SECTION 933 EVALUATION REPORT

THIMBLE SHOAL AND ATLANTIC OCEAN CHANNELS

RESORT STRIP

VIRGINIA BEACH, VIRGINIA

US Army Corps
ngineers

District

1989

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RESORT STRIP

VIRGINIA BEACH, VIRGINIA
SECTION 933 STUDY

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INTRODUCTION

STUDY AUTHORITY

The study contained herein was authorized by Section 145 of the Water Resources Development Act of 1976 (Public Law 94-587), dated October 22, 1976, which states in part:

> "The Secretary of the Army, acting through the Chief of Engineers, is authorized upon request of the State, to place on the beaches of such State beach-quality sand which has been dredged in constructing and maintaining navigation inlets and channels adjacent to such beaches, if the Secretary deems such action to be in the public interest and upon payment of the increased cost thereof above the cost required for alternative methods of disposing of such sand."

This authority was amended by Section 933 of the Water Resources Development Act of 1986 (Public Law 99-662) dated November 17, 1986, by the insertion of . . . "by such State of 50 percent" after "upon payment." In correspondence dated June 30, 1988, (contained in section C of the appendix), the Commonwealth of Virginia requested that a Section 933 study be initiated for the placement of sand dredged from the 55-foot outbound Thimble Shoal and Atlantic Ocean Channels onto the resort strip of Virginia Beach which is generally that area between Rudee Inlet northward to 49th Street.

STUDY PURPOSE AND SCOPE

The purpose of this study is to determine the Federal interest in participating in the cost of placing suitable material from Thimble Shoal and Atlantic Ocean Channels (see plate 1) on the resort beach at Virginia Beach rather than depositing it in an offshore disposal area. The evaluation report will consider only that material to be provided from the 55-foot-deep outbound channels which are part of the Norfolk Harbor and Channels, Virginia, project.

STUDY AREA

The study area is located within the city of Virginia Beach which contains almost 260 square miles of predominantly low-lying and flat terrain including 28 miles of ocean front and 10 miles of bay front. However, the specific area addressed by this study is the 3.3 miles of beach between Rudee Inlet and 49th Street. This area is the center of commercial and recreation-oriented development containing many motels, hotels, restaurants, and specialty shops catering to a large tourist and summer resort trade. The area is known locally as the "resort strip."

NAVIGATION PROJECT

The Norfolk Harbor and Channels project provides for deepening the existing 45-foot channels to 55 feet, constructing a new 60-foot-deep channel off Virginia Beach referred to as the Atlantic Ocean Channel, deepening the existing 40-foot portion of Elizabeth River and its Southern Branch to 45 feet, and deepening the existing 35-foot portion of Southern Branch to 40 feet up to the Gilmerton Bridge (River Mile 17.5) and providing an 800-foot turning basin at that point. Deepening of the Thimble Shoal Channel to a depth of 50 feet was completed in 1988. Further deepening of Thimble Shoal Channel from 50 to 55 feet and construction of the Atlantic Ocean Channel is scheduled to be initiated in the fall of 1990. It is the deepening of these two channels which would provide the source of material for beach deposition for the resort strip.

PRIOR STUDIES, REPORTS, AND EXISTING PROJECTS

There have been six previous reports prepared by the Corps of Engineers dealing with beach erosion control and/or hurricane protection and navigation for the study area. They are described briefly in the following paragraphs.

In 1952, the Corps of Engineers, in cooperation with the city of Virginia Beach, prepared a report on a beach erosion control study for Virginia Beach. The report, printed in House Document 186, 83rd Congress, 1st Session, concluded that artificial placement of sand on the beach between Rudee Inlet and 49th Street was justified. In his report, the Chief of Engineers recommended authorizing Federal participation in an amount equal to the cost of protecting the Federally owned frontage, plus one-third of the first cost of measures for the restoration and protection of the other publicly owned portions of the shores of Virginia Beach. The plan of protection included (a) artificial placement on the ocean shore of approximately 1,100,000 cubic yards of suitable sand fill to widen the beach berm to a minimum width of approximately 100 feet at elevation 7 feet above mean low water or elevation 5.4 National Geodetic Vertical Datum (NGVD), and (b) construction of a system of approximately 21 groins as deferred construction when experience indicates the need therefor. The total cost of the work was estimated at $2,024,500 at November 1951 price levels, and in accordance with the provisions of Public Law 727, 79th Congress, approved August 13, 1946, the Federal share was estimated at $675,000. The project was adopted by the River and Harbor Act of September 3, 1954 (Public Law 780, 83rd Congress, 2d Session), as recommended by the Chief of Engineers. In an effort to expedite construction, beach restoration, in accordance with the recommended plan, was completed by local interests in 1953. The groins have not been constructed to date.

In 1962, a brief review report on a beach erosion control study for Virginia Beach was made by the Corps of Engineers in cooperation with the Virginia Beach Erosion Commission. The report, printed in House Document 382, 87th Congress, 2d Session, was a review of the project for beach erosion control at Virginia Beach authorized by the River and Harbor Act of 1954. The review was made to determine the extent, if any, of Federal participation in the cost of periodic beach nourishment. The initial project was authorized prior to the passage of Public Law 826, 84th Congress, which provides a policy of Federal assistance for periodic nourishment. In this report, the Chief of Engineers recommended modification of the existing Federal project for Virginia Beach to authorize Federal participation in the amount of one-third of the costs of periodic nourishment of the shore. This participation would be for a period of 25 years from the placement of an initial quantity of nourishment material equal to the deficiency in the design beach at that time. This would be done generally in accordance with the plan of the District and Division Engineers with such modifications as deemed necessary by the Chief of Engineers. This was authorized in the River and Harbor Act of 1962. Local interests acquired their own dredging plant and borrow areas and replenished the beach. In accordance with Section 103 of the 1962 River and Harbor Act, the Federal Government bore one-half of the cost of this program. Federal participation in beach nourishment expired in February 1987.

A brief hurricane survey report on Virginia Beach, Virginia was prepared in 1965 in compliance with Public Law 71, 84th Congress, 1st Session. The report on the hurricane problem, printed in House Document 268, 89th Congress, 1st Session, recommended that no Federal expenditure be made and that the report be distributed to local interests for use in establishing flood plain regulatory measures and evacuation procedures.

A feasibility report for beach erosion and hurricane protection was completed in 1970 and published in House Document 96-365, 92d Congress, 2d Session. It encompassed the entire shoreline of Virginia Beach from the North Carolina line to Little Creek Inlet in Chesapeake Bay. It recommended that the existing project for beach erosion control for the city of Virginia Beach, Virginia be modified to provide for the construction of a Federal project for beach erosion control and hurricane protection between Rudee Inlet and 89th Street, a distance of about 6 miles.

As a result of the above recommendation, a Phase I report on Virginia Beach was prepared in partial response to Section 1(a) of the 1974 Water Resources Development Act. The report (as forwarded to Congress) recommends the construction of a new seawall from Rudee Inlet to 57th Street, the raising and/or widening of the existing sand dune from 57th Street to 89th Street, and the maintenance of a beach berm with minimum width of 100 feet between 49th Street and 89th Street. A General Design Memorandum (leading to construction plans) has been conditionally approved by NAD.

A study of Rudee Inlet was initiated in connection with an investigation of Virginia Beach Streams authorized by the Committee on Public Works of the House of Representatives on June 21, 1965. In view of the close relationship of Rudee Inlet to the beach erosion and hurricane protection project, referred to in the previous paragraph, the Chief of Engineers approved inclusion of Rudee Inlet as part of the Phase I study authorized for Virginia Beach. However, a separate report was prepared on the inlet. This approach was taken because any plan selected for Rudee Inlet would require that the proposed project bypass the same amount of littoral drift to the downdrift as would naturally bypass if there were no inlet present. Furthermore, the effect on the beach would be as if there were no inlet or no Federal navigation project at Rudee Inlet. Therefore, the selected plan for Rudee Inlet would be compatible with and independent of whatever plan is selected for implementation for beach erosion and/or hurricane protection. The final Phase I General Design Memorandum and Environmental Assessment for Rudee Inlet was submitted to North Atlantic Division, Corps of Engineers in August 1982. During the Phase I studies for Rudee Inlet, a number of alternatives were considered including channel deepening and modification of the north and/or south jetty. However, it was concluded that even though modification of the north and/or south jetty could have some impact on the littoral drift to the downdrift beaches, the results would not be significant. It was concluded that complete bypassing of the littoral drift to the downdrift beaches could best be accomplished by proper maintenance of the existing rock jetties and weir-sand trap system. Maintenance requirements for the navigation channel would include the dredging of 220,000 cubic yards annually in the entrance channel and sand trap. This dredging would be done semiannually and the material would be bypassed to the beaches north of the inlet. West of the inlet, only 3,000 cubic yards of dredging per year would be required but this would be accomplished about once every 10 years. It should be noted that any sand replenishment program included with alternative plans presented in this report would be in addition to the 220,000 cubic yards being bypassed at Rudee Inlet.

Draft plans and specifications were approved on August 9, 1984. They provide for a 10-foot-deep entrance channel from the Atlantic Ocean through the inlet; a 7-foot-deep inner channel, safety area, and turning basin; and an 18-foot-deep sand trap. Plate 2 outlines the plan of improvement. Under the "Continuing Federal Authority for Small Navigation Projects," this project can be constructed once the city satisfies the items of local cooperation.

In December 1987, the District completed a reevaluation report under authority of Sections 933 and 934 of the Water Resources Development Act of 1986 (P.L. 99-662) for the reach of beach between Rudee Inlet and 49th Street. Under the Section 933 authority, it was determined that a volume of 964,000 cubic yards of sand would be dredged from the Cape Henry Channel (a part of the Baltimore Harbor and Channels, Maryland and Virginia project) to provide a design berm containing 360,000 cubic yards of sand with a width of about 100 feet. The effectiveness of the berm would last an estimated 2 to 3 years. To date, this project has not been constructed.

Under the Section 934 authority of the reevaluation report, it was determined that Federal participation is warranted in the cost of nourishing the beach between Rudee Inlet and 49th Street with artificial placement of suitable sand fill to provide and maintain a berm having a width of approximately 100 feet at elevation 5.4 feet NGVD for an additional 10-year period. This project in effect extends the beach nourishment project authorized by the River and Harbor Act of 1962 which expired in February 1987. Funds for extending the project, however, will not be budgeted until such time as the effectiveness of the Section 933 sand supplied to the beach from the Cape Henry Channel has been diminished to a level where further nourishment is needed.

RESOURCES AND ECONOMY OF THE STUDY AREA

INTRODUCTION

The city of Virginia Beach was formed in 1963 by the merger of Princess Anne County with the former Virginia Beach city. The city is bordered by the Atlantic Ocean on the east, the Chesapeake Bay on the north, the cities of Norfolk and Chesapeake on the west, and Currituck County, North Carolina on the south. Virginia Beach has a total land area of 258.7 square miles, which includes 28 miles of ocean front and 10 miles of shoreline along the Chesapeake Bay. The area is shown on plate 1.

The following paragraphs discuss the natural, cultural, and human resources of the study area and describe the environmental setting as well as the development and economy.

NATURAL RESOURCES

The city is a large, diverse area in southeast Virginia with a mixture of agricultural-woodland sites and residential-shopping center complexes. In recent years, numerous residential developments have been constructed to house the large increase in population. The excellent inland waterways and attractive seashore areas have contributed to the growth of these residential developments. With its excellent beaches, the city attracts thousands of tourists and vacationers from not only the surrounding area, but also from all parts of the United States and from Canada.

The most significant oceanfront area of Virginia Beach, in terms of intense recreational use and commercial development, is the 3.3 miles of beach between Rudee Inlet and 49th Street. Together with the adjoining commercial shoreline, it represents the largest ocean resort area in Virginia, indeed one of the largest on the East Coast. This area includes many motels, hotels, restaurants, and specialty shops catering to a large tourist and summer resort trade.

The climate in Virginia Beach is temperate with moderate, seasonal changes. Winters are generally mild, and summers, though long and warm, are frequently tempered by cool periods resulting from winds off the Atlantic Ocean. Temperatures average 41 degrees in January and 78 degrees in July. The growing or frost-free season is about 222 days. Occasionally, during brief periods, the climatic conditions vary extremely due to storms of both extra-tropical and tropical origin. The average annual precipitation is about 45 inches. The precipitation is fairly evenly distributed throughout the year, with average monthly amounts ranging from 5.74 inches in July to 2.62 inches in November. Measurable amounts occur on an average of about 1 day out of 3. Overall, the climate is favorable to development of the area, and, in combination with sandy beaches, is particularly favorable to tourism during the warmer months.

HISTORICAL AND CULTURAL RESOURCES

The Virginia Research Center for Archaeology headquartered in Richmond, Virginia has stated that there are no known archaeological sites in the area from Rudee Inlet to 49th Street. However, there are 17 historic vessels which are known to have been lost off the coast from Cape Henry to Rudee Inlet and numerous other vessels which have been lost in the general area. The Atlantic Ocean along Virginia Beach was the location of a coastal trade route between the ports of the Chesapeake Bay southward and, thus, is a prime area for the location of past shipwrecks. A survey of the proposed Atlantic Ocean Channel, which is located off the coast of Virginia Beach, was accomplished in connection with the Norfolk Harbor and Channels Deepening and Disposal Project. However, no significant cultural resources were discovered in this area.

The only structure of historical importance within the project area itself is the U.S. Coast Guard Station located on Atlantic Avenue (adjacent to the ocean front) between 24th and 25th Streets. This building is on the National Register of Historic Places. It currently houses the Virginia Beach Maritime Historical Museum.

HUMAN RESOURCES

Population. Virginia Beach is the largest city in the state and one of the most rapidly growing ones as well. According to U.S. Census figures, the city had a 1980 population of 262,199. The most recent estimate by the state (Tayloe Murphy Institute) showed a figure of 350,100 for 1987, a 34 percent increase since 1980. By contrast, Norfolk's population is estimated to have increased only 5 percent during the same time period. Much of Virginia Beach's growth has been fueled by a high in-migration rate for the city. It is estimated that two-thirds of the city's growth between 1980 and 1987 can be attributed to in-migration with the remainder the result of births. Virginia Beach as well as most of the Hampton Roads area is greatly influenced by the military, especially the U.S. Navy.

Projections for Virginia Beach's future population show continued growth through the year 2030. Although this growth will be substantial, the average annual rate of growth is projected to decline from the 3.3 percent projected for the 1980-1990 decade to 1.2 percent for the 2020-2030 decade. Table 1 shows past and projected population growth for Virginia Beach and the surrounding area.

Projections by the Virginia Beach Planning Department indicate little population growth for the census tracts which encompass the area from Rudee Inlet to 49th Street. Most of the land here has already been developed, leaving few opportunities for new construction.

Housing. The number of housing units has increased even faster than the population because of the decrease in household size that has been occurring in recent years. Much of the new home construction has been taking place in the Kempsville and Holland Road areas which are some distance from the oceanfront. In the past few years, far less residential construction has occurred near the oceanfront since this area has already been highly developed for some time. The majority of the housing units in the Rudee Inlet to 49th Street area are multifamily units although there are a significant number of single-family units in the more northerly portion of the area.

Because of all the residential construction in Virginia Beach, housing as a whole tends to be newer here than in the older, more established cities of Norfolk and Portsmouth. Housing values and rents also tend to be higher in Virginia Beach than for the area as a whole.

Table 1. POPULATION DATA AND PROJECTIONS
(ROUNDED TO THOUSANDS)

	Year								
	1960	1970	1980	1987	1990	2000	2010	2020	2030
Virginia Beach	85	172	262	350	363	426	490	553	617
Norfolk -Virginia Beach-Newport News	622	1,059	1,160	1,346	1,372	1,511	1,649	1,787	1,923
Virginia	3,954	4,651	5,347	5,787	6,097	6,665	7,236	7,807	8,379

Sources: Bureau of the Census, U.S. Census of Population; Department of Planning and Budget, Virginia Population Projections; Tayloe Murphy Institute, Population Estimates for Virginia Localities, 1981-1986.

Employment and Income. Virginia Beach's economy is highly dependent on the Federal Government, which is the largest single employer in the city as well as the entire metropolitan area. Most of this employment is concentrated in the four Federal military bases located in the city; namely, Little Creek Naval Amphibious Base; U.S. Navy Training Center, Dam Neck; Oceana Naval Air Station; and the U.S. Army's Fort Story. In addition to these bases, there are several other military facilities in the region which employ many Virginia Beach residents. Traditionally, Virginia Beach has served as a bedroom community for Norfolk, and still does to some extent, although an increasing number of jobs are being created in Virginia Beach as the population grows.

The largest number of jobs in the city are in the services and trade sectors, which account for over half the employment located in Virginia Beach. Job creation in these areas will continue as long as the city's population keeps expanding. Associated with the growing population is the construction industry, which is an important component of the city's economy. Employment in this industry fluctuates more than most other segments of the economy because of changing interest rates and general economic conditions. Manufacturing employs a proportionally much smaller segment of the population here than in the state as a whole, although several foreign firms have recently located in the city, increasing this category of employment. Agriculture plays an important role in the rural sections of the city, but it has been declining as residential development spreads into these areas.

One of the most important segments of Virginia Beach's economy is tourism, which generated employment for over 11,000 people in 1985. Tourism provides significant employment in the service and retail trade segments of the city's economy and is a major source of revenue for the city. Tax receipts from tourist-related activities totaled $17.5 million in 1986, an amount which enables the city to have the lowest real estate tax rate in the southside Hampton Roads area. The U.S. Travel Data Center estimated that tourists spent $432 million in Virginia Beach in 1986, a significant contribution to the city's economy.

As would be expected with the higher educational and income levels for city residents, the occupational structure shows a higher percentage of white-collar jobs and fewer blue-collar jobs than the surrounding area and the state as a whole.

Unemployment rates traditionally are lower, with a rate of 3.7 percent in 1987, for example. Per capita income figures from the 1980 census show Virginia Beach with $7,704 compared to Norfolk with $6,113. Median family income showed a similar pattern with Virginia Beach being the highest of the five cities in the south Hampton Roads area, followed by Chesapeake. Projections of future per capita income, which are shown below for Virginia Beach, indicate a continuation of the city's position relative to its neighboring cities.

Table 2. PROJECTED INCOME FOR VIRGINIA BEACH & STATE OF VIRGINIA
(1984 Constant Dollars)

Item	Area	
	Virginia Beach	State of Virginia
1978	12,524	10,401
% of U.S.	106	97
1983	13,488	12,882
% of U.S.	109	104
1990	15,105	14,921
% of U.S.	103	102
2000	16,891	17,059
% of U.S.	101	102
2015	19,127	19,581
% of U.S.	99	102
2035	22,779	23,470
% of U.S.	99	102

Source: Bureau of Economic Analysis, County-Level Projections of Economic Activity and Population, Virginia 1990-2035.

ENVIRONMENTAL SETTING

Virginia Beach is a city of environmental contrasts, including beaches, lakes, woodlands, large agricultural and livestock areas, and a concentrated development of hotels, motels, restaurants, night clubs, and tourist shops which stretch northward along the oceanfront from Rudee Inlet for about 40 city blocks. No natural beach or dune vegetation is associated with the study area between Rudee Inlet and 49th Street.

Tides at Virginia Beach are semi-diurnal. The mean range is 3.4 feet with a spring mean range of 4.1 feet. Swells reaching Virginia Beach are predominantly from the southeast during the summer and from the northeast during the winter. The greatest yearly percentage of swells arrive from the east-northeast and range in height between 1 and 6 feet. Calm conditions prevail approximately 19 percent of the time.

During the 1974 maintenance dredging of Thimble Shoal Channel, approximately 500,000 cubic yards of sand was stockpiled at Fort Story and subsequently truck-hauled to the Virginia Beach oceanfront. Most of this material was hydraulically dredged from the eastern section of the 11-mile-long channel. Thimble Shoal is considered to be an excellent source of beach-compatible sand if the sand is extracted below the 50-foot mean low water depth. The sand source for this evaluation includes this area as well as the Atlantic Ocean Channel.

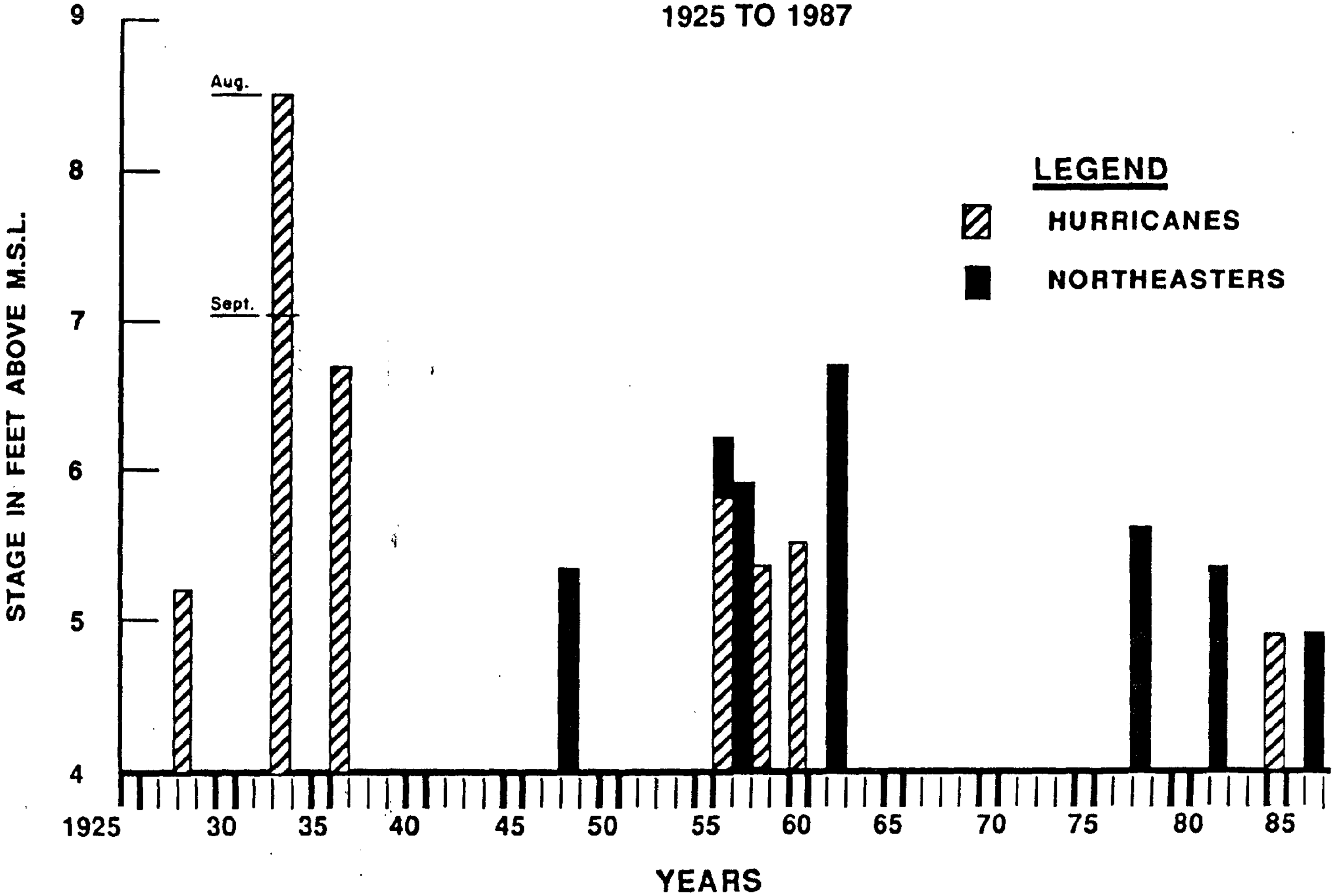
PROBLEMS, NEEDS, AND OPPORTUNITIES

THE STORM PROBLEM

The primary problem of the study area is the vulnerability of the oceanfront to direct wave attack during storms when greater than normal tide levels overtop the backshore. During such periods, waves impinge on the berm and existing bulkhead walls which front the shore and threaten or cause damage to adjacent developments.

Fifteen major storms have struck the Virginia Beach area within this century. The level to which the tide was raised during each storm is shown in the following graph.

