalls, bulkheads or revetments should not be placed in front of frontal dunes, except where severe erosion is indicated and unless there are no feasible alternatives or there is an overriding public interest.

8) Public access should be provided either over frontal dunes via walkover structures or by using natural breaks through frontal dunes. In no case shall access be provided by bulldozing or cutting openings through frontal dunes.

9) In all cases, the primary front-row sand dune, as defined in R.30-10(B), should not be permanently altered.

U.S. Department of Commerce, Office of Coastal Zone Management, "State of South Carolina Coastal Management Program and Final Environmental Impact Statement", Section IV 4(c), 1979.