Figure 1.
HIGHEST TIDES AT VIRGINIA BEACH
1925 TO 1987



Tidal heights reached in the Virginia Beach area during the northeaster of March 1962 were the second highest of record in the area but were almost 2 feet lower than those reached in the record August 1933 hurricane. The damaging effect was the greatest of any storm in the area due to the increased development along the shoreline since 1933.

During severe storms such as occurred in the March 1962 northeaster or the August 1933 hurricane, wave attack causes severe losses of sand and failure of bulkheads, thereby leading to structural damage to buildings behind them. Much of the damage can be attributed to the collapse of structures on undermined footings and direct wave attack on structures. A large amount of damage is also caused when water saturates floors, floor coverings, walls, furniture, and other articles in buildings behind bulkheads. Damage associated with storms of this magnitude cannot be completely eliminated with the existing facilities but their presence does ensure damage reductions.

The 3.3-mile reach between Rudee Inlet and 49th Street is an example of intensive development of an area which is susceptible to flood damage. Along this major resort area, which depends primarily on good recreational beaches to attract visitors, the need for construction of motels, hotels, and other buildings reasonably adjacent to the oceanfront is obvious. Today, there are commercial buildings in this area which are susceptible to flood damage since their first-floor levels are below the storm tide elevations of 1962. Damage incurred in the storm of 1962 emphasized the danger to a highly developed oceanfront. In 1962, bulkheads in this area were heavily damaged or destroyed and many commercial establishments and other buildings were flooded.

Without a protective beach, damages to commercial, residential, and public developments and to protective works along the Atlantic Ocean between Rudee Inlet and 49th Street are estimated at over $20 million at 1988 price levels for a repeat of the March 1962 storm. A repeat of the 1933 hurricane would result in damages estimated at over $30 million. Based on the relationship of the height of tides, the estimated frequency of storms, and the amount of damage caused by such storms, the existing average annual damages are estimated at over $10 million for the oceanfront property from Rudee Inlet to 49th Street.

THE BEACH EROSION PROBLEM

Another significant problem involves the instability and recession of the beach due to erosion. Between Rudee Inlet and 49th Street, erosion presents a serious problem. Although this segment of the beach has been reasonably stable in recent years due to its restoration and subsequent annual artificial nourishment, a serious problem can result from storms which strike the area. These storms materially reduce the width and height of the beach berm, thereby exposing the existing bulkhead and high-value waterfront developments to wave damage. In addition, they cause a loss of beach area available for recreational use. An estimated 1.6 million visitors used the beach between Rudee Inlet and 89th Street in 1987 with the highest concentration between Rudee Inlet and 49th Street.

Littoral transport is the longshore movement of waterborne sand. Along the Atlantic shoreline of the city of Virginia Beach, available evidence indicates that the predominant littoral transport is from south to north from False Cape to Cape Henry, and north to south from False Cape to the Virginia-North Carolina state line.

There are no shore structures or other visible indicators which can be used as an index to the direction of predominant littoral flow between False Cape and the state line. South of the state line, it has generally been accepted that the predominant littoral drift is to the south. Since there has to be a nodal point on the shoreline where the littoral drift splits into north and southbound paths, the configuration of the shoreline strongly suggests that this occurs in the vicinity of False Cape.

DREDGING AND PLACING OFFSHORE SAND ON THE BEACH

The following two basic dredges are available for removing sand from Thimble Shoal and Atlantic Ocean Channels and placing it on the beach between Rudee Inlet and 49th Street. One is a large cutterhead suction dredge which cuts up the material and pumps it continuously through a long pipeline to the shore. The diameter of the discharge line can be up to 42 inches. If the borrow area is such that the maximum length of pipe can be kept under about 18,000 feet, it is very likely that a large pipeline dredge working on swing wires from April through September could remove material and pump it ashore at the required area. A booster pumping plant located on a jack-up barge (or DeLong Pier) above wave action, though not at the surf zone, would be used. Another booster plant can be added onshore. However, a pipeline could not successfully compete with hopper dredge equipment if the summer months (when the beach is actively used by locals and tourists) were excluded from the dredging operation. The main problem with this system is keeping the submerged line connection with the dredge and booster pump intact in an ocean environment. With the borrow area located as much as 12 miles from the beach, additional booster pumps or a second dredge would be required, thereby doubling the problems and cost of pumping.

The second type of dredge that can be used is the hopper dredge. This dredge stores the material in its hoppers or bins, travels to the shoreline, then pumps the sand ashore through one or more booster pumps depending on the distance from its mooring facility to the beach. A hopper dredge cannot dredge and pump ashore in a continuous operation as does the pipeline dredge. Consequently, a substantial portion of the working time is spent traveling and pumping out its hoppers even if the travel distance is short. A connection between the beach dumping system and the hopper dredge requires an offshore hookup, such as use of a DeLong Pier barge partially jacked up above wave action as an intermediate discharge plant. It was used in the safer waters of Chesapeake Bay when sand was pumped ashore from Thimble Shoal Channel to Fort Story. The self-propelled hopper dredges have a capacity of up to several thousand cubic yards and a speed of up to 13 knots when loaded. An effective pump ashore system is a single point mooring which utilizes an anchored buoy that holds the open end of the submerged shoreline pipe to which the dredge attaches its pumpout system. The hopper dredge, when attached to the buoy, is free to pivot with its head into the wind, thus riding as if at anchor and achieving the best possible stability.

Generally, the dredges draw 25 to 30 feet of water and must therefore be located offshore where this depth of water is available. Any offshore borrow site contains a percentage of silt-size material. When more granular material is dredged, enough of the fine material will be mixed to yield a relatively easy pumping slurry. The pipeline dredge will handle this slurry without modifying it and will deliver it to the beach. The hopper dredge, on the other hand, sorts the material in its hopper causing the silt to be suspended and lost overboard during the loading process. The resulting material, while superior for beach fill, will be more difficult to transport through a pipeline. The hopper dredge transfer point, therefore, should be as close to the beach as safety will permit. A pipeline dredge can be located farther away and still achieve good results. Some of the difference in quality of the fill material can be compensated for by the shore crew. By allowing more of the fine material to flow into the surf from the pipeline, by using shorter training dikes in the ponding and settlement area, much of the silt-size material can be eliminated without damage to the new beach section.

WITHOUT PROJECT CONDITION

The "without project" condition is the land use and related conditions likely to occur under existing improvements, laws, and policies. The beach nourishment project authorized by the River and Harbor Act of 1962 expired in February 1987. The extension of this project has been approved under Section 934 of the Water Resources Development Act of 1986 as discussed previously in the "Prior Studies, Reports, and Existing Projects" section of this report. However, it is not considered likely that this project will be funded, constructed, and in-place prior to initiation of any sand deposition from the deepening of the Norfolk Harbor Channels project. Dredging of the 55-foot outbound channels is scheduled to begin in the fall of 1990. Accordingly, the "without condition" for the economic evaluation of placing sand on Virginia Beach dredged from the Norfolk Harbor Channels project is no nourishment of the beach other than the sand bypassing operation presently at Rudee Inlet.

PLAN EVALUATION

PLANNING OBJECTIVES

The Federal objective of water and related land resources planning is to contribute to NED consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements. Contributions to NED are increases in the net value of the national output of goods and services, expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the nation.

The planning objective of this study is to determine the Federal interest in cost sharing in the placement of Norfolk Harbor Channels sand on the beach at Virginia Beach between Rudee Inlet and 49th Street, thereby reducing storm damages associated with beach erosion and increasing the recreational potential within the study area.

PLANNING CONSTRAINTS

Planning constraints are any consideration that has the capacity to restrict or otherwise impact the planning process. Typical constraints include existing laws, policies, regulations, and the authorizing document; state-of-the-art technology; money; and time. More specific constraints include the following:

a. The dynamic nature and inherent uncertainty of coastal processes which act on the study area shoreline and potential offshore borrow sites.

b. The necessity of expediting the completion and approval of this report so appropriate local, state, and Federal decisions can be made prior to construction of the navigation project.

c. The limitation of this nourishment to a one-time event which includes no renourishment and no maintenance.

d. The limitation of the quantity and quality of the source material to that dredged from Norfolk Harbor Channels.

EVALUATION CRITERIA

Costs. The additional cost of placing Norfolk Harbor Channels sand, whether from the Thimble Shoal or Atlantic Ocean Channels, on the beach between Rudee Inlet and 49th Street is based on the difference in the cost over using the least costly, acceptable disposal alternative which is the Dam Neck Disposal Site. Details relative to the cost estimates for disposing of material from Cape Henry Channel into Dam Neck Disposal Site and onto the beach at Virginia Beach are shown in appendix A. The least costly alternative is based on disposing all 16 million cubic yards of dredged material into Dam Neck Disposal Site. Table 3 shows the additional cost associated with placing the material on the beach in lieu of disposal into Dam Neck Disposal Site. Costs are shown for utilizing both Thimble Shoal Channel and the Atlantic Ocean Channel as sources for sand.

Table 3. ADDITIONAL COSTS FOR BEACH PLACEMENT

Item	Cost
Atlantic Ocean Channel	
Least costly alternative	
9,600,000 cu. yds. to Dam Neck Disposal Site	
9,600,000 cu. yds. x $3.40 = $32,640,000	
60-foot berm	
660,000 cu. yds. to Virginia Beach @ $9.91 = 6,540,600 say	$ 6,541,000
8,940,000 cu. yds. to Dam Neck Disposal Site @ $3.40 = 30,396,000 say	$30,396,000
TOTAL	$36,937,000
Less least costly method	$32,640,000
Added cost	$ 4,297,000
100-foot berm	
1,300,000 cu. yds. to Virginia Beach @ $9.12 =	$11,856,000
8,300,000 cu. yds. to Dam Neck @ $3.40 =	$28,220,000
TOTAL	$40,076,000
Less least costly method	$32,640,000
Added cost	$ 7,436,000
140-foot berm	
1,900,000 cu. yds. to Virginia Beach @ $8.97 =	$17,043,000
7,700,000 cu. yds. to Dam Neck Disposal Site @ $3.40 =	$26,180,000
TOTAL	$43,223,000
Less least costly method	$32,640,000
Added cost	$10,583,000
Thimble Shoal Channel	
Least costly alternative	
6,400,000 cu. yds. to Dam Neck Disposal Site	
6,400,000 cu. yds. @ $6.60 = $42,240,000	
60-foot berm	
575,000 cu. yds. to Virginia Beach @ $12.25 = $7,043,750 say	$ 7,044,000
5,825,000 cu. yds. to Dam Neck Disposal Site @ $6.62 = $38,561,500 say	$38,562,000
TOTAL	$45,606,000
Less least costly method	$42,240,000
Added cost	$ 3,366,000

Table 3. ADDITIONAL COSTS FOR BEACH PLACEMENT
(Cont'd)

100-foot berm (a)	
1,100,000 cu. yds. to Virginia Beach @ $11.34 =	$12,474,000
5,300,000 cu. yds. to Dam Neck Disposal Site @ $6.63 =	$35,139,000
TOTAL	$47,613,000
Less least costly method	$42,240,000
Added cost	$ 5,373,000

(a) 100-foot berm is the largest available for construction using sand dredged from Thimble Shoal Channel.

Benefits. The following paragraphs discuss the beneficial impacts which would result from the one-time placement of up to 1.6 million cubic yards of sand dredged from the Norfolk Harbor navigation channels on the beach between Rudee Inlet and 49th Street. The beneficial impacts from the initial placement of the Norfolk Harbor Channel sand are (a) reduced flood damages, and (b) increased recreational use of the beach. Estimates of monetary benefits are based on October 1988 price levels and an interest rate of 8-7/8 percent. Details relative to the estimation of benefit values are shown in appendix B.

Flood Damage Reduction. Primary tangible flood damage reduction benefits are the equivalent average annual tidal flood damages prevented and represent the difference between average annual tidal flood losses without protection and residual average annual losses after providing protection. The without project condition assumes no sand nourishment over the period of analysis except for the sand bypassing operation at Rudee Inlet.

Average annual damages for a given condition were obtained by combining the total damage at various tidal flood stages with the corresponding frequency of flooding to those stages to obtain a damage-frequency relationship. The damage-frequency relationship is utilized to determine the average annual damages for the given condition. This is done for natural conditions without the sand deposition and conditions which would exist with the sand deposition, the difference being the average annual flood reduction benefits attributable to the project.

It is necessary to evaluate the flood damage reduction benefits for three alternative beach berm widths--60, 100, and 140 feet. Obviously, the wider berm widths will have longer physical lives and provide beneficial effects over a longer span of time. Based on past experience at Virginia Beach, it is estimated that the 60-foot berm would provide beneficial effects from 1.0 to 2.0 years, the 100-foot berm from 2.5 to 3.5 years, and the 140-foot berm from 3.5 to 4.5 years, with the Thimble Shoal Channel sand having a slightly longer life on the beach. The following table shows the average annual benefits based on the indicated berm widths and average life of sand placement. Details relative to the estimation of these values are contained in appendix B.

Table 4. AVERAGE ANNUAL EQUIVALENT FLOOD REDUCTION BENEFITS

Berm widths (feet)	Average useful life (years)	Amount ($)
60	1.5	2,650,000
100	3.0	3,660,000
140	4.0	3,930,000

Recreation. Benefit quantification for outdoor recreation is based on the Contingent Valuation Method (CVM) as prescribed by Economic and Environmental Principles and Guidelines for Water and Related Land Resource Implementation Studies. The CVM estimates changes in NED benefits by directly asking individuals their willingness to pay for changes in quantity of recreation at a particular site. Beach visitation segregated into overnight visits and day visits, is based on extensive surveys conducted in connection with the Virginia Beach Beach Erosion and Hurricane Protection study completed in 1983 and revised in 1984. The actual CVM survey was conducted in 1982.

It is necessary to evaluate the recreation benefits for three alternative berm widths--60, 100, and 140 feet. The following table shows the average annual benefits based on the indicated berm widths and life of sand placements as previously discussed. Details relative to the estimation of these values are contained in appendix B.

Table 5. AVERAGE ANNUAL EQUIVALENT RECREATION BENEFITS

Berm widths (feet)	Average useful life (years)	Amount ($)
60	1.5	1,600,000
100	3.0	2,700,000
140	4.0	2,700,000

The following table shows a summary of average annual equivalent benefits attributable to the sand placement.

Table 6. SUMMARY OF BENEFITS

Item	Berm widths (ft) 60	100	140
Flood Damage Reduction	$2,650,000	$3,660,000	$3,930,000
Recreation	$1,600,000	$2,700,000	$2,700,000
Total	$4,250,000	$6,360,000	$6,630,000

Environmental Effects. The Commonwealth of Virginia proposes that beach compatible material dredged from the Atlantic Ocean Channel during the deepening of Norfolk Harbor navigation project be placed along the Virginia Beach oceanfront to assure a greater amount of protection to the existing beach and to adjacent properties.

Impacts and effects of offshore dredging associated with new work and/or maintenance dredging of any channel or basin associated with a Federal navigation project is cleared through the environmental documentation process for each individual project. Additionally, numerous independent studies on the effects of offshore dredging and beach nourishment have been conducted by Federal and state governmental agencies as well as academic institutions. Below are appropriate passages from Corps of Engineers environmental documents addressing the direct placement of sand on the beach at Virginia Beach from nearby Federal navigation channels during either routine maintenance dredging or new work construction.

> *Virginia Beach, Virginia, Beach Erosion Control and Hurricane Protection, FEIS, September 1972.* "Possible sources of suitable material include . . . the Chesapeake Bay bottoms off the Lynnhaven River, and the potential supply from ocean bottom offshore." It also adds, "The nearshore borrow areas in the Chesapeake Bay off Lynnhaven Inlet are part of a highly significant crab wintering ground as well as a relatively important finfish zone, both of which might be affected by dredging operations. Accordingly, the timing and methods of sand extraction at any area would be coordinated with the appropriate Federal and state agencies before a borrow source is selected and during project construction to minimize effects."

> *Supplement 1, Virginia Beach Beach Erosion and Hurricane Protection, FEIS, February 1985.* "With the provision that the material meets the suitability requirements, one borrow option that remains under consideration is the use of material removed during construction and maintenance of the Norfolk Harbor Deepening and Disposal Project."

> *Thimble Shoal Channel (Maintenance Dredging), FEIS, August 1973.* As a potential alternative to use of the Dam Neck Disposal Site, the document states in part " . . . brought under consideration is the possibility of stockpiling at Cape Henry, Virginia, spoil material from the eastern portion of the channel. This quantity of sediments could later be trucked to the Virginia Beach oceanfront where it would greatly contribute to the beach nourishment program and result in minimal coverage of benthic organisms. This proposal is

> presently receiving much consideration and may possibly be implemented in the future."

In July 1974, the Norfolk District, Corps of Engineers, made a proposal to key Federal and state agencies to place 500,000 cubic yards of the expected yield of 1.6 million cubic yards of the Fiscal Year 1975 maintenance dredging at Fort Story for ultimate use as beach nourishment material for the Virginia Beach oceanfront. The period of the proposed action was from October through December. No negative responses were received; however, the National Marine Fisheries Service recommended that . . . "dredging be completed as soon as possible so as to reduce the likelihood of interruption and damage to the [blue/rock winter crab] fishery, and in no case extend beyond November 30."

> *Virginia Beach, Beach Erosion Control, FEIS, March,1975.* This document states in part, "Future nourishment requirements will most likely be satisfied through either the direct or indirect placement of maintenance material derived from Thimble Shoal Channel. Supplemental supplies should also be available from the maintenance dredging of Lynnhaven Inlet. In this manner, removal and destruction of estuarine waters and fastland may be eliminated."
>
> *Final Supplement 1, Norfolk Harbor and Channels Virginia, Deepening and Disposal, FEIS, June 1985.* After a discussion of needs within the Hampton Roads area for supplemental sand supplies, the document continued with, "The planned Atlantic Ocean Channel and the eastern end of Thimble Shoal Channel are known to contain sand which could be placed on area beaches. To the maximum extent practicable, the Norfolk District will recommend the placement of suitable quantities and types of dredged material on nearby shorelines, the creation of stockpiles, and other such beneficial uses . . . consistent with all project engineering, environmental, economic, legal, local cooperation, and cost-sharing requirements."

The above dredging was conducted on schedule and resulted in the placement of relatively coarse-grained sand from the eastern end (east of the Chesapeake Bay Bridge-Tunnel) of Thimble Shoal Channel onto the north shore of Fort Story. The area served as a stockpile site for hauling sand to the Virginia Beach oceanfront. Geotechnical investigations prior to subsequent maintenance of Thimble Shoal Channel have not shown the presence of sufficient quantities of beach quality sand to make it economically feasible to separate it from the major portion of the material. Maintenance operations have since taken the material to the Dam Neck Disposal Site.

Impacts of Channel Deepening. Two major types of impacts would result from the removal of sand from the Atlantic Ocean Channel. First would be the direct loss of benthic infauna within the dredged area. Inspections of core samples from beach surfaces, immediately after nourishment material has been pumped onto beaches, have verified that benthic sediments are defaunated following pumping at high pressures through mechanical impeller booster pumps. Such cores are totally and repeatedly devoid of live organisms. Remains of motile epibenthic forms, such as fish and crustaceans, are rarely found in pumped sediments. These would be expected to temporarily leave the dredging area and should not be significantly impacted.

The second impact associated with offshore dredging would be an increase in turbidity levels. Due to the sandy substrate and location of the channel in a dynamic ocean environment, it is not anticipated that there would be any release of pollutants or significant lowering of dissolved oxygen levels resulting from dredging activities. Surface sediments may have a percentage of silt which would be released in the water column; however, with use of a hydraulic pipeline dredge, turbidity increases should be below the lethal limit of most estuarine and marine organisms. Hopper dredging may result in higher surface turbidity levels due to the practice of allowing the hopper to overflow with finer material and water until a full load of coarser material is obtained. In channel areas where silt content is high, the material will be placed in the Dam Neck Disposal Site. It is anticipated that the dynamic wave and current conditions offshore from Virginia Beach would rapidly dissipate any suspended solids which might be released. Geotechnical investigations have determined that most of the material within the proposed dredging area of the Atlantic Ocean Channel is coarse sand with a high degree of similarity to the material on the berm and nearshore areas of the Virginia Beach oceanfront.

The Atlantic Ocean Channel, which would be the source area for the proposed nourishment, lies beyond oyster beds. These are a prime economic resource which can be seriously impacted when suspended sediments resettle, smothering the oysters. This channel is also beyond coves and quiet bays where settling effects would be more rapid and localized, allowing greater thickness of cover. The general conclusion, based upon available knowledge, is that turbidity and sediment effects on marine organisms from offshore dredging of sand and gravels are to be considered relatively insignificant or short term.

In the context of the Section 933 program, where, in this particular case, the state has requested that the Corps consider disposal of dredged sand onto the Virginia Beach oceanfront between Rudee Inlet and 49th Street (a distance of about 18,000 feet), there are no additional impacts from dredging operations above and beyond those which may occur from dredging the channel.

Impacts of Beach Nourishment. Impacts associated with placement of material on the beach would be loss of beach organisms by covering and nearshore organisms by high turbidity. Liquefaction of indigenous sediments often occurs during deposition, allowing for the possibility of escape from burial by motile species (amphipods, decapods, etc.).

During 1987, the Norfolk District conducted a study along the Virginia Beach shoreline to determine the effects of beach nourishment on beach fauna. A full discussion is presented in the *General Design Memorandum, Beach Erosion Control and Hurricane Protection, Virginia Beach, Virginia (draft of September 1988).* The data indicated that the nourished area did not undergo population changes that differed significantly from a similar control area at the north end of Virginia Beach. In three quarterly samplings, both the fill and control areas experienced the usual seasonal decline in the number of mole crabs (*Emerita talpoida*) and other species of beach fauna from the high spring populations. A second control area, located along the Croatan shoreline of Virginia Beach, experienced some extraordinary changes in population, elevating after nourishment at the fill area, and then, by fall, showing the greatest overall decline (53.3 percent vs. 36.8 percent for the north end control area and 47.0 percent for the primary fill area) from the spring counts. It is believed the data for Croatan was highly affected by the pockets of gravel and coarse shell material along this area. Seasonal population change comparisons between the control areas and the nourished beach were almost identical (one percent variance).

Other separate and independent studies have concluded that the greatest influencing factor on beach fauna populations appears not to be the introduction of additional material onto the beach, but the composition of the introduced material. Deposited sediments, when similar in composition (grain size and other physical characteristics) to existing beach material (whether indigenous or introduced by an earlier nourishment or construction event), do not appear to have the potential to reduce the numbers of species or individuals of beach infauna.

The effects of change in profile could also be significant. Beach zones are defined faunistically and in relation to water levels--above high tide, intertidal, and always submerged. Altering the slope of the profile would necessarily alter the proportion of surface available for each zone, hence altering the proportion of fauna typifying each zone. Beach slope is determined by a number of variables including wave period, wave amplitude, water table height, and composition of the material. Introduction of new material comparable to existing material, regardless of orientation at the time of deposition, also minimizes changes in beach slope.

Impacts of nourishment activities have been ongoing at Virginia Beach for the past quarter of a century in association with nourishment activities occurring on an annual basis. Impacts associated with sunbather usage are seasonal, but, when in effect, can be very intense, especially on ghost crab populations. The baseline conditions are, therefore, not comparable to those of an undisturbed beach system such as those on Virginia's Eastern Shore. There are no foreseeable adverse effects on threatened or endangered species that would result from the anticipated project impacts.

Justification. It is Corps policy to participate in the additional costs for placing clean sand or other suitable material, dredged by the Corps during construction or maintenance of Federal navigation projects, onto adjacent beaches or nearshore waters subject to the following:

(1) Placement of the material on a beach or beaches and Federal (Corps) participation in the costs must be requested by the state in which the beach or beaches are located.

(2) The added cost of such disposal must be justified by the benefits associated with protection of such beach or beaches.

(3) The storm damage reduction benefits resulting from the beach protection must exceed 50 percent of the total benefits, unless the placing of the dredged material is economically justified based on storm damage reduction benefits alone.

(4) The beaches involved must be open to the public.

(5) Local interests must pay 50 percent of the added cost of disposal above the alternative least costly and environmentally sound method of disposal.

(6) Local interests must provide (without cost sharing) any necessary additional lands, easements, rights-of-way, and relocations.

The above conditions have been satisfied in connection with placing sand on Virginia Beach. The following table shows that total benefits, as well as storm damage reduction benefits alone, from the provision of a 100-foot beach berm at elevation 5.4 feet N.G.V.D. (requiring the placement of about 1.0 million cubic yards of sand from Thimble Shoal Channel or 1.1 million cubic yards of sand from the Atlantic Ocean Channel) onto the beach between Rudee Inlet and 49th Street exceeds the added costs of such placement. Net benefits are maximized at this level of beach nourishment.

Table 7. PLAN EVALUATION AND JUSTIFICATION

Item	Berm widths 60 feet	100 feet	140 feet
Atlantic Ocean Channel			
Construction Volume (c.y.)	370,000	731,000	1,100,000
Beach Placement (c.y.)	575,000	1,100,000	1,700,000
Dredged from Channel (c.y.)	660,000	1,300,000	1,900,000
Life of Placement (yrs)	1.5	3.0	4.0
First Cost (Added Cost)	$4,297,000	$7,436,000	$10,583,000
Annual Costs	$3,185,000	$2,900,000	$3,300,000
Annual Benefits	$4,250,000	$6,360,000	$6,630,000
Annual Storm Damage Reduction Benefits	$2,650,000	$3,660,000	$3,930,000
Net Benefits	$1,065,000	$3,460,000	$3,330,000
Benefit-Cost Ratio	1.33	2.19	2.01
Thimble Shoal Channel			
Construction Volume (c.y.)	370,000	731,000	
Beach Placement (c.y.)	500,000	990,000	
Dredged from Channel (c.y.)	575,000	1,100,000	(a)
Life of Placement (yrs)	2.0	3.5	
First Cost (Added Cost)	$3,366,000	$5,373,000	
Annual Costs	$1,910,000	$1,853,000	
Annual Benefits	$4,250,000	$6,360,000	
Annual Storm Damage Reduction Benefits	$2,650,000	$3,660,000	
Net Benefits	$2,340,000	$4,507,000	
Benefit-Cost Ratio	2.23	3.43	

(a) 100-foot berm is the largest available for construction using sand dredged from Thimble Shoal Channel.

SELECTED PLAN

As discussed in the "Justification" section of this report, the placement of 1.1 million or 1.0 million cubic yards of sand, respectively, dredged from the Atlantic Ocean or Thimble Shoal Channels is estimated to be in the Federal interest. Based on overfill ratios of 1.78 for Atlantic Ocean Channel sand and 1.55 for Thimble Shoal Channel sand and a 3- to 3.5-year life for the sand placement, this quantity of sand placed on the beach would create a berm width of approximately 100 feet. Both total net benefits and net storm damage reduction benefits are maximized at this width of beach. Also, the additional cost of the beach placement is economically justified on the basis of storm damage reduction benefits alone. The criteria discussed previously required for Federal participation in the additional cost of placing sand on the beach in lieu of the least costly acceptable disposal alternative have been satisfied. The following table summarizes the economic evaluation of the selected plan.

Table 8. ECONOMIC EVALUATION OF SAND PLACEMENT

Item	Atlantic Ocean Channel	Thimble Shoal Channel
Annual Costs	$2,900,000	$1,853,000
Annual Benefits	$6,360,000	$6,360,000
Net Benefits	$3,460,000	$4,507,000
Benefit-Cost Ratio	2.19	3.43

RISK AND UNCERTAINTY

Risk and uncertainty refer to the unpredictable variability of future events. This unpredictability is addressed as it specifically relates to the placement of sand dredged from Norfolk Harbor navigation channels onto the beach. The key variable with respect to the sand placement is the length of time the material will stay on the beach and provide storm damage protection and recreational values. Over a relatively short timeframe, less than 4 years, average annual benefits are impacted very little by the life of the sand placement while annual costs are extremely sensitive. Accordingly, project justification and therefore the Federal interest can be very sensitive to this variable. The following tables show the impact of varying the useful life of the sand placement on the average annual costs, average annual benefits, net benefits, and benefit-cost ratios. As indicated in the tables, the life of the sand placement has a substantial effect on annual costs of sand placement.

Table 9. ECONOMIC SENSITIVITY TO LIFE OF SAND PLACEMENT
ATLANTIC OCEAN CHANNEL SAND

Item	Life of sand placement (years)						
	1.0	1.5	2.0	3.0	3.5	4.0	4.5
60-Foot Berm (a)							
Annual costs ($000)	4678	3185	2439	1694	1482	1323	1199
Annual benefits ($000)	4250	4250	4250	4250	4250	4250	4250
Net benefits ($000)	-428	1065	1811	2556	2768	2927	3051
Benefit-cost ratio	0.91	1.33	1.74	2.51	2.87	3.20	3.54
100-Foot Berm (b)							
Annual costs ($000)	8096	5512	4220	2900	2564	2289	2075
Annual benefits ($000)	6360	6360	6360	6360	6360	6360	6360
Net benefits ($000)	-1736	1148	2140	3460	3796	4071	4285
Benefit-cost ratio	0.79	1.15	1.51	2.19	2.48	2.78	3.07
140-Foot Berm (c)							
Annual costs ($000)	11522	7844	6006	4172	3649	3300	2954
Annual benefits ($000)	6630	6630	6630	6630	6630	6630	6630
Net benefits ($000)	-4892	-1214	624	2458	2981	3330	3676
Benefit-cost ratio	0.58	0.85	1.10	1.59	1.82	2.01	2.24

(a) Equivalent to 575,000 cubic yards placed on beach.
(b) Equivalent to 1,100,000 cubic yards placed on beach.
(c) Equivalent to 1,900,000 cubic yards placed on beach.

Table 10. ECONOMIC SENSITIVITY TO LIFE OF SAND PLACEMENT
THIMBLE SHOAL CHANNEL SAND

Item	Life of sand placement (years)						
	1.0	1.5	2.0	3.0	3.5	4.0	4.5
60-Foot Berm (a)							
Annual costs ($000)	3665	2495	1910	1327	1161	1036	939
Annual benefits ($000)	4250	4250	4250	4250	4250	4250	4250
Net benefits ($000)	585	1755	2340	2923	3089	3214	3311
Benefit-cost ratio	1.16	1.70	2.23	3.20	3.66	4.10	4.53
100-Foot Berm (b)							
Annual costs ($000)	5850	3982	3049	2118	1853	1654	1500
Annual benefits ($000)	6360	6360	6360	6360	6360	6360	6360
Net benefits ($000)	510	2378	3311	4242	4507	4706	4860
Benefit-cost ratio	1.09	1.60	2.09	3.00	3.43	3.85	4.24

(a) Equivalent to 500,000 cubic yards placed on beach.
(b) Equivalent to 990,000 cubic yards placed on beach.

COORDINATION

Coordination has been maintained during the course of the study with appropriate Federal, state, regional, and local agencies. Key agencies specifically involved with the conduct of the evaluation include the Virginia Port Authority, Virginia Commission on the Conservation and Development of Public Beaches, and the city of Virginia Beach. Pertinent correspondence is contained in section C of the appendix.

LOCAL COOPERATION

Federal participation in the cost of placing sand dredged from the 55-foot outbound Norfolk Harbor Channels on the Virginia Beach shoreline from Rudee Inlet to 49th Street is based on the Commonwealth of Virginia ensuring the Chief of Engineers that:

a. The state will pay 50 percent of the added cost of placement of the sand on the beach above that cost for placement in the Dam Neck Disposal Site. Furthermore, the state will pay 100 percent of the added cost for that quantity of sand exceeding the amount determined to be in the Federal interest.

b. The state will provide all necessary lands, easements, and rights-of-way and relocations.

c. The state will hold and save the United States free from damages that may result from the placement of sand on the beach except where such damages are due to the fault or negligence of the United States or its contractors.

d. The state will ensure that the beach involved will be open to the public.

CONCLUSIONS

Based on this report, it is concluded that:

a. The added cost of the placement of 1.1 million cubic yards of sand from the Atlantic Ocean Channel or 1.0 million cubic yards of sand from Thimble Shoal Channel on the beach is justified by the benefits associated with the placement and,

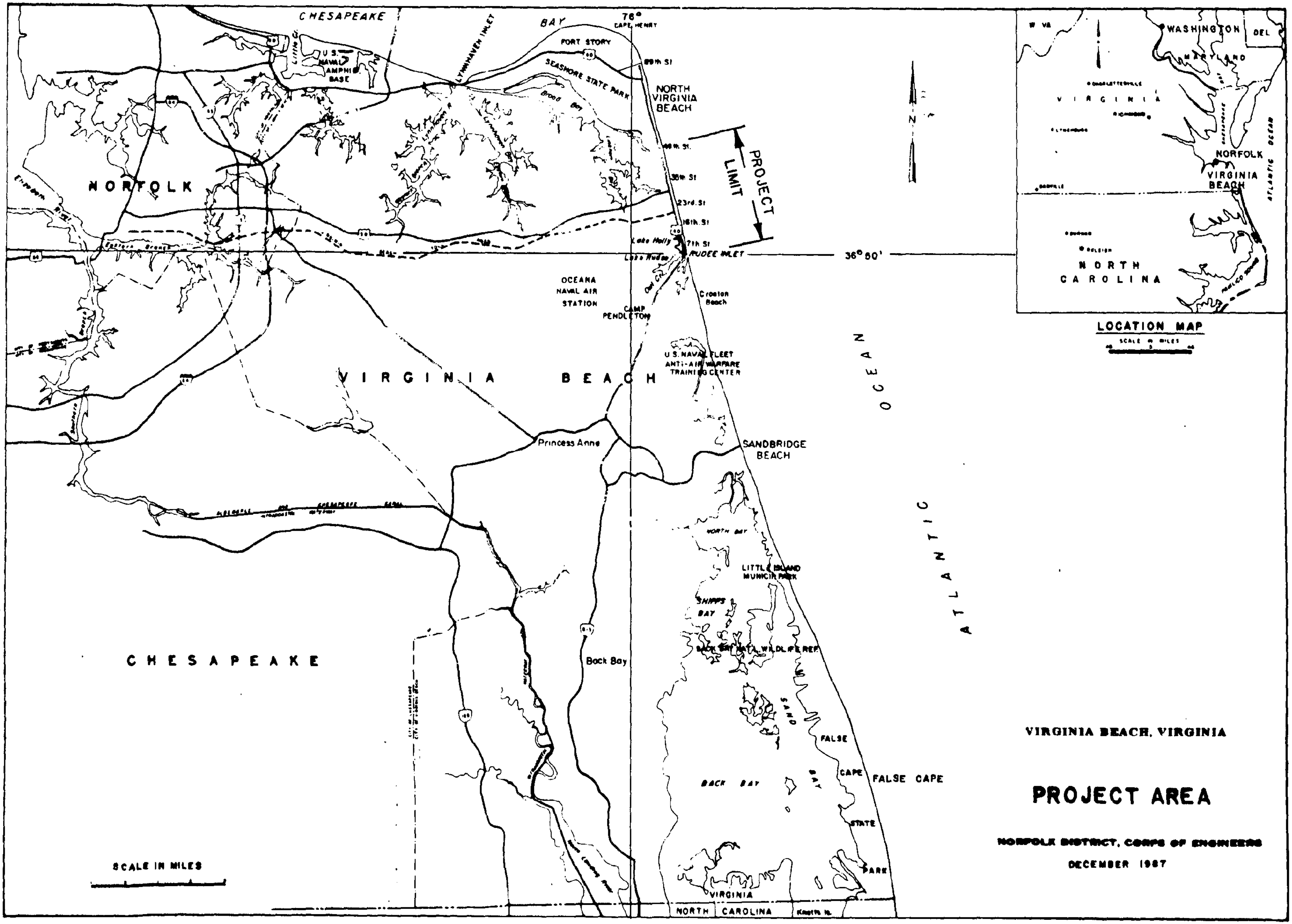
b. The storm damage reduction benefits alone exceed the added cost of beach placement.

At this time, the added costs of placing 1.1 and 1.0 million cubic yards of sand on the beach from Atlantic Ocean and Thimble Shoal Channel sources is estimated at $7.4 million and $5.4 million, respectively. However, due to the unpredictability of coastal processes, the inherent difficulties in determining an exact quantity of sand placement to be in the public interest, and the need for flexibility in the physical placement of dredged sand on the beach, it is recommended that a range of dredged sand from 900,000 cubic yards to 1.2 million cubic yards be considered in the Federal interest for cost-sharing purposes. This range would be applicable to either Atlantic Ocean or Thimble Shoal Channels sources.

RECOMMENDATIONS

It is recommended that the Federal Government participate in the additional cost of placing from 900,000 to 1.2 million cubic yards of sand on Virginia Beach between Rudee Inlet and 49th Street either from the Atlantic Ocean or Thimble Shoal Channel sources. The recommendation is contingent upon non-Federal interests, in this case the Commonwealth of Virginia, providing the required items of local cooperation as stated previously in this report.

J. J. THOMAS
Colonel, Corps of Engineers
Commanding

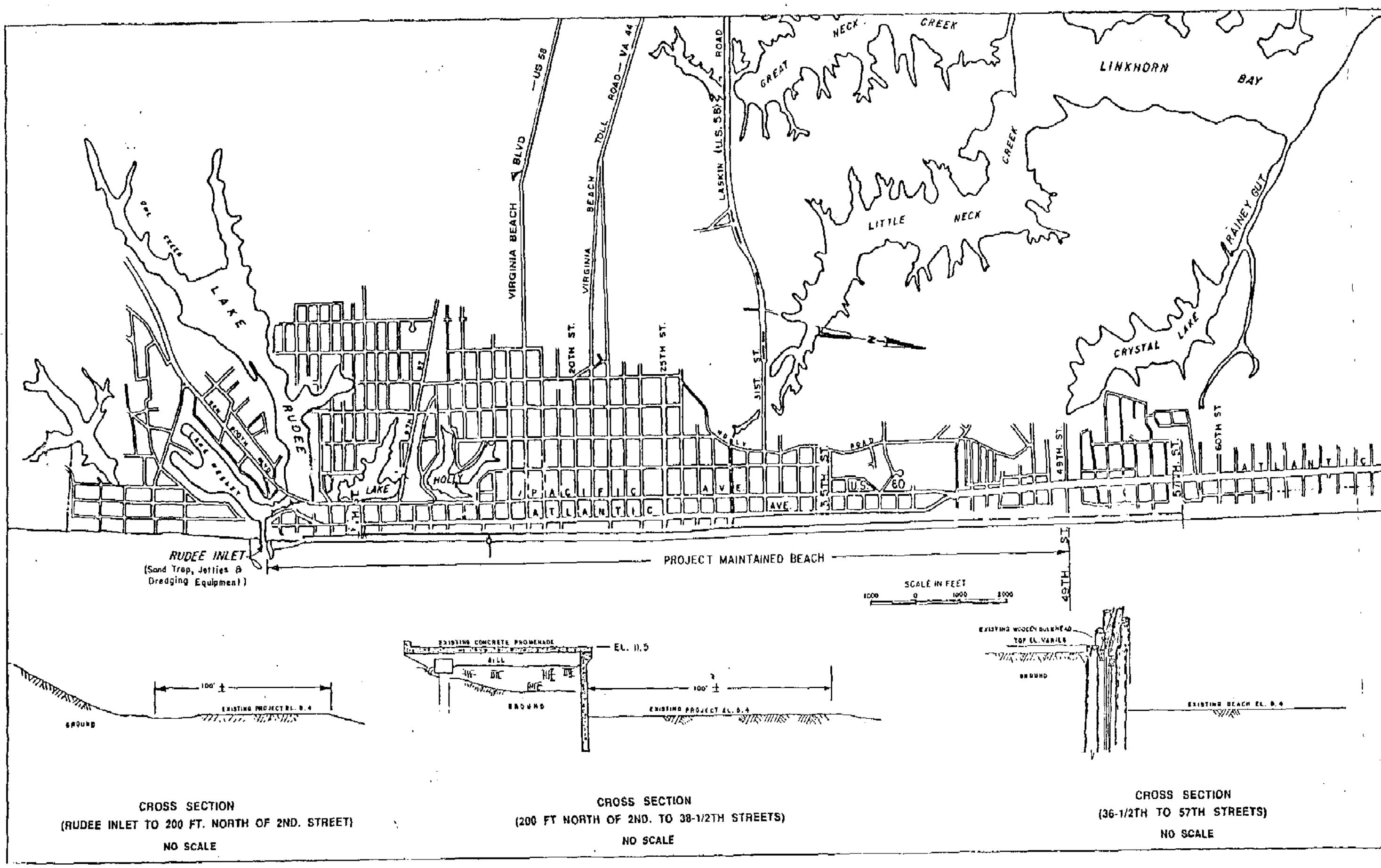


VIRGINIA BEACH, VIRGINIA

PROJECT AREA

NORFOLK DISTRICT, CORPS OF ENGINEERS

DECEMBER 1987



NOTE:

a. Project maintained beach between Rudee Inlet and 49th. street. Federal participation in beach nourishment expired in February 1997.

b. All elevation referred to National Geodetic Vertical Datum (N.G.V.D.). Which is 1.6 feet above mean low water.

VIRGINIA BEACH, VIRGINIA
VIRGINIA BEACH NOURISHMENT PROJECT
NORFOLK DISTRICT, CORP OF ENGINEERS
DECEMBER 1997

PLATE 2

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COST ESTIMATES

PURPOSE

1. This section of the appendix presents the methodology and assumptions used in estimating the costs of placement of sand dredged from the Thimble Shoal and Atlantic Ocean Channels onto Virginia Beach between Rudee Inlet and 49th Street. Costs are based on October 1988 price levels.

GEOLOGY AND LITTORAL TRANSPORT

2. Virginia Beach lies wholly on the Coastal Plain Province of the Atlantic Seaboard. The Coastal Plain Province is underlain principally by sediments which dip gently seaward upon a basement of crystalline rocks. These sediments consist of unconsolidated sands, clays, and gravels.

3. A significant problem exists that involves the instability and recession of the ocean beach due to erosion. South of Cape Henry to about 49th Street, the Atlantic shoreline has a history of relative stability. In the study area, between Rudee Inlet and 49th Street, erosion presents a serious problem which is exacerbated by storms which strike the area. These storms materially reduce the width and height of the beach berm, thereby exposing existing high-value waterfront developments to wave damage. In addition, they cause a loss of beach area available for recreational use.

4. Littoral transport is the longshore movement of water-transported sand. Along the Atlantic shoreline of Virginia Beach, evidence indicates that the predominant littoral transport is from south to north from False Cape near the state line to Cape Henry just north of 89th Street; there seems to be a north-south transport from False Cape to the Virginia-North Carolina state line. However, there are no shore structures or other visible indicators which can be used as an index to the direction of predominant littoral flow between False Cape and the state line. South of the North Carolina line, it is generally

accepted that predominant littoral drift is southward. Since there has to be a nodal point on the shoreline where littoral drift splits to north and south, the configuration of the shoreline strongly suggests that this point occurs in the vicinity of False Cape.

THIMBLE SHOAL CHANNEL

5. The Thimble Shoal Channel is located in the southern portion of the Chesapeake Bay. It extends westward from the mouth of the Chesapeake Bay to the mouth of the Hampton Roads Harbor. The channel is bounded on the north side by the submarine topographic features known as the Horseshoe and Tail of the Horseshoe. To the south, the channel is bounded by the submarine features referred to as Crumps Bank and Willoughby Bank. Thimble Shoal Channel is approximately 9.5 nautical miles long and 1,000 feet wide with auxiliary channels located on each side of the main channel. The auxiliary channels are 450 feet wide. The location of the channel is shown on plate 1 of the main report.

6. In May 1983, August 1984, and July 1985, the Norfolk District personnel supervised subsurface investigations for the Thimble Shoal Channel, Norfolk Harbor and Channels, Deepening Project, Virginia. The scope of work was fourfold; namely:

a. To determine substrata conditions to a minimum depth of minus 58 feet below mean low water. Detail was given to identifying areas where sediment changes occurred both vertically and horizontally.

b. To perform laboratory tests on soil identification, moisture content, natural density, and soil strength.

c. To determine the side slopes for the channel.

d. To identify areas within the project area which may have sand texturally suitable and available in appreciable quantities for mining.

7. Details from the above investigations are contained in appendix C of the General Design Memorandum dated June 1986.

8. The Corps is currently dredging the channel to provide for a Congressionally authorized outbound channel 50 feet deep from Norfolk Harbor to the Atlantic Ocean. This dredging has not provided any satisfactory sand. However, a 55-foot channel has also been Congressionally authorized into Norfolk Harbor. Investigations indicate the 6.4 million cubic yards of total pay quantity material will be dredged from this channel of which 1.2 million cubic yards is expected to be beach quality sand. The mean grain size, based on samples, ranges from 0.181 mm to 0.308 mm. The overfill ratio is estimated at 1.55, meaning that to obtain one cubic yard of this sand on the beach, 1.55 cubic yards must be dredged from the channel to account for placement losses between the dredge and the beach.

ATLANTIC OCEAN CHANNEL

9. The Atlantic Ocean Channel is located offshore of Virginia Beach, Virginia in the Atlantic Ocean. It extends southeastward from a point approximately 3.5 nautical miles offshore of Cape Henry to approximately 10 nautical miles offshore of Rudee Inlet, Virginia Beach, Virginia. Its northern end leads into one of the largest estuaries in the world, the Chesapeake Bay. Approximately 9 nautical miles of the channel was investigated in connection with the preparation of the General Design Memorandum for deepening the Norfolk Harbor Channels. The scope of work for this investigation was identical to that indicated previously for the Thimble Shoal Channel. The location of the channel is shown on plate 1 of the main report.

10. Investigations indicate that sand suitable for disposal on area beaches is found in the middle and outer reaches of the channel. It is estimated that 9.6 million cubic yards of total pay quantity of material will be dredged from this channel of which 5.2 million cubic yards is expected to be beach quality sand. The mean grain size, based on samples, is estimated to be 0.25 mm. The overfill ratio is estimated at 1.78.

PLACEMENT OF OFFSHORE SAND ON BEACH

11. The following two basic dredges are available for deposition of sand from Thimble Shoal and Atlantic Ocean Channels onto Virginia Beach.

a. A large cutterhead suction dredge which cuts up the material and pumps it continuously through a long attached pipeline to the shore. The diameter of the discharge line can be as much as 42 inches. If the borrow area is such that the maximum length of pipe can be kept under about 18,000 feet, it is very likely that a large pipeline dredge working on swing wires from April through September could remove material and pump it onshore through a booster pumping plant located on a jack-up barge (or DeLong pier) above wave action, though not at the surf zone. Another booster pump can be added onshore. However, a pipeline could not successfully compete with hopper dredge equipment if the summer months (when the beach is actively used by residents and tourists) were excluded from the dredging operation. The main problem with this system is keeping the submerged line connection with the dredge and booster pump intact in an ocean environment. With the borrow area located as much as 6 miles from the beach, additional booster pumps or a second dredge would be required, thereby doubling the problems and cost of pumping.

b. The hopper dredge stores the material in its hoppers, travels to the shoreline, and then pumps the sand onshore through one or more booster pumps depending on the distance from its mooring facility to the beach. A hopper dredge cannot dredge and pump onshore in a continuous operation as does the pipeline dredge. Consequently, a substantial portion of the work time is spent traveling and pumping out its hoppers even if the travel distance is short. A connection between the beach pumping system and the hopper dredge requires an offshore hookup, such as use of a DeLong pier barge partially jacked up above wave action as an intermediate discharge plant. It was used in the calmer waters of Chesapeake Bay when sand was pumped onshore from Thimble Shoal Channel to Fort Story. The self-propelled hopper dredges have a capacity of up to several thousand cubic yards and a speed of up to 13 knots when loaded. An effective offshore pump system is a single point mooring which utilizes an anchored buoy that holds the open end of the submerged shoreline pipe to which the dredge attaches its pumpout system. The hopper dredge, when attached to the buoy is free to pivot with its head into the wind, thus riding as if at anchor and achieving the best possible stability.

12. Generally, the dredges draw 25 to 30 feet of water and must therefore be located offshore where this depth of water is available. Any offshore borrow site contains a percentage of silt-size material. When more granular material is dredged, enough of the fine material will be mixed to yield a relatively easy pumping slurry. The pipeline dredge will handle this slurry without modifying it and will deliver it to the beach. The hopper dredge, on the other hand, sorts the material in its hopper causing the silt to be suspended and lost overboard during the loading process. The resulting material, while superior for beach fill, will be more difficult to transport through a pipeline. The hopper dredge transfer point, therefore, should be as close to the beach as safety will permit. A pipeline dredge can be located farther away and still achieve good results. Some of the difference in quality of the fill material can be compensated for by the shore crew. By allowing more of the fine material to flow into the surf from the pipeline and by using shorter training dikes in the ponding and settlement area, much of the silt-size material can be eliminated without damage to the new beach section. However, in view of the distances involved from the Atlantic Ocean and/or Thimble Shoal Channels to the beach and the sensitivity of the hydraulic pipeline dredge to weather conditions, the hopper dredge is considered a more practical alternative for accomplishing the work.

SAND REQUIRED FOR VARIOUS BEACH BERMS

13. The erosion rate of the beach is estimated at 370,000 cubic yards per year. This erosion rate has been calculated for the period 1981 to present. If the present beach is widened to 100 feet, the erosion rate can be expected to increase. This increase in erosion would be contributed to the beach not being in dynamic equilibrium with wave conditions, sediment characteristics, offshore topography, and slope as well as foreshore-backshore geometrics. This implies that erosion is expected to be accelerated until the portion of the active beach

out to closure depth is filled in with the required volume of sand. The closure depth is defined as the seaward limit of the extreme surf-related effect on the sediment movements. An important factor when increasing the subaerial portion of the beach seaward is the additional volume of material needed to fill in the area out to closure depth. For many beaches, the design beach does not include the volume of material needed to fill in the offshore zone. When this zone is not filled in, the beach is not in dynamic equilibrium. Erosion rates are expected to increase until this area is filled. The closure depth for Virginia Beach is estimated to be around -20.0 feet mean low water.

14. When the grain size distribution of the borrow material is finer than the native material found on the beach, then overfill and renourishment factors can be expected to increase. The renourishment factor is the ratio of the annual beach erosion rate associated with borrow material to the annual rate of erosion of the native material. The erosion rate after placement of beach fill can be estimated by multiplying the current rate by this renourishment factor.

15. According to a recent paper by Hansen and Lillycrop (CERC, 1988) which included Virginia Beach as a study example, the conventional design procedure (similar to the one used in volume calculations in this study) may be deficient by as much as 60 percent of material after establishment of the post-equilibrium profile or, in other words, a 60 percent volumetric increase would be required to fill in the offshore zone.

16. The computed 370,000 cubic yards of material required to maintain the beach at a berm width of approximately 60 feet is based on the total amount of sand bypassed at Rudee Inlet each year and the estimated annual truck haul. These amounts are estimated to be 220,000 cubic yards and 150,000 cubic yards, respectively.

17. To achieve a berm width of 100 feet or approximately 40 feet beyond the naturally occurring present berm requires about 361,000 cubic yards of material. This does not include the quantity of material required for the offshore zone. The material required to fill in the offshore zone for a 100-foot berm is estimated to be approximately 700,000 cubic yards. As mentioned before, because this area is not filled in, the erosion can be expected to increase

initially. As this area fills in, the erosion rate can be expected to decrease; however, depending upon several factors, the erosion rate would not decrease below the original estimated erosion rate. Data are not available on the amount that moves offshore annually. The Traverse Group Report (1980) estimates 25 percent of the present annual erosion rate of 315,000 cubic yards moves offshore and 75 percent moves alongshore. This would imply approximately 93,000 cubic yards of material is deposited in the offshore area. This offshore amount does not take into account the initial annual accelerated erosion rate expected to occur with the development of a 100-foot berm or larger. Assuming the erosion is increased by 35 to 40 percent when using material from Thimble Shoal Channel, the erosion rate would increase from 370,000 cubic yards per year to 500,000 cubic yards per year to 520,000 cubic yards per year. Assuming 25 percent is deposited offshore, the volume deposited would vary from 125,000 cubic yards to 130,000 cubic yards per year. This accelerated erosion can be expected to continue each year until the offshore zone is filled.

18. If a finer sediment than the material found on the native beach is used for the borrow material, then the material can be expected to erode faster than using material similar to the native beach. The ratio of the annual erosion rate between these two is the renourishment ratio. The Atlantic Ocean Channel borrow material is finer than the native beach material. The renourishment factor for this borrow source is estimated to be 1.5 times as fast as native-like sediments. In addition, erosion would increase due to the building of the beach further seaward without filling in the offshore area. Erosion rates should be expected to increase from 370,000 cubic yards per year to 550,000 cubic yards per year to 650,000 cubic yards per year.

19. The erosion rates discussed above do not consider the sand which is bypassed at Rudee Inlet. Estimating the bypass volume to be 220,000 cubic yards per year, the estimated net erosion using borrow material from Thimble Shoal Channel is approximately 280,000 cubic yards per year to 300,000 cubic yards per year. Estimated net erosion using material from the Atlantic Ocean Channel is between 330,000 cubic yards per year to 430,000 cubic yards per year.

20. As the berm is constructed seaward, a greater amount of borrow material is required to fill in the area of the active beach which is below mean low water. The further the berm or subaerial portion of the beach is extended, greater amounts of material are placed below the water line because the water depth increases. When the berm is developed from 100 feet to 140 feet, approximately 550,000 cubic yards of additional material is required. Much of this material is placed below the mean low water datum. Most of the material which is above mean low water is not in a dynamic equilibrium state. As much as 40 to 60 percent of this material is eventually displaced offshore. Therefore, only 1 year of additional berm life is estimated if the berm were extended from 100 to 140 feet.

21. Table A-1 summarizes the quantity of sand required by berm width for sand dredged from the Atlantic Ocean and Thimble Shoal Channels.

Table A-1. SUMMARY OF SAND REQUIREMENTS

Berm width (feet)	Design volume (cu. yds.)	Placed on beach (cu. yds.)	Dredged from channel (cu. yds.)	Life of placement (years)
		Atlantic Ocean Channel Sand		
60	370,000	573,500	658,600	1.5
100	731,000	1,133,050	1,301,180	3.0
140	1,088,000	1,686,400	1,936,680	4.0
		Thimble Shoal Channel Sand		
60	370,000	499,500	573,500	2.0
100(a)	731,000	986,850	1,133,050	3.5

(a) 100-foot berm is the largest available for construction using sand dredged from Thimble Shoal Channel.

COST DATA

22. Cost estimates are based on using a Manhatten Class hopper dredge with pumpout capability. This dredge would load material, proceed to a mooring buoy, and connect to a submerged pipeline leading to shore. Pumping would be assisted by boosters as needed. It may not be efficient to spread some of the smaller quantity along the beach. Estimates assume that an efficient placement method will be used. Use of the hopper dredge, with the long periods of no pumping, would allow more time to switch the discharge pipe without losing efficiency.

23. Pertinent assumptions relative to the estimation of costs are shown in tables A-2 and A-3.

Table A-2. HOPPER DREDGE DATA

Item	Cubic yards						
	100,000	250,000	500,000	1,000,000	2,000,000	4,000,000	6,000,000
Cycle time in minutes							
Dredging	130	120	110	100	100	100	100
Turning	10	10	10	10	10	10	10
To disposal area							
Thimble Shoal Channel	72	72	72	72	72	72	72
Atlantic Ocean Channel	30	30	30	30	30	30	30
Discharge to beach	190	180	170	150	145	145	145
Discharge to Dam Neck	10	8	5	5	5	5	5
To dredging area							
Thimble Shoal Channel	60	60	60	60	60	60	60
Atlantic Ocean Channel	25	25	25	25	25	25	25
Operating days/month	21	22	23	23	23	23	23

Table A-3. OVERHEAD AND PROFIT
FOR HOPPER DREDGE

Cubic yardage	Overhead and profit (percent)
100,000	26
250,000	26
500,000	25
1,000,000	24
2,000,000	23
4,000,000	21
6,000,000	20

24. In determining costs, all contract costs were increased by 6 percent for Engineering and Design and Supervision and Administration and by 10 percent for contingencies. Other miscellaneous data used to determine the cost of offshore sand using the hopper dredge include:

Length of line to beach:	4,000 feet	
Booster requirements:	0-5,000'	-0
	5,000'-13,000'	-1
	13,000'-21,000'	-2
	over 21,000'	-3

25. Tables A-4, A-5, A-6 and A-7 show the computation of costs per cubic yard of sand based on 1 million cubic yards dredged from Atlantic Ocean and Thimble Shoal Channels and placed in Dam Neck Disposal Site and on Virginia Beach between Rudee Inlet and 49th Street. Unit cost estimates for other quantities ranging from 100,000 to 6 million cubic yards were calculated in the same manner and are shown in table A-8; they are also plotted in figure A-1.

Table A-4. UNIT COST, ATLANTIC OCEAN CHANNEL SAND TO DAM NECK DISPOSAL SITE
(1,000,000 CY)

Plant: Manhatten Island Class Hopper Dredge
Channel Segment: Atlantic Ocean Channel
Disposal Area: Dam Neck Ocean Disposal Area
Haul Distance (Miles): 3
Pumping Distance:

Cycle Time (In Minutes):		
Dredging		100
Turning		10
To Disposal Area	3 Miles @ 10 MPH	18
Discharging		5
To Dredging Area	3 Miles @ 12 MPH	15
Total Cycle Time (In Minutes):		148
Monthly Plant Cost:		
Dredge	36,000/Day X 30	$1,092,000
Mooring Barge or Buoy		
Booster Pump	X 125,000	
Shore Men and Equipment		
24" Submerged Pipe	LF @ 4.35/LF	
24" Shore Pipe	LF @ 3.00/LF	
Subtotal		$1,092,000
24% Overhead & Profit		262,080
Total Monthly Plant Cost		$1,354,080
Production and Cost Estimates:		
Loads Per Day	9.73	
Cubic Yards/Load	2,000	
Operating Days/Month	23	
Monthly Production (Cubic Yds):		447,580
Quantity of Material (Cubic Yds):		1,000,000
Dredging Time:	2.23 Mos.	
Dredging Cost:		$3,019,598
Mobilization/Demobilization:		62,000
Total Job Cost:		$3,081,598
Unit Cost/CY Contract:		$3.08
E&D + S&A (6%):		0.18
Contingencies (10%):		0.33
Unit Cost/CY Total:		$3.59

Table A-5. UNIT COST, THIMBLE SHOAL CHANNEL SAND TO DAM NECK DISPOSAL SITE
(1,000,000 CY)

Plant: Manhatten Island Class Hopper Dredge
Channel Segment: Thimble Shoal Channel
Disposal Area: Dam Neck Ocean Disposal Area
Haul Distance (Miles): 15
Pumping Distance:

Cycle Time (In Minutes):		
Dredging		100
Turning		10
To Disposal Area	15 Miles @ 10 MPH	90
Discharging		5
To Dredging Area	15 Miles @ 12 MPH	75
Total Cycle Time (In Minutes):		280
Monthly Plant Cost:		
Dredge	36,000/Day X 30	$1,092,000
Mooring Barge or Buoy		5,200
Booster Pump	X 125,000	
Shore Men and Equipment		16,000
24" Submerged Pipe	LF @ 4.35/LF	
24" Shore Pipe	LF @ 3.00/LF	
Subtotal		$1,113,200
24% Overhead & Profit		267,168
Total Monthly Plant Cost		$1,380,368
Production and Cost Estimates:		
Loads Per Day	5.14	
Cubic Yards/Load	2,000	
Operating Days/Month	23	
Monthly Production (Cubic Yds):		236,571
Quantity of Material (Cubic Yds):		1,000,000
Dredging Time (One Dredge):	4.23 Mos.	
Dredging Cost:		$5,838,957
Mobilization/Demobilization:		62,000
Total Job Cost:		$5,900,957
Unit Cost/c.y. Contract:		$5.90
E&D + S&A (6%):		0.35
Contingencies (10%):		0.63
Unit Cost/c.y. Total:		$6.88

Table A-6. UNIT COST, ATLANTIC OCEAN CHANNEL SAND TO VIRGINIA BEACH
(1,000,000 CY)

Plant: Manhatten Island Class Hopper Dredge
Channel Segment: Atlantic Ocean Channel
Disposal Area: Rudee Inlet - 49th Street
Haul Distance (Miles): 5
Pumping Distance: 7,000 feet

Cycle Time (In Minutes):		
Dredging		100
Turning		10
To Disposal Area	5 Miles @ 10 MPH	30
Discharging		150
To Dredging Area	5 Miles @ 12 MPH	25
Total Cycle Time (In Minutes):		315
Monthly Plant Cost:		
Dredge	36,000/Day X 30	$1,092,000
Mooring Barge or Buoy		5,200
Booster Pump	1 X 125,000	125,000
Shore Men and Equipment		16,000
24" Submerged Pipe	4,000 LF @ 4.35/LF	17,400
24" Shore Pipe	9,000 LF @ 3.00/LF	27,000
Subtotal		$1,282,600
24% Overhead & Profit		307,824
Total Monthly Plant Cost		$1,590,424
Production and Cost Estimates:		
Loads Per Day	4.57	
Cubic Yards/Load	2,000	
Operating Days/Month	23	
Monthly Production (Cubic Yds):		210,220
Quantity of Material (Cubic Yds):		1,000,000
Dredging Time (One Dredge):	4.76 Mos.	
Dredging Cost:		$7,570,418
Mobilization/Demobilization:		77,000
Total Job Cost:		$7,647,418
Unit Cost/c.y. Contract:		$7.65
E&D + S&A (6%):		0.46
Contingencies (10%):		0.81
Unit Cost/c.y. Total:		$8.92

Table A-7. UNIT COST, THIMBLE SHOAL CHANNEL SAND TO VIRGINIA BEACH (1,000,000 CY)

Plant: Manhatten Island Class Hopper Dredge
Channel Segment: Thimble Shoal Channel
Disposal Area: Rudee Inlet - 49th Street
Haul Distance (Miles): 12
Pumping Distance: 7,000 feet

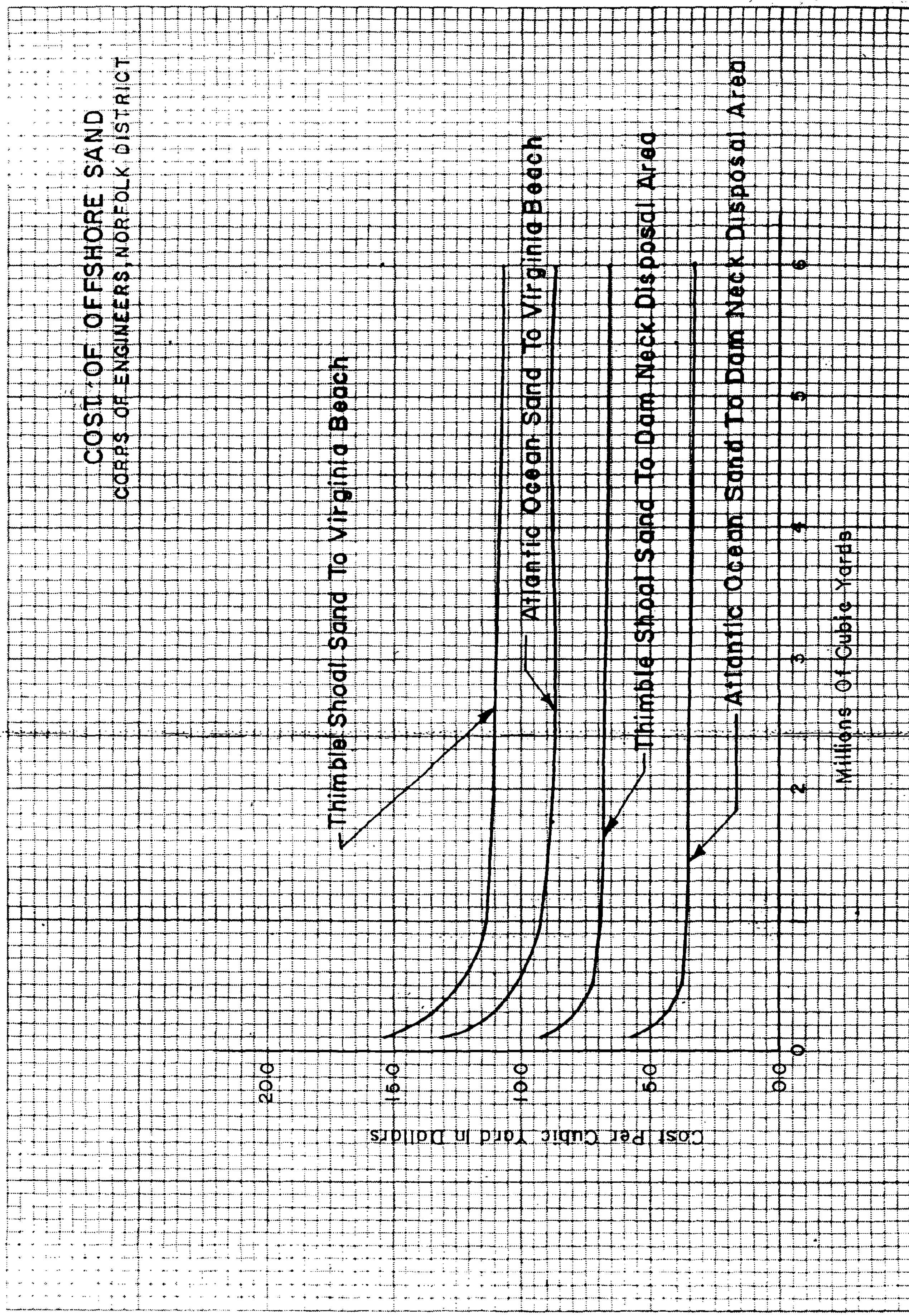
Cycle Time (In Minutes):		
Dredging		100
Turning		10
To Disposal Area	12 Miles @ 10 MPH	72
Discharging		150
To Dredging Area	12 Miles @ 12 MPH	60
Total Cycle Time (In Minutes):		392
Monthly Plant Cost:		
Dredge	36,000/Day X 30	$1,092,000
Mooring Barge or Buoy		5,200
Booster Pump	1 X 125,000	125,000
Shore Men and Equipment		16,000
24" Submerged Pipe	4,000 LF @ 4.35/LF	17,400
24" Shore Pipe	9,000 LF @ 3.00/LF	27,000
Subtotal		$1,282,600
24% Overhead & Profit		307,824
Total Monthly Plant Cost		$1,590,424
Production and Cost Estimates:		
Loads Per Day	3.67	
Cubic Yards/Load	2,000	
Operating Days/Month	23	
Monthly Production (Cubic Yds):		168,980
Quantity of Material (Cubic Yds):		1,000,000
Dredging Time (One Dredge):	5.92 Mos.	
Dredging Cost:		$9,415,310
Mobilization/Demobilization:		77,000
Total Job Cost:		$9,492,310
Unit Cost/c.y. Contract:		$9.49
E&D + S&A (6%):		0.57
Contingencies (10%):		1.01
Unit Cost/c.y. Total:		$11.07

26. Table A-8 summarizes the estimated costs for offshore sand from Thimble Shoal and Atlantic Ocean Channels to be deposited in Dam Neck Disposal Site or on the beach at Virginia Beach. The costs are also plotted by graph shown in figure A-1.

Table A-8. COST SUMMARY FOR OFFSHORE SAND(a)

Yardage (c.y.)	Cost of sand from offshore site ($/cy) Thimble Shoal to Dam Neck	Atlantic Ocean to Dam Neck	Thimble Shoal to Va Beach	Atlantic Ocean to Va Beach
100,000	9.22	5.54	15.28	13.06
250,000	8.14	4.60	13.65	11.41
500,000	7.25	3.71	12.40	10.23
1,000,000	6.88	3.59	11.37	9.22
2,000,000	6.82	3.56	11.09	8.94
4,000,000	6.68	3.48	10.93	8.80
6,000,000	6.61	3.44	10.67	8.59

(a) Costs shown for Virginia Beach include $0.30/c.y. for spreading material on the beach.



COST OF OFFSHORE SAND
CORPS OF ENGINEERS, NORFOLK DISTRICT
Thimble Shoal Sand To Virginia Beach
Atlantic Ocean Sand To Virginia Beach
Thimble Shoal Sand To Dam Neck Disposal Area
Atlantic Ocean Sand To Dam Neck Disposal Area
Cost Per Cubic Yard In Dollars
200
150
100
50
00
Millions Of Cubic Yards
0
2
3
4
5
6

Figure A-1

APPENDIX B

BENEFIT EVALUATION

APPENDIX B

BENEFIT EVALUATION

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APPENDIX B

BENEFIT EVALUATION

GENERAL

1. This section of the appendix evaluates the beneficial impacts associated with protection of the resort strip of Virginia Beach between Rudee Inlet and 49th Street by the placement of sand dredged from the 55-foot-deep outbound Norfolk Harbor Channels onto the beach. The beneficial impacts from the initial placement of the dredged sand are (a) reduced tangible primary physical damages, and (b) increased recreational use of the beach. Estimates of monetary benefits are based on October 1988 price levels and an interest rate of 8-7/8 percent.

FLOOD DAMAGES

2. The first step in estimating average annual tidal flood damage is to obtain pertinent data through flood damage surveys. Detailed surveys were made in connection with the Phase One General Design Memorandum for Virginia Beach completed in June 1984. These surveys were updated by a new survey conducted in June-July 1987 for the Virginia Beach Nourishment, Section 933 and 934 Study. Following the compilation of the flood damage survey data, benefits were then estimated by evaluating damages with and without the project over the estimated life of the sand placement.

3. Primary tangible flood damage reduction benefits for the sand placement are the equivalent average annual tidal flood damages prevented and represent the difference between average annual tidal flood losses without protection and residual average annual losses after providing protection. The without project condition assumes no sand nourishment over the period of analysis except for the bypassing operation at Rudee Inlet.

4. Average annual damages for a given condition were obtained by combining the total damage at various tidal flood stages with the corresponding frequency of flooding to those stages to obtain a damage-frequency relationship. The damage-frequency relationship is utilized to determine the average annual damages for the given condition. This is done for natural conditions without protection and conditions which would exist with the sand placement, the difference being the average annual flood prevention benefits attributable to the project.

DAMAGE SURVEYS

Purpose and Method

5. Investigations were made to determine the relationship between the tidal flood stage in the project area and the resulting damages to existing developments. Such a relationship, when compared with the probable frequency of recurring tidal flood stages, is a guide to the forecast of future flood losses. It also furnishes data required to determine the economic justification of depositing sand on the beach in lieu of open-water disposal areas.

6. A stage-loss relationship cannot be based entirely on the damages from tidal stages caused by past hurricanes or northeasters, as such data are not always available. Most of the occupants of business establishments in the areas at the time of the record 1933 hurricane are no longer in business. Records relative to structural damage, stock and equipment damage, business losses, and unemployment caused by floods are not always maintained by small business establishments. Furthermore, recent developments must be considered, particularly in Virginia Beach proper where the older hotels are being replaced by modern motels. The June-July 1987 survey indicated that 31 new structures have been added to the flood plain since the 1981 survey.

7. U.S. Geological Survey quadrangle sheets to a scale of 1:24,000 were used to delineate the limits of the area inundated by the March 1962 storm. City plat maps to a scale of 1 inch equals 200 feet showed the location and extent of each parcel of property. The ground-floor elevation for each structure in the area was obtained. Reliable high water marks were established for the August 1933 and March 1962 storms. These enabled a determination of the elevations

to be expected from tidal flood stages of varying magnitude and the effect of wave heights in the area.

8. The stillwater level tidal flood stage was used as an index of the damage, since it could be expressed on a frequency basis. The wind-driven waves rushed up and over the beaches and seawall causing damage at elevations considerably higher than the stillwater level offshore. The probable damage associated with a given stillwater level was approximated by estimating the depth and extent of flooding in areas adjacent to the shore, using that experienced in March 1962 as a basis, and estimating the damage which would occur under those conditions. The stage-damage relationship was defined by determining the damages which would result in a recurrence of the tide levels reached in March 1962 and August 1933 and in a storm producing a tide level of elevation 12 feet.

Commercial Damage

9. In determining flood damages to commercial structures and contents, first-floor elevations or other points of zero damage were obtained by field surveys and maps from the Virginia Beach Department of Public Works dated February 1987. Each commercial establishment was classified by size based on available square footage of floor space or other physical characteristics of the structure. For example, a drugstore with less than 550 square feet would be classified as small, greater than 800 square feet would be large and anything between 550 and 800 square feet would be classified as medium. Having established the size and first-floor elevation of each establishment, the damage was then determined from tables prepared for this purpose. These tables were the result of detailed studies for specific types of commercial establishments such as drugstores, banks, men's clothing stores, offices, restaurants, etc. Damages for commercial establishments that did not correspond to fit the table, such as hotels and motels, were determined by personal interviews in which each owner or manager was contacted and an estimate made of the losses. The response of motel and hotel owners and managers in furnishing reliable cost estimates was excellent. The physical loss included the damage to the building, including furnishings, fixtures, equipment, stock, and cleanup. The emergency cost and the indirect losses included those additional expenses resulting from a tidal flood that would not otherwise be incurred. For example,

indirect losses included such items as wages, insurance, taxes, and other items that would continue while the establishment was closed due to flooding.

10. In addition to damages from normal flooding, it was recognized that buildings directly exposed to wave attack would incur higher damage because of waves and undermining. In order to estimate damages resulting from direct wave attack, it was necessary to determine which structures would be directly affected. This was accomplished by estimating, based on past history, the number of structures which would be undermined by the hypothetical storms being considered. Undermining not only causes an increase in damage but also exposes the structure to direct wave attack. In the absence of empirical data, wave damage to oceanfront structures was estimated to be 60 percent of the structure value for structures undermined by a repeat of the 1962 storm, 75 percent for those structures undermined by a repeat of the 1933 storm, and 90 percent for those structures that would be undermined by a storm with an equivalent stillwater level of 12.0 feet NGVD. These estimates were based on an inspection of the construction method, foundation, natural protection, and visual observation of similar damages during past flood events. Commercial structures constructed on piles, such as large hotels, were not included as structures subject to undermining. The 31 structures added to the flood plain since the 1981 survey are not subject to undermining since they have either been built on pilings or built in locations not subject to undermining.

Residential Damages

11. Residential development is centered primarily in the section of beach between 42nd and 49th Streets. Damages were evaluated based on depth-damage functions with allowances for loss of market value when undermining occurs. Damages to structures which were undermined were estimated at 60 percent and 75 percent, respectively, for a repeat of the 1962 and 1933 events and at 90 percent for those structures that would be undermined with an equivalent stillwater level of 12 feet NGVD.

Utility Damages

12. Utility damages were small during the 1962 storm. Most of the damage occurred to electric and telephone lines and was caused by severe wind. Storms of greater magnitude than the 1962 storm would not appear to produce

a substantial increase in the damage to utilities. Even though it was recognized that there would be some damage to the utilities in the area, no such damage has been included in the damage estimate.

Highway Damages

13. Flood damages to highway routes were obtained by estimating the stretches of road which would be undercut by the various storms and would require replacement or repair. Damage data were also supplemented by other pertinent information gathered in previous surveys and adjusted to current price levels such as that which actually occurred in the March 1962 storm.

Other Damages

14. When evaluating the potential damages at Virginia Beach, the damages to the existing boardwalk and bulkhead must also be included. The damages to the boardwalk and bulkhead were significant during the 1933, 1948, and 1962 events. For example, during the 1962 storm about 4,100 feet of wall or bulkhead were destroyed or so badly damaged that it had to be replaced. In addition, a large volume of material was lost behind the bulkhead due to erosion. There are certain other categories of losses which were not included, or were included only in part because complete information in usable form was meager or unavailable. There is evidence, however, to suggest that these losses are substantial. These categories consist of (a) losses to non-fixed or transient items such as vehicles parked on streets or in parking lots, (b) damages to automobiles moving through the sea water which flooded the streets, and (c) losses outside the immediate flood area as a result of the inundation of the main business section, and (d) intangible losses such as detrimental effects upon health and security which are monetarily not measurable.

15. Although intangible damages are not adaptable to monetary measurement, they are of considerable importance in the flood plain area. Although no significant loss of life or epidemic diseases have been recorded as directly attributable to tidal flooding in recent years, the danger is ever present. Also of importance is the adverse effect of prolonged periods of inundation on the general welfare of the residents. During a major storm such as occurred in March 1962, communications are interrupted, utilities become inoperative, and

transportation routes are impassable. These breakdowns in communications and services result in delays in evacuation, prevent the rendering of needed assistance, and add to the already difficult problem of rehabilitation.

EXISTING STAGE-DAMAGE DATA

16. Based on the 1981 damage survey, supplemented by the June-July 1987 survey updated to reflect October 1988 price levels, the data for damages to existing commercial property, recreational property, public use facilities, streets, and utilities based on October 1988 price levels were summarized and correlated. The damages were based on a stillwater level of 3.5 feet NGVD. Table B-1 presents the stage-damage relationships for the reach of beach between Rudee Inlet and 49th Street under without project conditions.

Table B-1. STAGE-DAMAGE DATA FOR VIRGINIA BEACH SHORELINE FROM RUDEE INLET TO 49TH STREET ($1,000s)

Stage ft., NGVD	Commercial	Residential	Highways	Sand loss & bulkheads	Total
12.0	43,805	13,047	957	20,630	78,439
11.5	35,622	10,832	830	19,897	67,181
11.0	31,272	9,887	709	19,048	60,916
10.73	29,586	9,365	649	18,492	58,092
10.0	25,028	8,290	485	16,990	50,793
9.5	22,417	7,656	390	15,375	45,838
9.0	19,961	7,036	300	13,579	40,876
8.7	18,835	6,736	242	11,978	37,791
8.6	18,337	6,635	221	11,446	36,639
8.5	18,016	6,520	217	10,993	35,746
8.0	16,583	6,093	147	9,619	32,442
7.5	14,945	5,624	96	8,412	29,077
7.0	12,795	5,003	63	7,135	24,996
6.7	11,339	4,563	46	6,051	21,999
6.5	10,211	4,060	41	5,467	19,783
6.0	7,984	3,452	32	4,197	15,665
5.0	4,555	1,828	19	2,248	8,650
4.0	1,433	564	5	670	2,672
3.5	0	0	0	0	0

AVERAGE ANNUAL DAMAGES

17. In order to convert the stage-damage data in the previous table to average annual values, it is necessary to relate them to stage-frequency data. This is accomplished in the following table which shows the frequency data, the corresponding stages, the damage at each stage, and the annualized damage values for the reach of beach between Rudee Inlet and 49th Street under without project conditions.

Table B-2. AVERAGE ANNUAL FLOOD DAMAGES (WITHOUT CONDITION) ($1,000)

Frequency (years)	Stage (feet)	Damage at stage ($)	Avg. annual value ($)
0	12.0	78,439	10,360
500.0	11.0	60,916	10,219
256.4	10.0	50,793	10,113
125.0	9.0	40,876	9,927
54.1	8.0	32,442	9,554
20.4	7.0	24,996	8,685
6.7	6.0	15,665	6,754
2.5	5.0	8,650	3,110
1.0	4.0	2,672	0
1.0	3.5	0	0

FLOOD REDUCTION BENEFITS

18. The data presented previous to this section of the appendix relate to existing flood damages in the study area. The following section will quantify the average annual benefits attributable to the one-time placement of sand dredged from the outbound 55-foot deep navigation channels.

19. The damages for the with project condition consist of three principal alternative berm width considerations of 60, 100, and 140 feet, respectively.

The following table shows the estimated stillwater level zero damage points with the 60-foot, 100-foot, and 140-foot berm widths in place.

Table B-3. STILLWATER LEVEL ZERO DAMAGE ELEVATIONS

	Zero damage points	
Berm width (ft.)	Commercial, residential and highways (ft., NGVD)	Sand loss and bulkheads (ft., NGVD)
60	5.0	4.7
100	5.7	5.4
140	5.9	5.6

20. Tables B-4, B-5, and B-6 show average annual damages for berm widths of 60, 100, and 140 feet, respectively.

Table B-4. AVERAGE ANNUAL FLOOD DAMAGES (WITH PROJECT)
60-FOOT PROJECT
($1,000)

Frequency (years)	Stage (feet)	Damage at stage ($)	Avg. annual value ($)
0	12.0	78,439	5,620
500.0	11.0	60,916	5,478
256.4	10.0	50,793	5,374
125.0	9.0	40,876	5,189
54.1	8.0	32,442	4,816
20.4	7.0	24,996	3,947
6.7	6.0	13,348	2,104
2.2	5.0	778	80
1.5	4.7	0	0

Table B-5. AVERAGE ANNUAL FLOOD DAMAGES (WITH PROJECT)
100-FOOT PROJECT
($1,000)

Frequency (years)	Stage (feet)	Damage at stage ($)	Avg. annual value ($)
0	12.0	78,439	3,822
500.0	11.0	60,916	3,680
256.4	10.0	50,793	3,573
125.0	9.0	40,876	3,387
54.1	8.0	32,442	3,015
20.4	7.0	24,996	2,146
6.7	6.0	8,926	473
4.5	5.7	1,591	88
3.0	5.4	0	0

Table B-6. AVERAGE ANNUAL FLOOD DAMAGES (WITH PROJECT)
140-FOOT PROJECT
($1,000)

Frequency (years)	Stage (feet)	Damage at stage ($)	Avg. annual value ($)
0	12.0	78,439	3,342
500.0	11.0	60,916	3,202
256.4	10.0	50,793	3,097
125.0	9.0	40,876	2,910
54.1	8.0	32,442	2,539
20.4	7.0	24,996	1,670
6.7	6.0	5,322	151
5.8	5.9	1,934	70
4.1	5.6	0	0

21. Existing flood damage reduction benefits are derived from the previous tables, i.e., damages eliminated correspond directly to the average annual value at the specified frequency and stages considered for protection. The difference between the damages for the with and without project conditions is defined as the benefit to the plan under consideration. The average annual benefits attributable to storm protection for all three berm widths are detailed by category in table B-7. These benefits are estimated to be $4,741,000, $6,542,000, and $7,019,000 for 60-foot, 100-foot, and 140-foot berm widths, respectively.

22. For comparative purposes, the average annual flood damages prevented are based on the berm width not being maintained and allowed to erode back to a level equal to the without project condition. The average annual equivalent benefits will vary depending on how long after the initial placement the beach reaches the without condition. Obviously, the wider berm widths will have longer, physical lives and provide beneficial effects over a longer span of time. Based on past experience at Virginia Beach, it is estimated that the 60-foot berm would provide beneficial effects from 1.0 to 2.0 years, the 100-foot berm from 2.5 to 3.5 years, and the 140-foot berm from 3.5 to 4.0 years. Table B-8 shows the average annual equivalent values for berm widths of 60, 100, and 140 feet based on estimated lives of 1.5 years, 3.0 years, and 4.0 years, respectively.

Table B-7. FLOOD REDUCTION BENEFITS

Benefit category	60-foot berm	100-foot berm	140-foot berm
Residential			
Structure	$669,000	$960,400	$1,053,300
Content	282,000	391,300	414,700
Indirect	44,300	59,800	65,300
Commercial			
Structure	1,418,800	1,902,200	1,974,700
Content	1,023,800	1,393,400	1,497,400
Indirect	195,300	268,100	290,900
Highway	12,900	15,400	15,900
Sand Loss	273,700	380,300	411,900
Bulkheads	821,100	1,171,000	1,294,700
Total	$4,740,900	$6,541,900	$7,018,800
Rounded	$4,741,000	$6,542,000	$7,019,000

Table B-8. AVERAGE ANNUAL EQUIVALENT BENEFITS

Berm widths (ft.)	Average useful life (years)	Amount ($)
60	1.5	2,650,000
100	3.0	3,660,000
140	4.0	3,930,000

RECREATION

BACKGROUND

23. Present day Virginia Beach is a large diverse area in southeast Virginia with a mixture of agricultural-woodland sites and residential-shopping center complexes. It has no central or core business district. In the summer, Virginia Beach is probably best known for its recreational ocean and bay beaches. The city has 28 miles of oceanfront and 10 miles of bay front. A little more than 6 miles of ocean beach from Rudee Inlet north to Fort Story attracts visitors from near and far. The area between Rudee Inlet and 42nd Street is often referred to as the resort strip. This area is where most of the hotel/motel complexes catering to tourists are located. The Virginia Beach boardwalk, a concrete wall and walkway with railing, runs from 2nd to 38th Street. At frequent intervals, access steps to the beach have been provided. From 42nd Street to 89th Street which is adjacent to Fort Story, the ocean beach widens and the backdrop is residential rather than commercial. Additional recreational activities in this area include beach volleyball, throwing footballs and frisbees, and sailboating. One of the beneficial impacts of the one-time placement of sand dredged from the 55-foot outbound channel onto the beach is to enhance recreational use of the affected stretch of ocean beach.

24. During calendar year 1982, recreational use and benefits for the entire beach area between Rudee Inlet and 89th Street were calculated. This was in connection with the Virginia Beach Beach Erosion and Hurricane Protection Project. The calculations utilized the Contingent Valuation Method (CVM) as prescribed by Economic and Environmental Principles and Guidelines for Water and Related Land Resource Implementation Studies (March 1983). CVMs obtain estimates of changes in NED benefits by directly asking individuals their willingness to pay for changes in quantity of recreation at a particular site. Individual values may be aggragated by summing the "willingness to pay" responses for all users in the area. Iterative bidding surveys ask the respondent to react to a series of values posed by the enumerator. Following establishment of the market and a complete description of the recreational good, service, or amenity to be valued, the respondent is asked to answer "yes" or "no" to whether he or she is willing to pay the stated amount of money to obtain the

stated increment in recreation. The values are iteratively varied until the highest amount willing to be paid is reached.

VISITATION

25. Visitation for the entire beach from Rudee Inlet to 89th Street was segregated into overnight and day use. The length and width of beach available was measured, and spot attendance counts were made for various blocks (street to street) periodically during the CVM survey. Based on the literature available on recreation standards as well as several aerial photos taken, it was determined that an area 10 feet by 10 feet (100 square feet) was adequate for the users in the resort strip portion of the ocean beach. This, however, did not allow for games such as beach volleyball and frisbee throwing. The final report was prepared and revised in 1984. The beach itself was divided into four segments between Rudee Inlet and 89th Street. The fourth segment was 42nd Street to 89th Street or 47 blocks. Since this study concludes at 49th Street, this represents about 17 percent of the fourth segment.

26. In calculating recreation use and benefits, peak utilization times were observed. For a 100-day season between Memorial Day and Labor Day and an 8-hour day from 10 a.m. to 6 p.m., peak use was from 12 noon to 2 p.m. The intensity of beach use was also measured. This is the length of time each section of beach is occupied over time. The average time spent on the beach collected during the CVM survey was 4.5 hours. Theoretically, a turnover factor could be calculated which would indicate how may persons could use a given area of beach during a day. Thus, for an 8-hour day with an average of 4.5 hours per stay, the turnover factor would be 1.8. For the peak use period of 12 to 2, there would be no turnover. A separate calculation of beach recreational use was generated for overnight (hotel/motel guests) and day visitors because the two types were not homogeneous with respect to visitation. Both the nature of the visit and the demographic characteristics vary between the two.

27. The total number of overnight visitors traveling to Virginia Beach during the summer season was forecast using a site-specific use estimating model (UEM). The data used were from a 1981 origin study made by the city. The study utilized 25,000 observations from a sample of overnight accommodation

records over the entire summer season. The purpose of the data was to accurately determine the origins of overnight visitors. Since not all overnight visitors use the ocean beach every day because of other competing activities in the nearby area, overall demand was adjusted by applying information from the CVM. The forecast of overnight visitors using the beach between 1st Street and 89th Street for 1982 was 910,590. In order to obtain a similar figure for the reach Rudee Inlet or 1st Street to 49th Street, the data from the 1984 report were used. This time the whole beach was segmented into two parts (1-42 and 43-88). The estimate of visitation for Rudee Inlet to 49th Street is therefore 1=42 plus 17 percent of 43-88 or 609,687.

28. Day use of the beach at Virginia Beach for 1982 was obtained during the study by subtracting overnight visitation from total visitation (1,406,500 - 910,590 = 495,910). The forecast of day visitor beach use was generated using per capita visitation rates by origin from the CVM and applying a population forecast to the constant per capita visitation rate. The forecasts reflect one-time beach use for the period 12:00 to 2:00, the most heavily occupied period. The 1982 study determined total use of the beach by segments. One was the resort strip from 1st to 42nd Street. This figure for the 100 summer days was 946,483. To reach 49th Street, 17 percent was added, thus making total use 1,024,784. From the above ratio of overnight to day users (910/1406 or 65 percent, it appears that 35 percent are day users, thus 35 percent of 1,024,784 is 358,674. The total visitation for the Rudee Inlet to 49th Street area in 1982 for the 100-day summer season is thus 609,687 plus 358,674 or 968,361.

BEACH CAPACITY

29. The 1982 study calculated the capacity of the beach at Virginia Beach to accommodate the total visitation. The primary purpose of this is to make sure that the beach can reasonably handle the total attendance for which monetary benefits will be claimed at this time and in the future. Beach capacity over time is based on total square footage available, the recreation standard of square feet per person, and the time span. Only peak period use is calculated, not turnover. The square footage per person used was 100 from Rudee Inlet to 42nd Street and 218 from 43rd to 89th Street. The time span was the number of weekend and week days during the 100-day summer season. For purposes of this present study, it is not necessary to break out weekend and week days.

According to the 1982 study, the existing beach between Rudee Inlet and 42nd Street has a summer season capacity of 2,497,320 user days during the peak period of 12:00 to 2:00 p.m. From 43rd to 89th Street, the capacity is 1,281,963 of which 17 percent is 217,934; hence, there is a total of 2,715,254 user days. It is apparent that the capacity of the beach is sufficient to handle the peak time user days seasonally; however, it also assumes that demand is uniform throughout the entire reach which is not the case. The reach from 5th to 30th Street was the most active area in the 1982 study and still remains so today.

FORECAST OF BEACH USE

30. The without project condition assumes no sand nourishment over the period of analysis except for the bypassing operation at Rudee Inlet. With the deposition of sand on the beach from the dredging of the outbound 55-foot-deep Atlantic Ocean and Thimble Shoal Channels, alternative beach widths of 60, 100, and 140 feet are being considered. The estimates of recreation use in connection with the sand placement are shown in the following table and are based on ratio and proportion from the above 1982 study projection to 1990. The beach capacity provided by the 100-foot berm would not be exceeded prior to 1996. Accordingly, the 140-foot berm would provide no additional recreational benefits over the 100-foot berm. It is possible that over time a wider beach could attract more visitation; on the other hand, a narrower beach could detract from use, especially the overnight tourist. However, no factors for the possible variations were calculated.

Table B-9. ANNUAL RECREATION USE-1990

Berm, ft	User days
60	741,600
100	1,236,000
140	1,236,000

UNIT DAY VALUES

31. The 1988 unit day value for beach recreation (UDV) was estimated by utilization of the average annual increases in the recreation day values for

General Recreation activities presented in the Principles and Guidelines for Water and Related Land Resources Studies and the Fiscal Year 1987 Reference Handbook. Based on the above references, the values for two fiscal years were available -- 1982 and 1985. General Recreation values presented are the low and high dollar units per day. For purposes of this study, the mid-range value was chosen; that is, the mid-range between the low and high figures. For FY 1982, the low value was $1.60 and the high was $4.80, or a mid-range of $3.20. For FY 1985, the low value was $1.75 and the high was $5.30, or a mid-range of $3.55 Over the 3 years, the low-range values increased 15¢ for an average of 5¢ per year; the high-range values increased 50¢ for an average of 17¢ per year. Therefore, the mid-range average increase became 22¢/2¢ or 11¢ per year. The projection of this increase to FY 1988 became the base $3.55 plus 11¢ per year for 3 years (33¢), or $3.88 per visitor day.

32. Table B-10 shows the recreation benefits for the one-time placement of sand on the beach between Rudee Inlet and 49th Street. It utilizes the visitor days from table B-9 above times $3.88 per visitor day.

Table B-10. RECREATION BENEFITS
FOR THREE WIDTHS OF BEACH

Widths, ft	Benefits
60	$2,877,000
100	$4,796,000
140	$4,796,000

33. For comparative purposes, the average annual recreation benefits are based on the berm width not being maintained and allowed to erode back to a level equal to the without project condition. The average annual benefits will vary depending on how long after the initial placement the beach reaches the without condition. As discussed previously in the Flood Damage section of this appendix, the wider berm widths will have longer physical lives and accordingly will provide beneficial effects over a longer span of time. Table B-11 shows

average annual equivalent values for useful lives of 1.5 years, 3.0 years, and 4.0 years for the 60-, 100- and 140-foot berms, respectively.

Table B-11. AVERAGE ANNUAL EQUIVALENT BENEFITS

Berm widths (ft.)	Average useful life (years)	Amount ($)
60	1.5	1,600,000
100	3.0	2,700,000
140	4.0	2,700,000

SUMMARY

34. The following table shows the average annual equivalent benefits applicable to the placement of Norfolk Harbor Channels sand with beach berm widths of 60 feet, 100 feet and 140 feet.

Table B-12. SUMMARY OF BENEFITS

Item	Berm widths (ft)		
	60	100	140
Flood Damage	$2,650,000	$3,660,000	$3,930,000
Recreation	$1,600,000	$2,700,000	$2,700,000
TOTAL	$4,250,000	$6,360,000	$6,630,000

APPENDIX C

HYDROLOGY AND HYDRAULICS

APPENDIX C

HYDROLOGY AND HYDRAULICS

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APPENDIX C

HYDROLOGY AND HYDRAULICS

INTRODUCTION

1. This section provides information on the hydrologic, hydraulic, and coastal engineering-related aspects of the study area under both existing and anticipated project conditions. More specifically, it will include discussions on natural forces, design criteria and assumptions, and the effects which may be expected for certain project features.

STUDY AREA

2. The study area is situated along the Atlantic Ocean in the city of Virginia Beach, Virginia, specifically the shoreline between Rudee Inlet and 49th Street. The study area is shown on plate C-1. The study area currently depends on a limited degree of protection provided by combinations of existing bulkheads, beachfill, and natural beach as noted by plate C-2. Offshore depths are shown on plate C-3.

NATURAL FORCES

3. Knowledge of such physical phenomena as storms, tides, waves, and winds and their magnitudes is necessary in order to identify the many variable forces affecting the coastal waters and the adjacent beach. Establishment of these forces is necessary to analyze their effects on developments along the shoreline under existing conditions and also to consider the design and performance of possible protective measures.

CLIMATE

4. Virginia Beach is temperate with moderate, seasonal changes. Winters are generally mild, and summers, though long and warm, are frequently tempered by cool periods resulting from winds off the Atlantic Ocean. Occasionally, during brief periods, the climatic conditions vary extremely from normal due to storms of both extra-tropical and tropical origin. The average annual precipitation is about 45 inches. It is fairly evenly distributed throughout the year, with average monthly amounts ranging from 5.74 inches in July to 2.62 inches in November. Measurable amounts occur on an average of about 1 day out of 3. Two general types of major coastal storms affect the Virginia Beach area in the form of northeasters and hurricanes.

5. "Northeaster" is the term given to a particular type of storm which seemingly occurs periodically throughout the fall, winter, and spring months along the Atlantic Coast. The Virginia Beach area, for some peculiar reason, appears to be the focal point or spawning ground for a disproportionately large number of these storms. A northeaster is characterized by high wind circulating around an essentially stationary low pressure area and producing high tides, large waves, and potentially heavy rainfall along the coast. Like all cyclonic wind systems in the northern hemisphere, the wind direction is always rotating inward and counter-clockwise about the low pressure area. Winds, more often than not, are from the northeast quadrant relative to Virginia Beach, hence the term "northeaster." Northeasters sometimes develop into complex storms having more than one influencing pressure cell. The location of high pressure centers and low pressure centers with respect to each other may greatly intensify the wind speeds that would be expected from a single storm cell. Strong winds reaching almost hurricane strength may occur over many thousands of square miles. Northeasters may form with little or no advance warning and persist for as long as a week to 10 days. The average duration of a northeaster, however, is only about 2 or 3 days. Noteworthy northeasters of recent years occurred in April 1956, March 1962, and April 1978. The most severe of these was the March 1962 storm, which caused serious tidal flooding and widespread damage along the Middle Atlantic Coast. Pertinent information about the March 1962 storm is shown on plate C-4.

6. The term "hurricane" is applied to an intense cyclonic storm originating in the tropical and subtropical latitudes in the Atlantic Ocean north of the equator. These storms normally gain intensity as they move over water in the southern latitudes, and decay or decrease in intensity as they pass over land or move into the northern latitudes where conditions are such that the energy of the storm cannot be maintained. A hurricane is characterized by low barometric pressure, high winds (over 74 mph), heavy rainfall, large waves, and tidal surges. The most severe hurricane affecting Virginia Beach was that of August 1933. Pertinent information concerning this storm is shown on plate C-4.

WINDS

7. Examination of the winds which have been experienced in the past and can be expected in the future within the study area is necessary to determine the effects on the natural forces and processes affecting the study area. Wind-generated waves cause the greatest loss of material from the beaches.

8. A compilation of wind velocities, durations, and directions was made from the records of the United States Weather Bureau Station located at Cape Henry, Virginia. Wind data for the 16-year period, 1930 to 1945, inclusive, are shown on plate C-5. Destructive wave attack and elevated water levels are caused by winds which have components ranging from a north-northeast clockwise to a south-southeast direction. Analysis of the data on plate C-5 indicates that the prevailing local winds were from the southern quadrants, but that the velocities and total wind movement were greater from the northern quadrants. These data, along with the information available from the March 1962 storm, cover the most severe periods which have been experienced to date and are considered adequate for this study.

9. Plate C-4 shows the direction and velocities of winds experienced at Norfolk, Virginia, during the hurricane of August 1933 and during the northeaster of March 1962.

WAVES AND SWELLS

10. Although there are other sources which will be mentioned, the pertinent published information which was of real value to this study included the following:

a. The Coastal Engineering Research Center's (CERC) T.R. 77-1 entitled "Wave Climate at Selected Locations Along U.S. Coasts" by Edward F. Thompson.

b. Atlantic Coast Hindcast, Shallow-Water, Significant Wave Information (WIS Phase III).

The configuration of the Atlantic coastline of Virginia Beach is such that only waves approaching it from the north-northeast through east to southeast can act upon the beach. It is interesting to note that deepwater waves greater than 60 feet in height have been reported by shipping traffic off the coast of Virginia Beach. As the storm waves approach the shoreline, however, their characteristics are altered by the friction of the bottom, the change in water depth, and local meteorological conditions such as wind or rain.

11. By using the "wave spectrum" method, wave characteristics were determined for a station just east of the mouth of Chesapeake Bay at 37°00' north latitude and 75°30' west longitude. These were based on weather maps from the U.S. Weather Bureau and the U.S. Coast Guard covering the 3-year period 1947-1949, using observed rather than computed winds. Details of the analysis are published in Beach Erosion Board's (BEB) T.M.-57. Wave roses indicating the average deepwater wave conditions to be expected during the winter, spring, summer, and fall are shown on plate C-6. Wave characteristics were also determined by the Bretschneider--revised Sverdrup-Monk Method for the same station using synoptic weather charts for the 3-year period, 1948-1950. These are published in BEB's T.M.-55 and show the characteristics for the significant wave. Duration of the deepwater significant waves is shown for the entire year and is reasonably consistent with data shown on plate C-6.

SURF

12. In planning shore protection measures and the ways and means by which shore erosion may be controlled, surf conditions are an important consideration. They consist of the characteristics of waves and currents in the vicinity of the normal low water line. From October 1954 through December 1957, a Virginia Beach Lifeboat Station made daily observations of surf conditions during every

4-hour watch, unless there was poor visibility. The information obtained consisted of: the time in seconds for ten complete breakers, a visual estimate of the significant height of the surf, the angle at which the wave broke on shore, and the direction of wave approach 1/2 to 1 mile offshore. Observations included surf conditions experienced during hurricanes "Connie" and "Diane" of August 1955. All the information obtained was included in BEB's T.M.-108. Plate C-7 indicates the wave heights and periods experienced in August 1955 and the cumulative frequency of surf from all directions at Virginia Beach, Virginia.

13. The swell diagram shown on plate C-8 was compiled from records of the United States Hydrographic Office. The swells are classified according to the height of the waves and are indicated on the diagram by the width of the lines weighted in proportion to the swell heights squared. The data from which the swell diagram was developed were obtained from ships operating within the 5° area immediately offshore of Virginia Beach. The data include swells moving away from the shore. These swells obviously can have no effect on the shore of the study area.

14. Waves and swells approaching the Virginia Beach shoreline from a due east direction make an angle of approximately 12° with the shoreline and tend to create a slight northward littoral transport. A study of the swell diagram indicates that the greatest percentage of low swells are from directions which would tend to produce northward transport; however, a predominance of medium and heavy swells are from directions which would tend to cause southward movement of littoral drift.

TIDES

15. Tides in the Atlantic Ocean at Virginia Beach are uniformly semidiurnal with the principal variations following the changes in the moon's distance and phase. The mean range of tide is 3.4 feet and the spring range is 4.1 feet. Variations in water surface elevations of more than 9 feet from predicted values have resulted from storms.

LITTORAL TRANSPORT

16. There appear to be two predominant directions of littoral transport along the Atlantic shoreline of Virginia Beach. From Cape Henry to the vicinity of False Cape, 2 miles north of the state line, the predominant direction is undoubtedly to the north. South of False Cape to the state line, the drift is believed to be predominantly southerly.

17. Of all the winds and swells to which the shoreline of Virginia Beach is exposed, those from directions which tend to produce southward littoral transport are of greater magnitude than those that would tend to produce northward littoral transport. Consequently, a marked predominance of southerly littoral transport as a result of wave energy would logically be expected. However, the following evidence does not support this theory.

18. Prior to 1950 there were no structures projecting a sufficient distance into the ocean to act as a barrier to littoral transport. In the latter part of June 1950, the city completed construction of an "experimental" groin extending 210 feet into the ocean from the south end of the seawall at 7th Street. During the summer and fall months, the groin trapped considerable material on its south side (the fill) in places reaching a depth of 4 feet and extending updrift in excess of 400 feet. In the late fall and winter months, material was eroded from the updrift impoundment area. The quantity of material trapped on the north side of the groin was considerably less than that on the south side. This same general situation prevailed over the several years the groin remained in place. It was subsequently removed as being a menace to bathers.

19. Further evidence of predominant northerly drift at Virginia Beach is furnished by a fishing pier located between 14th and 15th Streets. This pier was completed by private interests in May 1950. The pier has an inshore concession area 130 feet wide, built parallel with the shoreline, and extends out approximately 100 feet beyond the low water line. The large number of piles supporting the concession area function as a permeable groin. As a result, during the late spring, summer, and early fall months, material is accreted updrift or south of the pier in the form of a fillet. During the late fall and winter months, much of this material is eroded from the beach face. In the late spring months when material again begins to accrete beneath the pier, it is almost

invariably offset by the development of a "pocket" in the beach face, 300 to 400 feet north of the pier. This is the typical updrift accretion and downdrift erosion associated with groins. On several occasions, it has been necessary to hydraulically pump material into this "pocket" in order to avoid damage to the seawall. In the winter months, no such phenomena are observed.

20. In January 1968, the city of Virginia Beach completed construction of two stone jetties at Rudee Inlet extending approximately 800 feet into the ocean. A timber weir 490 feet long was incorporated in the south jetty to permit material moving in the littoral zone to pass over its top and thence into an impoundment area to be dredged between the jetties. To date the city has been unable to dredge the impoundment area at such a rate as to serve its intended purpose. Between November 1968 and April 1969, a graduate student conducted a fluorescent tracer study at Rudee Inlet. In all, five tests were made. In four, the longshore currents were to the north, and in the other, to the south. Approximate littoral transport rates determined from analyses of the movement of tracer material ranged from 760 cubic yards/day to 170 cubic yards/day. A mean northerly littoral transport rate of approximately 70,000 cubic yards/year was calculated for this period. Subsequent information based on practical experience at Rudee Inlet has indicated that the present net northerly littoral transport rate is closer to 250,000 cubic yards/year.

21. Since completion of the jetties at Rudee Inlet in early 1968, there has been no evidence of any appreciable southerly littoral transport. Occasionally, small fillets of material have been observed on the north side of the north jetty but they do not endure for long periods of time. Even here there is some question as to whether the small amount of accretion that has been occasionally observed was due to southerly littoral transport or discharge from hydraulic dredges working in the inlet. Close observations of local conditions have failed to disclose any indications of any material passing around the outboard end of the north jetty and into the inlet proper or being bypassed across the opening to the south.

22. It had been hoped that with completion of the jetties and the inauguration of a dredging program by the Virginia Beach Erosion Commission to create a "sand trap" between the jetties and a channel through the inlet to interior waters,

a determination could be made of the rate and volume of littoral drift reaching the inlet. Unfortunately, the dredging and surveys have been conducted in such a manner as to preclude this determination from being made. However, the observations and the analyses of surveys which have been made indicate that some part of the northerly littoral drift is naturally bypassing the inlet at the jetty heads. According to the aforementioned fluorescent tracer study, it appears that the annual volume of littoral drift from the south is low based on the rated capacities of the two dredges which have been operating in the inlet and its forebay area and the actual time these dredges were engaged in dredging (pumping).

23. The anomaly with respect to northward littoral transport at Virginia Beach was apparently first recognized in a previous report, "Virginia Beach, Va., Beach Erosion Control Study" (House Document No. 18/83/1). At that time, it was assumed that the northward littoral transport was attributable to a tidal eddy extending south of the Chesapeake Bay entrance. Since that time, several other investigators have advanced and partially confirmed this theory. The southern limits of the tidal eddy, if one does in fact exist, are not known. However, based on the configuration of the shoreline and underwater trailing spits, its influence is believed to extend southerly to False Cape, which appears to be a nodal point beyond which the littoral transport is to the south. Undoubtedly, the southerly limits of such an eddy vary over several miles, depending on the direction and stage of tide, the wave environment, etc. Another possible contributing factor is that the higher energy waves from the northerly directions are generally short period and crested which tends to direct material offshore rather than along the shoreline. Conversely, the southerly waves are generally long period and long crested and thus conducive to longshore transport to the north. The net northerly transport direction is probably due to a combination of both causes.

24. As indicated above, between False Cape and the state line the littoral transport is believed to be to the south. There are no shore structures or other visible indicators which could be used as an index to the direction of flow in this area. South of the state line, it has generally been accepted that the predominant littoral transport is to the south. Since there has to be some place along the shoreline where the predominant littoral transport splits into north and

southbound paths, the configuration of the shoreline would strongly suggest that this nodal point occurs in the vicinity of False Cape.

STORMS

25. Numerous northeasters occur each year, many of which cause moderately high tides and flooding. Hurricanes producing abnormally high tides are much less frequent but have been responsible for creating the two highest tides of record and six of the nine highest tides. The number of tropical storms of consequence recorded each year has been highly variable, ranging from a minimum of only 1 to a maximum of 21 storms. A study of the tracks of all tropical storms of record indicates that once a year on an average, a tropical storm of hurricane force passes within 250 miles of Virginia Beach, thus posing a threat to the area. A summary of the paths of tropical storms is shown on plate C-9. Plate C-10 shows the number of occurrences and the azimuth distribution of paths followed by hurricanes which posed a threat to the Virginia Beach area between 1886 and 1966. While hurricanes may affect the Virginia Beach area from May through November, nearly 80 percent occur in the months of August, September, and October, and about 40 percent occur in September.

HURRICANE TIDES AND HIGH WATER MARKS

26. Ocean tide data was recorded at irregular intervals at Virginia Beach from October 1959 to March 1971. No tide gage presently exists at the study site. Maximum tide data is not available for the three highest stillwater level events experienced during the period the gage was in service because the gage malfunctioned during the storm events. The problem stemmed from the inability to find a suitable location to install the gage. In the past, quite frequently during severe storms, waves damaged or carried away parts of the pier to which the gage was attached. The maximum tidal stillwater level of record occurred in August 1933. In contrast, high water marks (HWM), presumably the results of wave overlapping and ponding landward of streets and dunes, were 8 feet higher during this storm and 3 to 9 feet higher during the March 1962 storm which endured for a much longer period. These HWMs are indicative of

damage potential which may be caused by wave runup and overtopping. Virginia Beach gaged data which are available are shown in table C-1.

27. Existing tide records at Virginia Beach alone are considered inadequate to establish a reliable tide-frequency relationship. In conjunction with the Phase I Virginia Beach, Beach Erosion Control and Hurricane Protection Study, a tide-frequency relationship for the study area was developed. This relationship was utilized for the Phase II study and is considered appropriate for use in this study. The following is a discussion of the development of that relationship.

28. One tide-frequency relationship was obtained by correlation of available tide records and high water marks at Virginia Beach with the tide-frequency curve developed for the Norfolk Harbor gage located about 10 miles inside Chesapeake Bay. There are historical accounts of tidal flooding for nearly 300 years, but a reasonably accurate indication of the heights reached in Norfolk Harbor is available only since 1908 and a complete record since 1928. Some of the extreme Norfolk Harbor data are provided in table C-2.

Table C-1. HIGHEST RECORDED GAGE READINGS AT VIRGINIA BEACH (a)

Year	Gage readings in feet											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1959											8.4	8.6
1960	8.8	8.5	8.5	7.9	8.3	9.3	8.0	8.3	9.5			
1961					8.2	7.7	8.1	7.6	9.1	9.9	8.2	8.3
1962	7.6	8.1										
1963							8.0	7.5	9.1	8.5	8.7	8.0
1964	8.3	8.1	7.9	8.2	8.2	8.2	8.2	7.9	9.4	8.3	8.6	8.1
1965	9.7	8.4	7.8								8.4	
1966		8.0	7.9	8.0	8.2	7.9	8.4	7.8			8.7	8.2
1967	8.1			8.8	9.6	8.9	7.7	8.6	9.5	8.8	9.1	9.1
1968	8.8	8.2	7.9	8.7	9.2	8.7	8.1	8.2	8.0	8.7	9.2	8.3
1969	8.9	8.8	9.5	8.4	8.3	8.1	8.4	8.5	8.7	9.2		8.2
1970	9.1	8.1	8.5	8.3	8.2	7.8	7.7	8.4	7.8	9.5	9.1	8.9

(a) Lat. 36°51'; longitude 75°58' (broken record). Subtract 5.17 feet to refer heights to National Geodetic Vertical Datum (NGVD).

Table C-2. HIGHEST RECORDED TIDES AT NORFOLK HARBOR (a)

Date	Gage readings in feet
Period of record	1928 to 1978
23 August 1933	14.9
18 September 1936	14.4
7 March 1962	14.2
11 April 1956	13.4
16 September 1933	13.2
12 September 1960	13.2
27 April 1978	13.2
27 September 1956	12.8
18 September 1928	12.7
6 October 1957	12.6
5 October 1948	12.3

(a) Latitude 36°49.3'; longitude 76°17.6'. Subtract 7.37 feet to refer heights to NGVD.

29. There has been a gradual rise in sea level over the investigated period of record at Norfolk Harbor. Variation by epoch and allowances which must be made for all gage readings follows.

Table C-3. SEA LEVEL VARIATION AT NORFOLK HARBOR (a)

Epoch years	NGVD feet	Change feet
1924-1942	4.87	-
1941-1959	5.15	+0.28
1960-1978	5.39	+0.24

(a) These changes are considered applicable to the lower Chesapeake Bay and the open coast area of Virginia Beach. For gage readings prior to 1942, add 0.52 foot. After 1941, reduce the 0.52 foot at the rate of 0.0137 ft./yr.

30. Since the Virginia Beach gage was only in operation from 1959 through 1970 (a portion of which was a broken record), there is a scarcity of recorded high water information. However, this lack of data has been supplemented by estimates determined from high water marks in the study area. Estimates at the time of the storm for August 1933, October 1957, September 1960, and March 1962 are 8.6 feet, 5.9 feet, 4.3 feet and 6.5-7.0 feet NGVD, respectively. Table C-4 provides the elevation of some of these extreme events if they were to occur under present conditions.

Table C-4. ESTIMATED CURRENT TIDAL STILLWATER LEVELS AS A RESULT OF A REPEATED HISTORICAL RECORD (a)

Date	Maximum elevations in NGVD (b) Norfolk Harbor	Virginia Beach
23 August 1933	8.05	9.12
18 September 1936	7.55	-
7 March 1962	7.06	6.73-7.23
16 September 1933	6.35	-
11 April 1956	6.34	-
12 September 1960	6.09	4.56
18 September 1928	5.85	-
27 April 1978	5.84	-
27 September 1956	5.74	-
6 October 1957	5.53	6.2
5 October 1948	5.35	-

(a) Additional correlations between Norfolk Harbor and Virginia Beach can be determined from plate C-12.
(b) Allowances for increases in sea level have been incorporated.

FREQUENCY ANALYSIS

31. The procedure to develop the Virginia Beach frequency curve using the Norfolk Harbor tidal data is defined as follows:

a. A Norfolk Harbor statistical analysis was performed in accordance with the procedures set forth in Hydrology Subcommittee, Guidelines for Determining Flood Flow Frequency Bulletin 17B Revised September 1981, Editorial Corrections March 1982. The Pearson Type III methodology without the logs was incorporated for the selected period of record from 1928 through 1978. The Pearson Type III distribution without the logs was selected as a result of the following:

(1) The New England Division attempted to fit a number of different distributions to tidal elevation data. They found the Pearson Type III distribution without the logs provided the best fit of the data points.

(2) The Pearson Type III distribution without the logs was found to fit the Norfolk Harbor data fairly well.

(3) It was felt that a statistical analysis would produce a morereliable and reproducible result when compared to a graphical approach.

b. Consideration was given to separating hurricane and non-hurricane events. Although objective statistical approaches are available for incomplete samples (a hurricane-related tide exists for less than 50 percent of the years on record), they do not always provide reasonable results. Therefore, all tropical and extratropical events were included together in the analysis of the annual maximum tides.

c. The analysis of the 51 years of systematic record indicated that the 1933 and 1936 events could be high outliers. However, assuming that the true distribution is defined by the computed (non-adjusted) statistics, the value of 8.05 feet for the 1933 event has an exceedence probability of 0.010. It has been determined that, with 51 years of record, the probability of an event this rare being exceeded is 40 percent. Since this risk is so high and it is known that several events as large if not larger than the 1933 event have historically occurred, the 1933 event (and any smaller events) was not considered to be a high outlier.

d. Historical accounts indicate that tides have occurred in Norfolk Harbor at approximately 8.0 feet in 1667 and 1785 and approximately 7.9 feet in 1846. As noted earlier, there has been a gradual rise in sea level. There was some question as to the amount of adjustment that should be made to the historic events. To avoid overestimating the impact of sea level rise, the historic events were increased by only 0.50 foot (approximately the same adjustment for the 1924 to 1942 period). The analysis based on a historical period of 312 years resulted in a slight move to the left of the upper portion of the frequency curve when compared.to the systematic record. Since the adjustment was not very large and there is some question as to the reliability of the historical data, the District has accepted the computed statistics based on the 51 years of systematic record.

e. The upper portion of the statistical curve was adjusted to include expected probability.

f. The lower portion of the statistical curve was adjusted with a partial duration analysis using plotting positions in accordance with Weibull. It included all elevations above 4.26 NGVD.

g. The following table is a summary of the analysis based on the 51 years of systematic record at the Norfolk Harbor gage. The Norfolk Harbor curve is shown on plate C-11. This curve was then translated to Virginia Beach by a correlation relationship of known tidal elevations. This correlation relationship and the Virginia Beach curve (by NAO) are shown on plate C-12.

Table C-5. FINAL RESULTS OF FREQUENCY CURVE FOR NORFOLK HARBOR

Tidal elevation				
Computed	Expected probability	Exceedence probability	Confidence limits 0.05 limit	Confidence limits 0.95 limit
9.4	9.9	0.002	10.3	8.7
8.6	8.9	0.005	9.4	8.0
8.0	8.2	0.010	8.7	7.5
7.4	7.6	0.020	8.0	7.0
6.8	6.9	0.040	7.3	6.4
6.0	6.0	0.100	6.3	5.7
5.4	5.4	0.200	5.6	5.1
4.5	4.5	0.500	4.7	4.2
4.0	4.0	0.800	4.2	3.7
3.8	3.8	0.900	4.1	3.5
3.7	3.7	0.950	4.0	3.4
3.6	3.6	0.990	3.9	3.3

FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN	4.7345	HISTORIC EVENTS	0
STANDARD DEVIATION	0.9521	HIGH OUTLIERS	0
COMPUTED SKEW	1.7014	LOW OUTLIERS	0
GENERALIZED SKEW	-99.0000	ZERO OR MISSING	0
ADOPTED SKEW	1.7014	SYSTEMATIC EVENTS	51

32. Information on tidal frequency studies in the Virginia Beach area by others is as follows:

T.M. NWS HYDRO-32 by NOAA - In this analysis, tropical and extratropical events were studied separately. The annual frequencies from each at a given tide level were then summed to obtain the overall annual frequency of that level. The resulting curve is plotted on plate C-12.

33. OCE was concerned about the differences between the frequency analysis which NAO developed using the Norfolk Harbor data and that presented by NOAA. The adopted Virginia Beach frequency curve which is shown on plate C-12 was selected during conversations between OCE, NAD, and NAO. It

basically compromised the NAO and NOAA analyses. Estimated stillwater levels and associated frequencies are presented in the following table.

Table C-6. ADOPTED FREQUENCY OF STILLWATER LEVELS (SWL)

SWL	Exceedence frequency in percent	Remarks
5.13	40.0	
5.80	20.0	Plate C-12 shows the entire range
6.32	10.0	of probable frequencies for the
7.90	2.0	adopted curve. The correlation
8.75	1.0	analysis is not considered
11.00	0.2	applicable to the adopted curve.
12.20	0.1	

DESIGN CONSIDERATIONS

34. Proper planning for protection against hurricanes and/or northeasters requires that attention be devoted to other factors like wave heights, ensuing runup, and associated characteristics.

35. The procedures which follow were those used for the Virginia Beach, Virginia Beach Erosion Control and Hurricane Protection Phase I, GDM published as House Document 99-216, May 8, 1986. Deviations from that work came as a result of physical model tests of irregular wave overtopping and pressure measurements. The physical model tests are documented in CERC's Coastal Engineering Studies in Support of Virginia Beach, Virginia, Beach Erosion Control and Hurricane Protection Project, Report 1, entitled "Physical Model Tests of Irregular Wave Overtopping and Pressure Measurements" (Technical Report CERC-88-1). Those deviations consisted of a smaller value for setup in determining zero points of damage and longer wave periods for wave and runup calculations.

WAVE HEIGHTS

36. The determination of wave heights that might be experienced within the study area was based on the methodology of the solitary wave theory as presented in the 1984 edition of CERC's Shore Protection Manual (SPM).

37. A typical example of wave height calculations for the without project conditions is as follows:

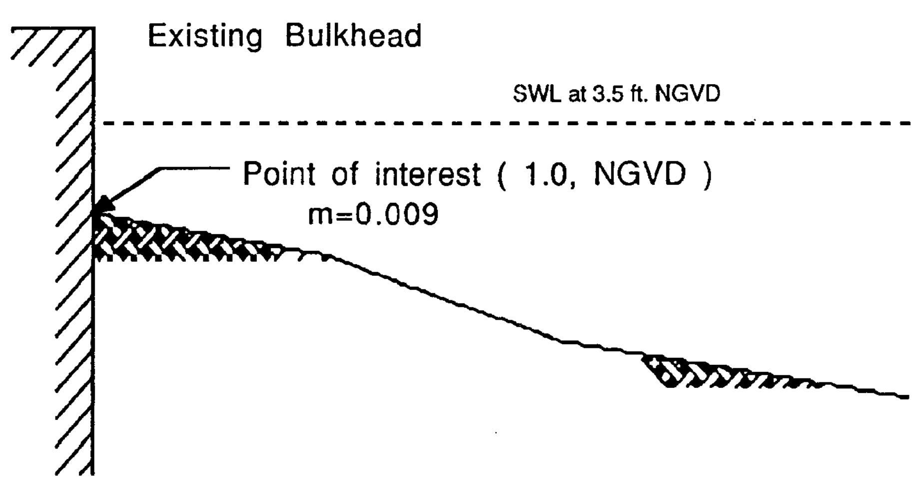


Figure C-1. Typical Section

Problem: Determine breaker height (H_b) at "Point of Interest."

Solution:

a. Setup;

S_w = 0.60 ft. (CERC Model Studies)

b. $d_s' = d_s + S_w$

$= (3.5 - 1.0) + 0.6 = 3.1$ ft.

c. T = 13 seconds. (CERC Model Studies)

d. $\frac{d_s'}{gT^2} = \frac{3.1}{(32.2)(13^2)} = 0.00057$

e. From Fig. 7-4 with m = 0.009,

$$\frac{H_b}{d_s'} = 0.85$$

and, H_b = (0.85) (3.1) = 2.6 ft.

WAVE RUNUP

38. Prior to determining the magnitude of runup, an evaluation of the shaping of the berm as a result of storm erosion was performed. Since there are no specific data relating shore erosion to storm waves with high exceedence frequencies for the study area, the extent of erosion was analytically determined. The evaluation was made using procedures by T. Edelman, "Dune Erosion During Storm Conditions," 11th Conference on Coastal Engineering, London, England, September 1968.

39. Edelman assumed that the material eroded from the dune and beach system would be deposited offshore within the limits of the surf zone, i.e., landward of the breaking point of the storm waves. In this procedure, it is assumed that all materials eroded from the dune and foreshore are transported and deposited offshore. Sand deposition is determined by the breaking depth of the wave associated with a particular storm. In the absence of suitable wave data for various storms, Edelman suggests using a storm wave height equal to 1.5 times the storm surge level measured from NGVD. Also, the breaking depth of the storm wave, relative to the prestorm profile, was assumed to equal 1.3 times the storm-wave height in accordance with the solitary wave theory.

40. For the without project conditions in which typical wave height determinations are shown under paragraph 36, the degree of erosion was governed by guidance provided in DAEN-CWP-E (NAOPL/30 Dec 86) 2d End dated 26 February 1987. With this and input from Engineering Division describing the subsurface, Edelman was used to define the resulting cross section.

41. Typical examples of the methodology used in the determination of runup using the SPM follow.

a. Find the runup associated with a dune for the following condition:

SWL = 3.5 ft. NGVD.
Berm = 1.0 ft. NGVD.

b. Wave height determinations were made as described under paragraph 36.

c. Calculate runup elevation:

(1) $d_s = 3.5 + 0.6 - 1.0 = 3.1$ ft.

(2) $H_b = 2.6$ ft.

(3) From Table C-1

with $\frac{d}{L_0} = \frac{3.1}{5.12 \times 13} = 0.0466,$

$\frac{H}{H_0'} = 1.036$ and, $H_0' = \frac{2.6}{1.036} = 2.5$ ft.

(4) Using Fig. 7-14 of SPM,

$$\left.\begin{array}{l} \frac{2.5}{(32.2)(13^2)} = 0.00046 \\ \\ \frac{3.1}{2.5} = 1.24 \end{array}\right\} \frac{R}{H_0'} = 2.6$$

(5) Correction for scale from Fig. 7-13,

k = 1.168

(6) Runup = (2.6)(2.5)(1.168) = 7.6 ft.

(7) Top of wall = SWL + S_W + Runup

= 3.5 + 0.6 + 7.6 = 11.7 ft., NGVD, (USE).

(8) SWL elevation 3.5 is therefore the non-overtopping surge level and greater values will cause damage to the existing wall and the property behind it. This premise is supported in the following paragraph.

42. The following table provides a subjective summary of the integrity of the existing wall. Although subjective, determinations were based upon field examination by qualified engineers as well as documented failures during storms of record. It was also concluded that a significant potential exists for unraveling of the bulkhead should initial failure occur at one or more areas of the structure.

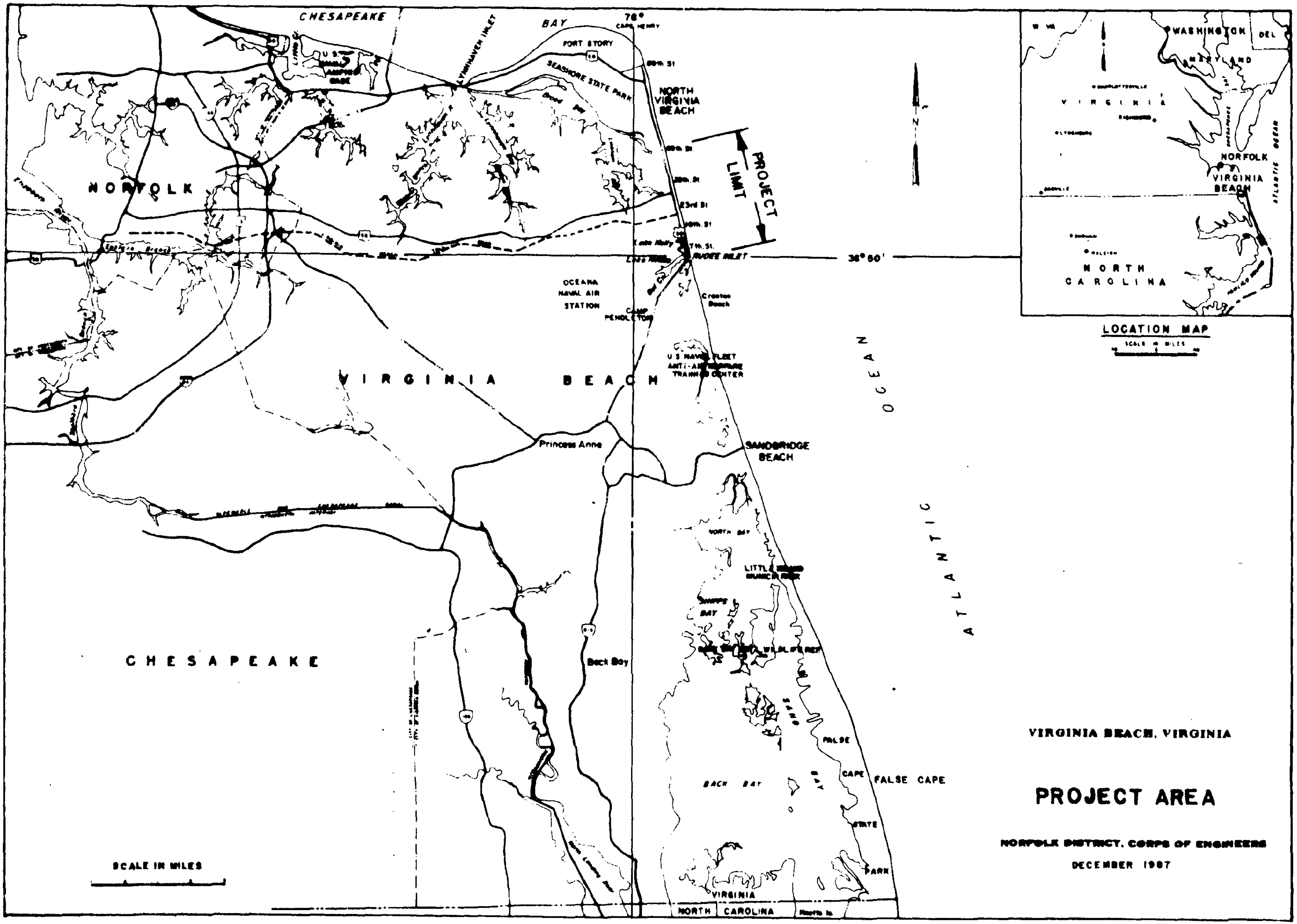
Table C-7. INTEGRITY OF EXISTING WALL

Street block	Type	Material	Condition	Failure sequence	Backshore damage
2-7	Wakefield	Wood	Excellent	9	Minimal
7-8.5	Sheetpile	Steel	Fair	4	Extensive
8.5-20.5	Kingpile	Concrete	Fair to Poor	2	Total
20.5-29	Wakefield	Wood	Fair	3	Total
29-36.5	Kingpile	Concrete	Fair	5	Extensive
36.5-38.5	Wakefield	Wood	Fair to Poor	1	Total
38.5-46	Sheetpile	Steel	Excellent	8	Minimal
46-47	Wakefield	Wood	Excellent to Fair	7	Minimal

43. The following table summarizes the SWLs and associated conditions where the berm, bulkhead and facilities behind the existing wall would begin to be lost or damages would begin to occur (e.g., points of zero damage).

Table C-8. SUMMARY OF POINTS OF ZERO DAMAGE FOR WITH AND WITHOUT CONDITIONS

		Zero Damage Point (Ft., NGVD)	
Condition	Berm Width (Ft.)	Berm and Bulkhead	Commercial and Residential
With project	100	5.4	5.7
	200	5.8	6.1
	300 and greater	6.3	6.3
Without project	Erosion to wall	3.5	3.5

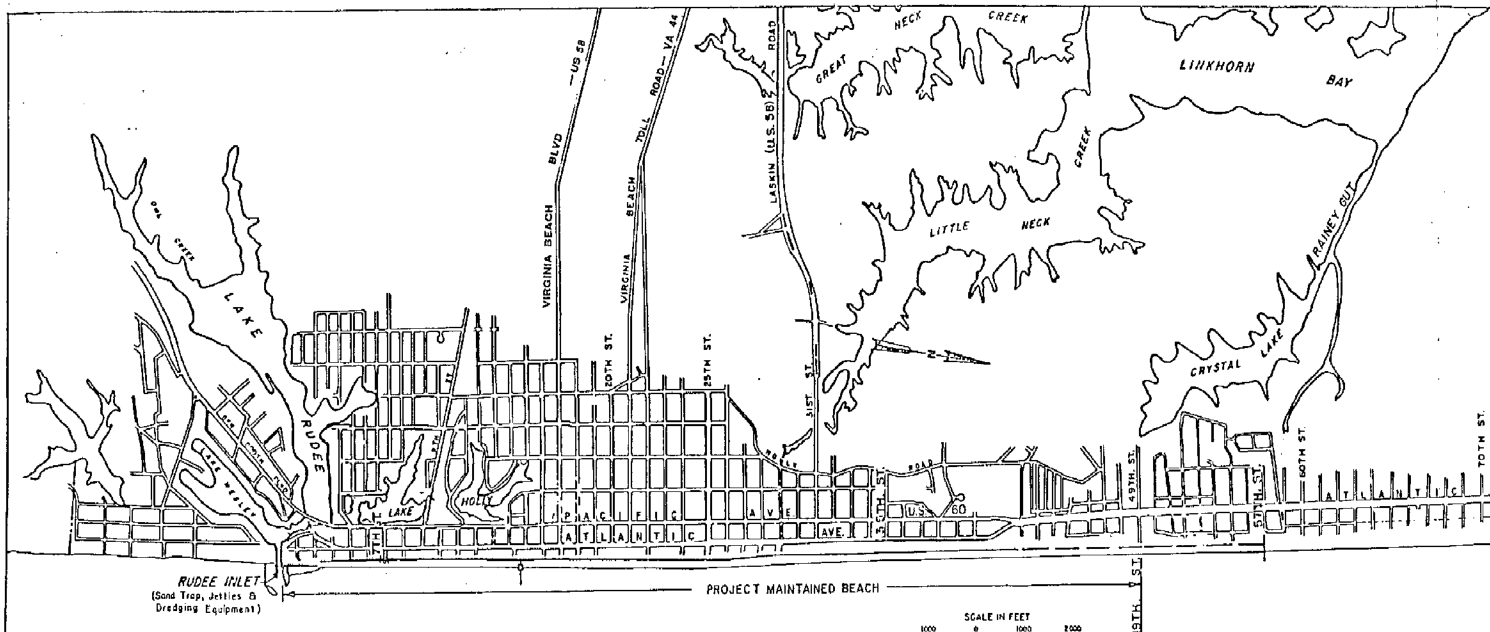


VIRGINIA BEACH, VIRGINIA

PROJECT AREA

NORFOLK DISTRICT, CORPS OF ENGINEERS

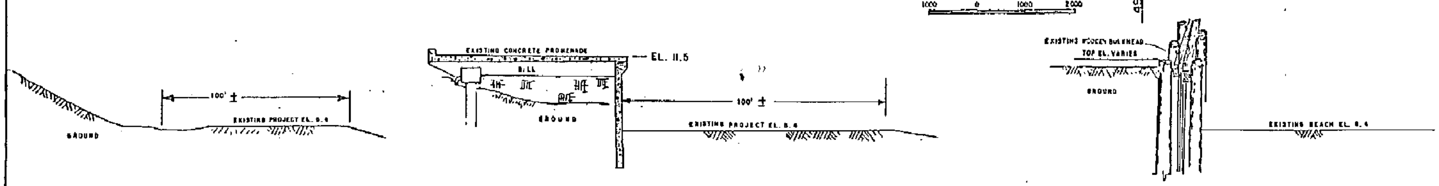
DECEMBER 1987



NOTE:

a. Project maintained beach between Rudee Inlet and 49th. street. Federal participation in beach nourishment expired in February 1987.

b. All elevation referred to National Geodetic Vertical Datum (N.G.V.D.). Which is 1.6 feet above mean low water.

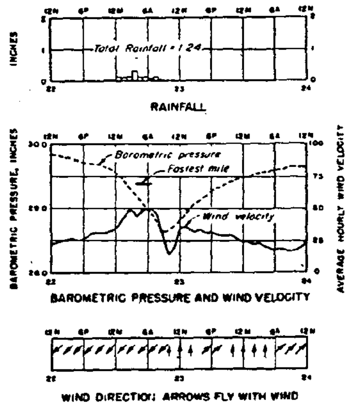


CROSS SECTION
(RUDEE INLET TO 200 FT. NORTH OF 2ND. STREET)
NO SCALE

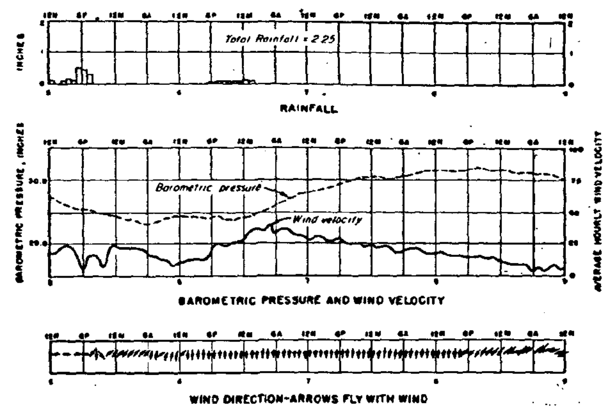
CROSS SECTION
(200 FT NORTH OF 2ND. TO 38-1/2TH STREETS)
NO SCALE

CROSS SECTION
(36-1/2TH TO 57TH STREETS)
NO SCALE

VIRGINIA BEACH, VIRGINIA
VIRGINIA BEACH NOURISHMENT PROJECT
NORFOLK DISTRICT, CORP OF ENGINEERS
DECEMBER 1987



CLIMATOLOGICAL DATA



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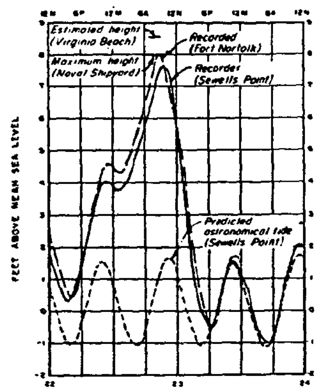
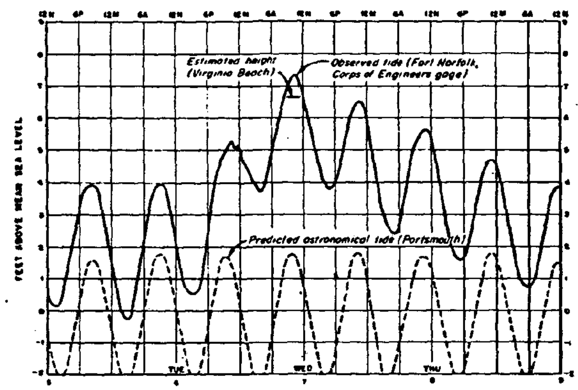
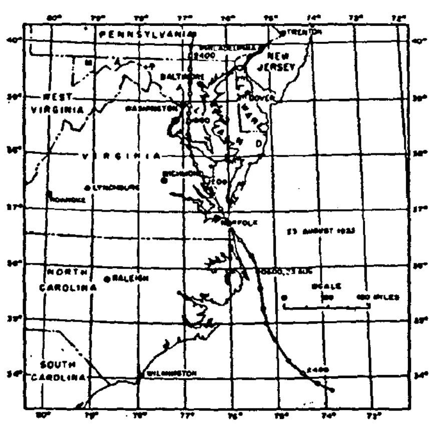


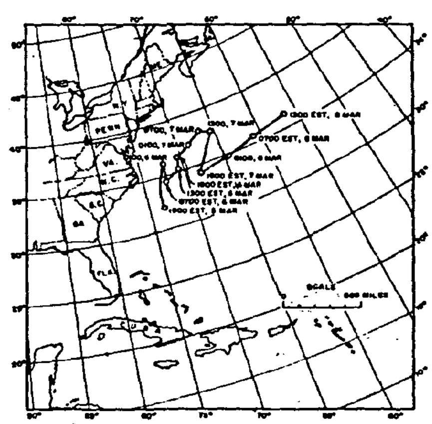
TIDE RECORD



TIDE RECORD



TRACK OF HURRICANE
AUGUST 1933



TRACK OF STORM
MARCH 1962

VIRGINIA BEACH, VIRGINIA

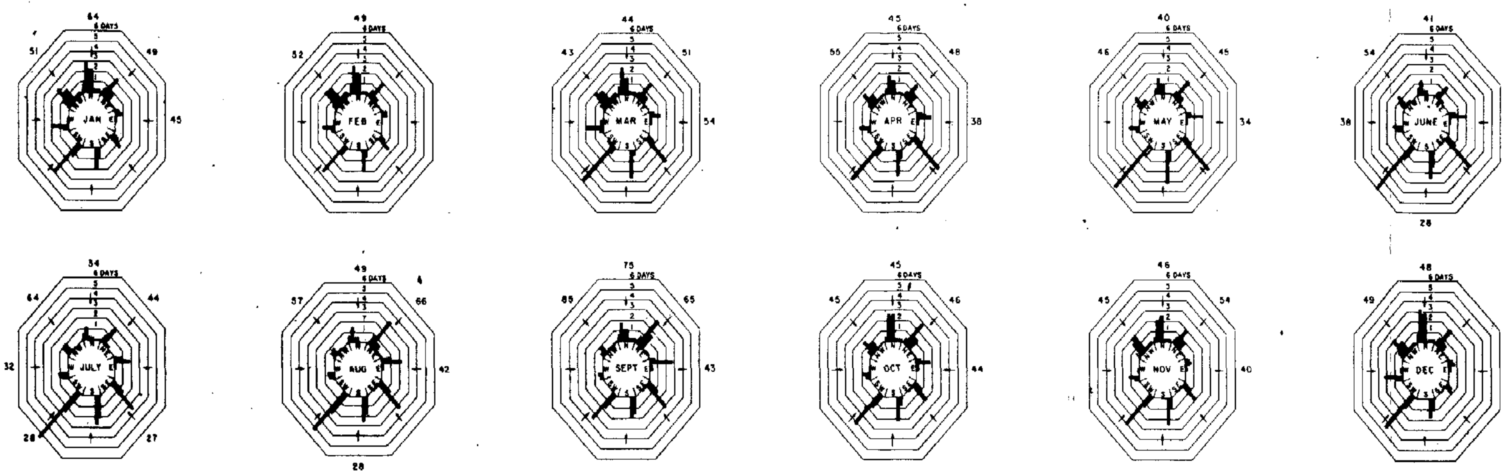
METEOROLOGIC AND HYDROLOGIC DATA

STORMS OF AUGUST 1933 AND MARCH 1962

NORFOLK DISTRICT, CORPS OF ENGINEERS

JUNE 1969 FILE: H-31-10-41

PLATE C - 4



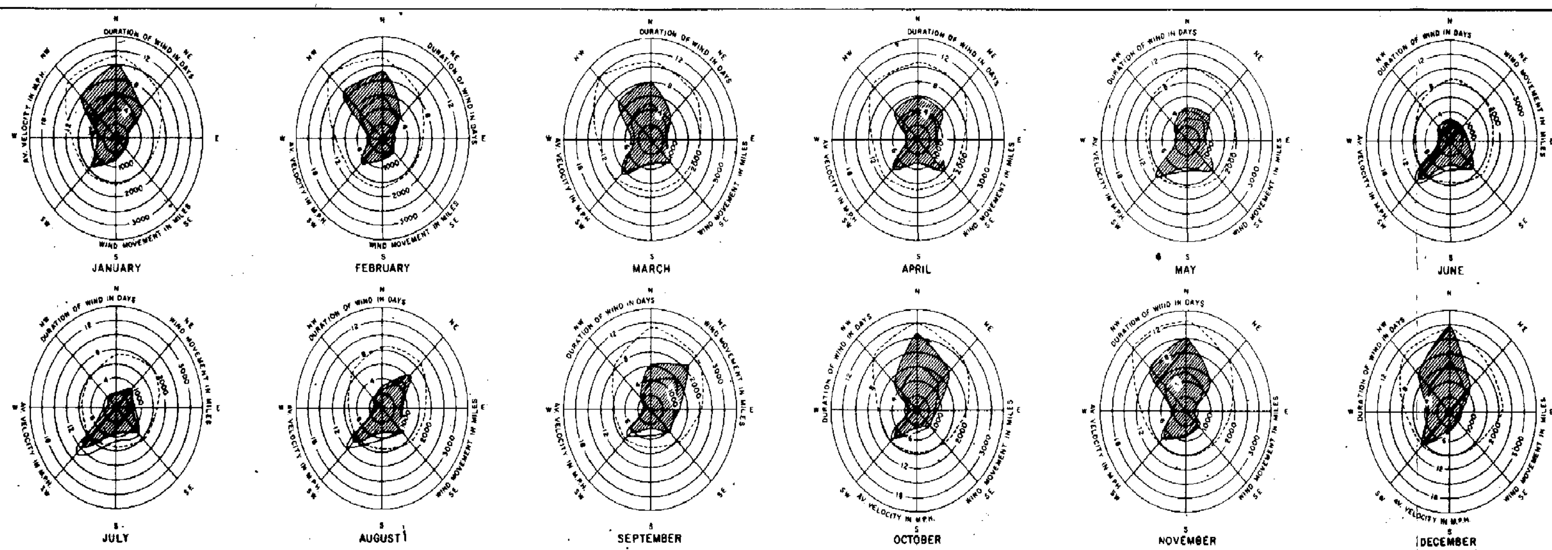
DIRECTION AND VELOCITY OF WINDS

Direction is indicated by arrows, velocity by widths, and frequency by length of shaded lines.
Length of shaded lines indicates number of days duration in an average month.
Data obtained from U.S. Weather Bureau, Cape Henry, Va.
Figures outside diagrams denote maximum wind velocities recorded during period 1930-1945.

LEGEND

Velocity Range M.P.H.	Force Beaufort Scale
0 to 7	0 to 2
8 to 18	3 & 4
19 to 31	5 & 6
over 31	7 & over

DIRECTIONAL-DURATION WIND ROSES
MONTHLY LONG-TERM AVERAGE
16 YEARS: 1930-1945



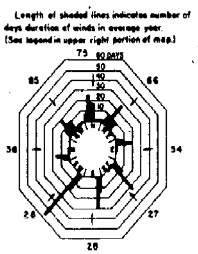
Dynamic wind roses shown hereon represent average monthly values based on 16 years of record of the U.S. Weather Bureau's Cape Henry Station for the period 1930-1945.

LEGEND

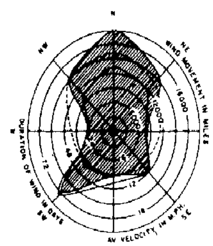
Average velocity in M.P.H.
Duration of wind in days
Wind movement in miles

DYNAMIC WIND ROSES
MONTHLY LONG-TERM AVERAGE
16 YEARS: 1930-1945

Length of shaded lines indicates number of days duration of winds in average year. (See legend in upper right portion of map.)



DIRECTIONAL-DURATION WIND ROSE
AVERAGE YEAR
16-YEAR PERIOD: 1930-1945



DYNAMIC WIND ROSE
AVERAGE YEAR
16-YR PERIOD: 1930-1945

FREQUENCY IN DAYS PER 100 YEARS OF WINDS OVER 45 M.P.H.

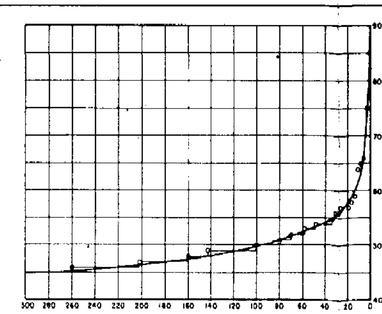
Velocity in M.P.H.	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	64	65	66	75	85
Number of observed days	17	22	19	6	17	7	4	5	4	6	1	2	4	1	1	1	1	1	1	1
Number of days wind velocity equalled or exceeded velocity shown on top line	121	104	82	63	57	40	33	29	24	20	14	13	11	7	6	5	4	3	2	1
Frequency in days per 100 years	297	228	184	142	120	98	78	62	50	42	33	27	23	20	16	9	8	7	3	1

FREQUENCY BY MONTHS OF WINDS OVER 45 M.P.H.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number of observed days	21	17	16	8	3	6	6	11	10	6	7	10
Frequency in days per 100 years	53	41	37	20	7	15	15	27	25	15	17	25

FREQUENCY BY DIRECTIONS OF WINDS OVER 45 M.P.H.

Direction	N	NE	E	SE	S	SW	W	NW
Number of observed days	36	28	5	0	0	0	0	52
Frequency in days per 100 years	88	69	12	0	0	0	0	128



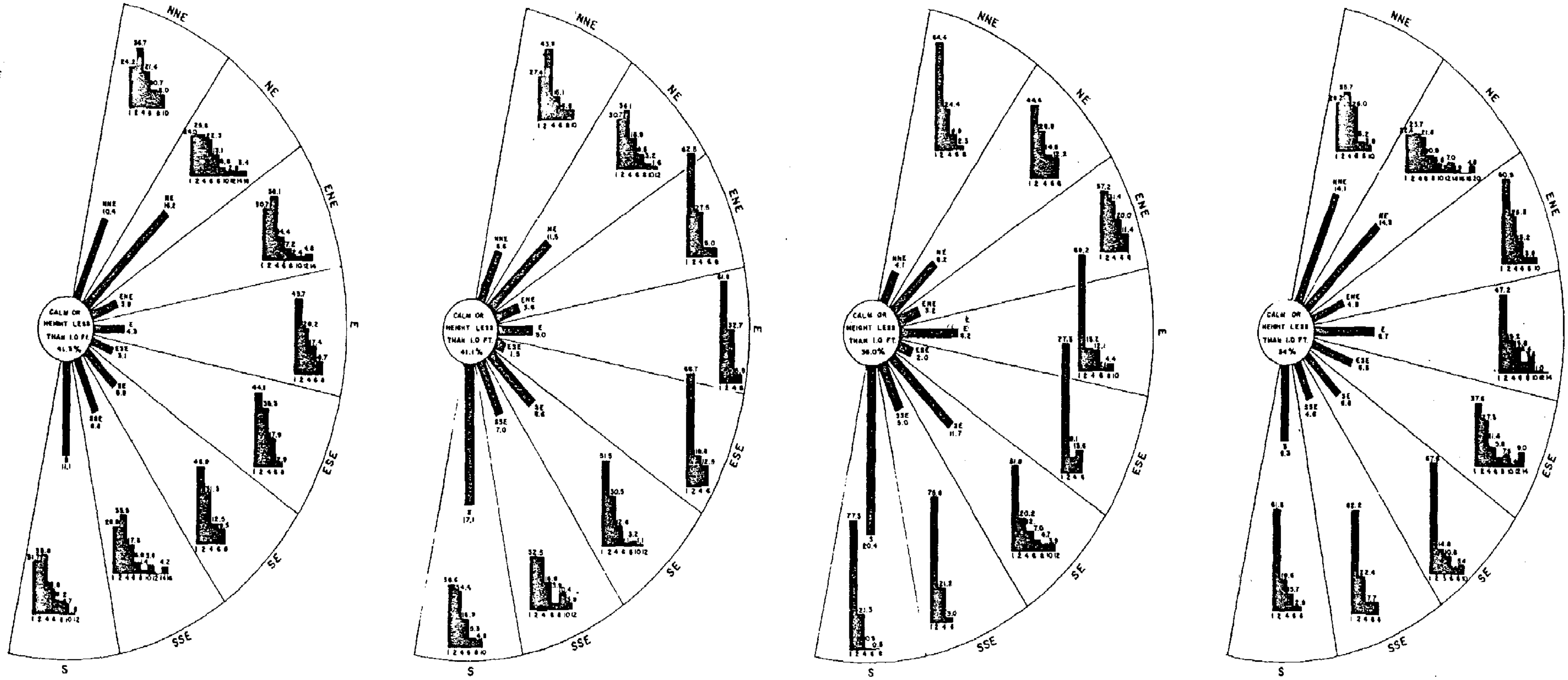
NOTE:
Wind frequencies shown hereon were developed from 40 years of record covering the period 1906-1945, incl.

VIRGINIA BEACH, VIRGINIA

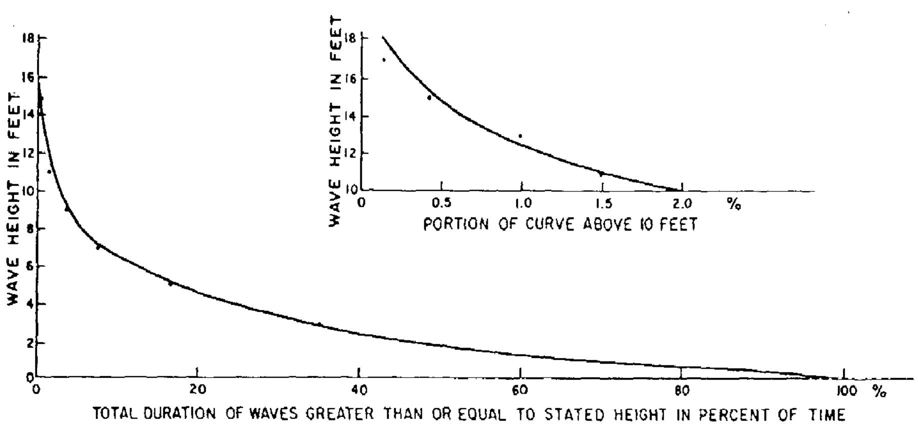
WIND ROSE DATA

NORFOLK DISTRICT, CORPS OF ENGINEERS
JANUARY 1983

PLATE C-5



WINTER SPRING SUMMER FALL



NOTES:

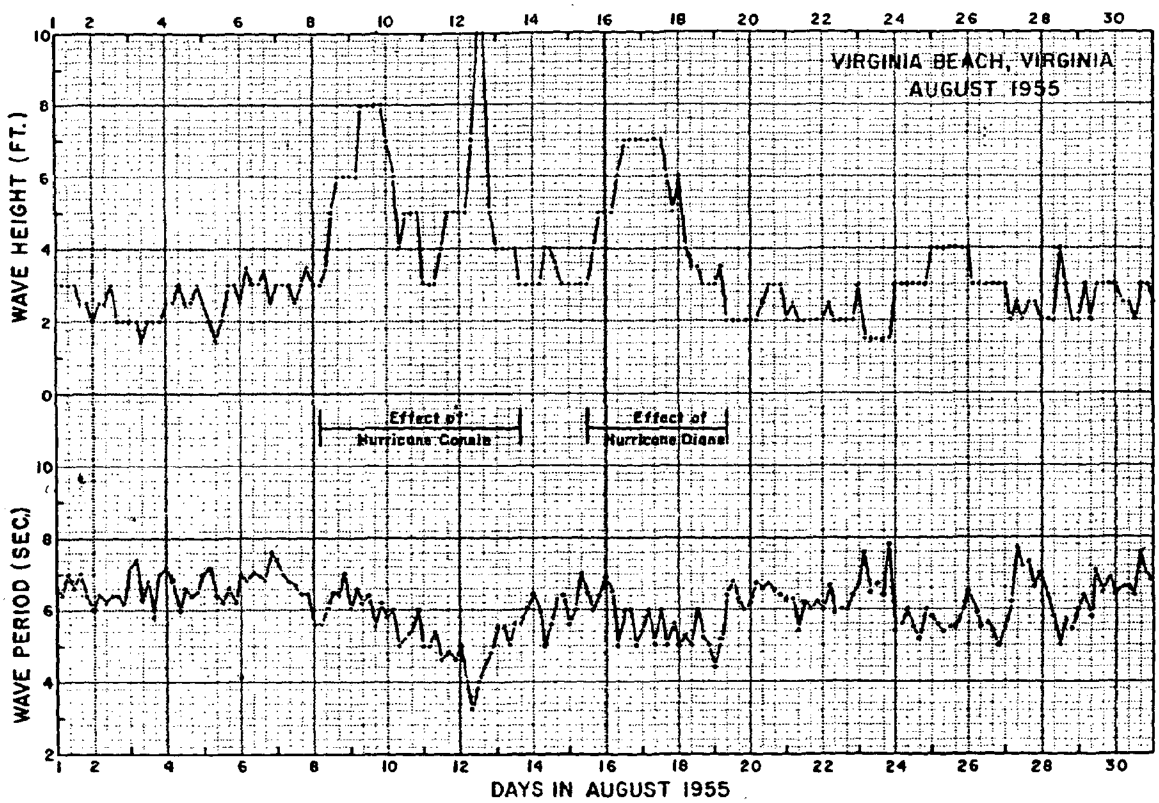
1. *Data hereon based on data contained in BEB Technical Memorandum No. 57, "North Atlantic Coast Wave Statistics Hindcast by the Wave Spectrum Method," Appendix D, Wave Statistics for Station D off Chesapeake Bay Entrance."*
2. *Wind data over a 3-year period, 1947-1949 inclusive, was used as a basis for the hindcast study.*
3. *Wave roses show percentage frequency of wave direction and percentage frequency distribution of significant wave height for each direction.*

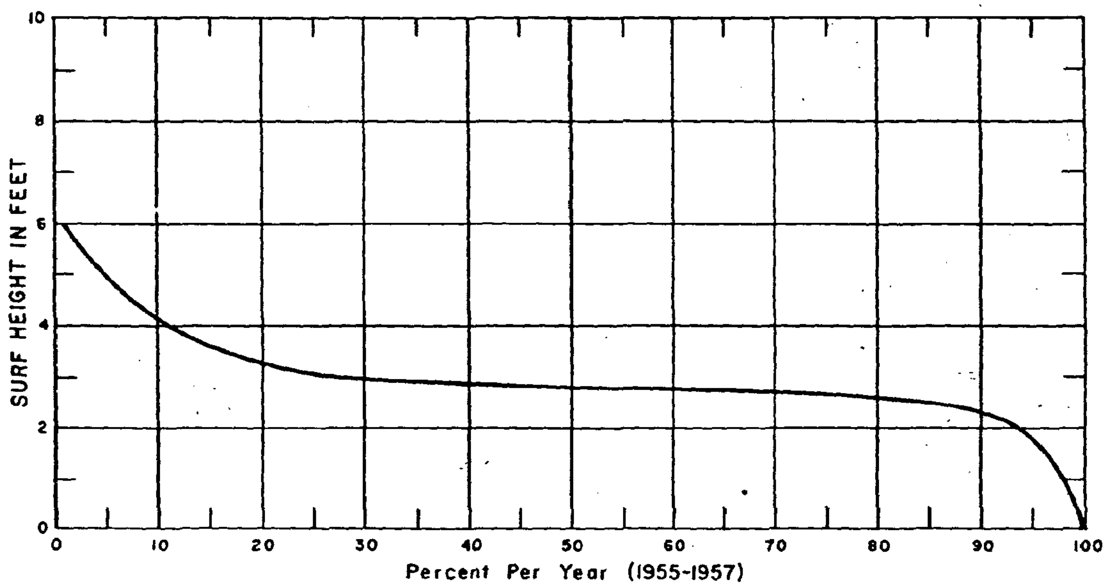
VIRGINIA BEACH, VIRGINIA

WAVE ROSE DATA BY SEASONS

NORFOLK DISTRICT, CORPS OF ENGINEERS

JANUARY 1983





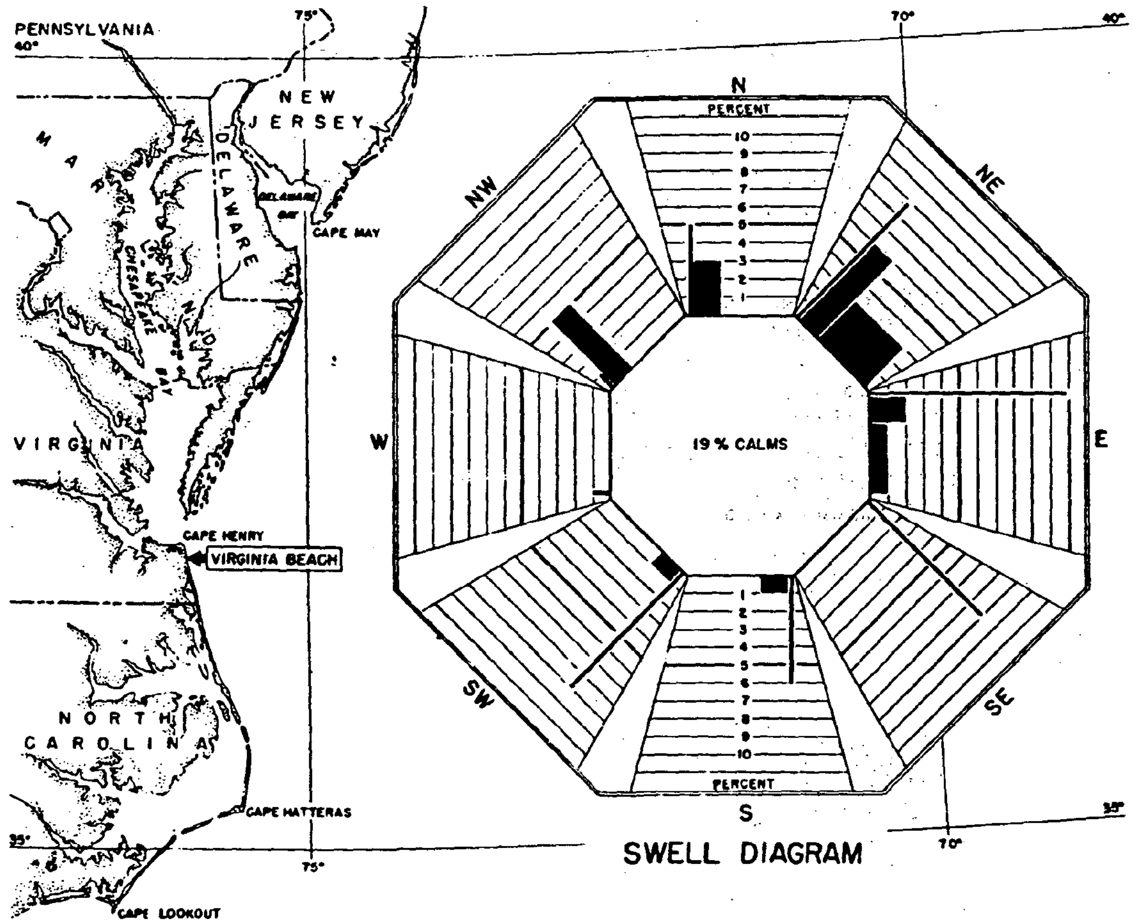
CUMULATIVE FREQUENCY OF SURF FROM ALL DIRECTIONS

NOTE:
Data obtained from CERC's T.M. No. 108, "Surf Statistics for the Coasts of the United States."

VIRGINIA BEACH, VIRGINIA

SURF DATA

JANUARY 1983
NORFOLK DISTRICT, CORPS OF ENGINEERS



SWELL DIAGRAM

IN THE SWELL DIAGRAM THE LENGTH OF THE BAR DENOTES THE PERCENT OF THE TIME THAT SWELLS OF EACH TYPE HAVE BEEN MOVING FROM OR NEAR THE GIVEN DIRECTION. THE FIGURE IN THE CENTER OF THE DIAGRAM INDICATES THE PERCENT OF CALMS.

LOW SWELLS (1—6 FEET)
MEDIUM SWELLS (6—12 FEET)
HIGH SWELLS (OVER 12 FEET)

WIDTH OF BARS HAVE BEEN WEIGHTED IN PROPORTION TO THE SWELL HEIGHT SQUARED.

THE SWELL DIAGRAM SHOWN ABOVE APPLIES TO THAT PORTION OF THE ATLANTIC OCEAN BETWEEN LATITUDE 35° AND 39° NORTH AND FROM THE SHORE EASTWARD TO THE 70 TH. MERIDIAN WEST.

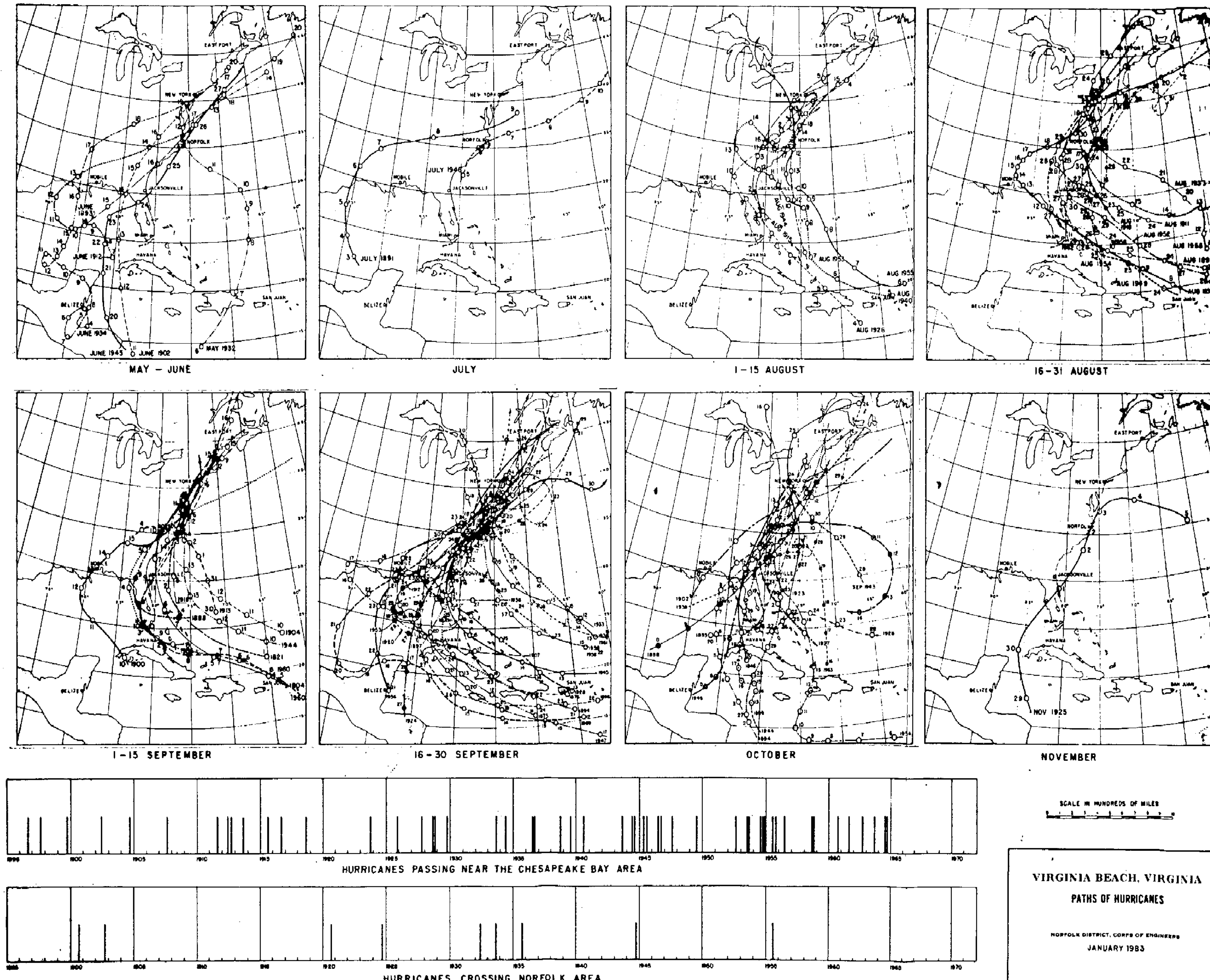
VIRGINIA BEACH, VIRGINIA

SWELL DIAGRAM

NORFOLK DISTRICT, CORPS OF ENGINEERS

JUNE 1969

FILE: H-31-10-44

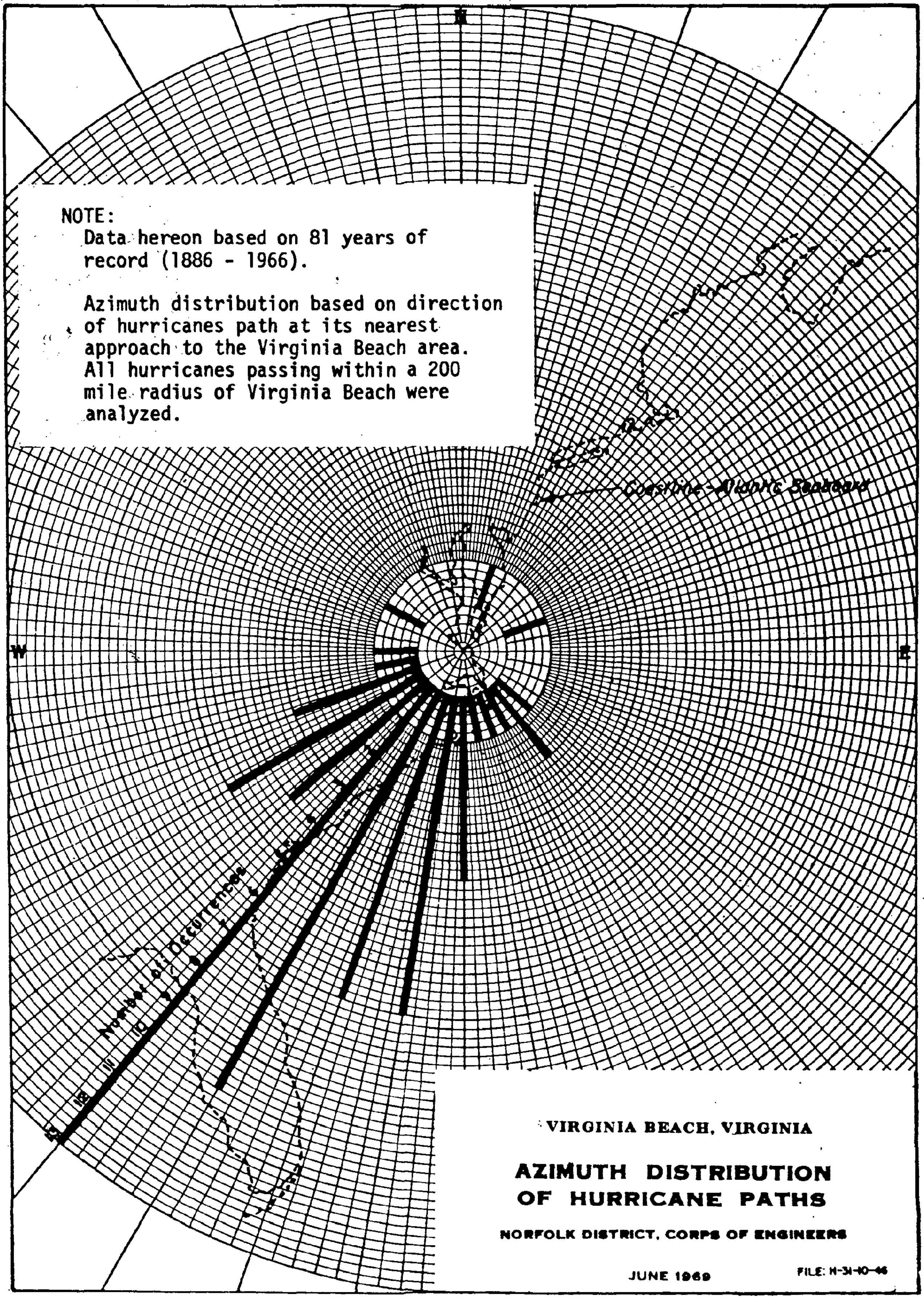


VIRGINIA BEACH, VIRGINIA

PATHS OF HURRICANES

NORFOLK DISTRICT, CORPS OF ENGINEERS

JANUARY 1983



NOTE:
Data hereon based on 81 years of record (1886 - 1966).

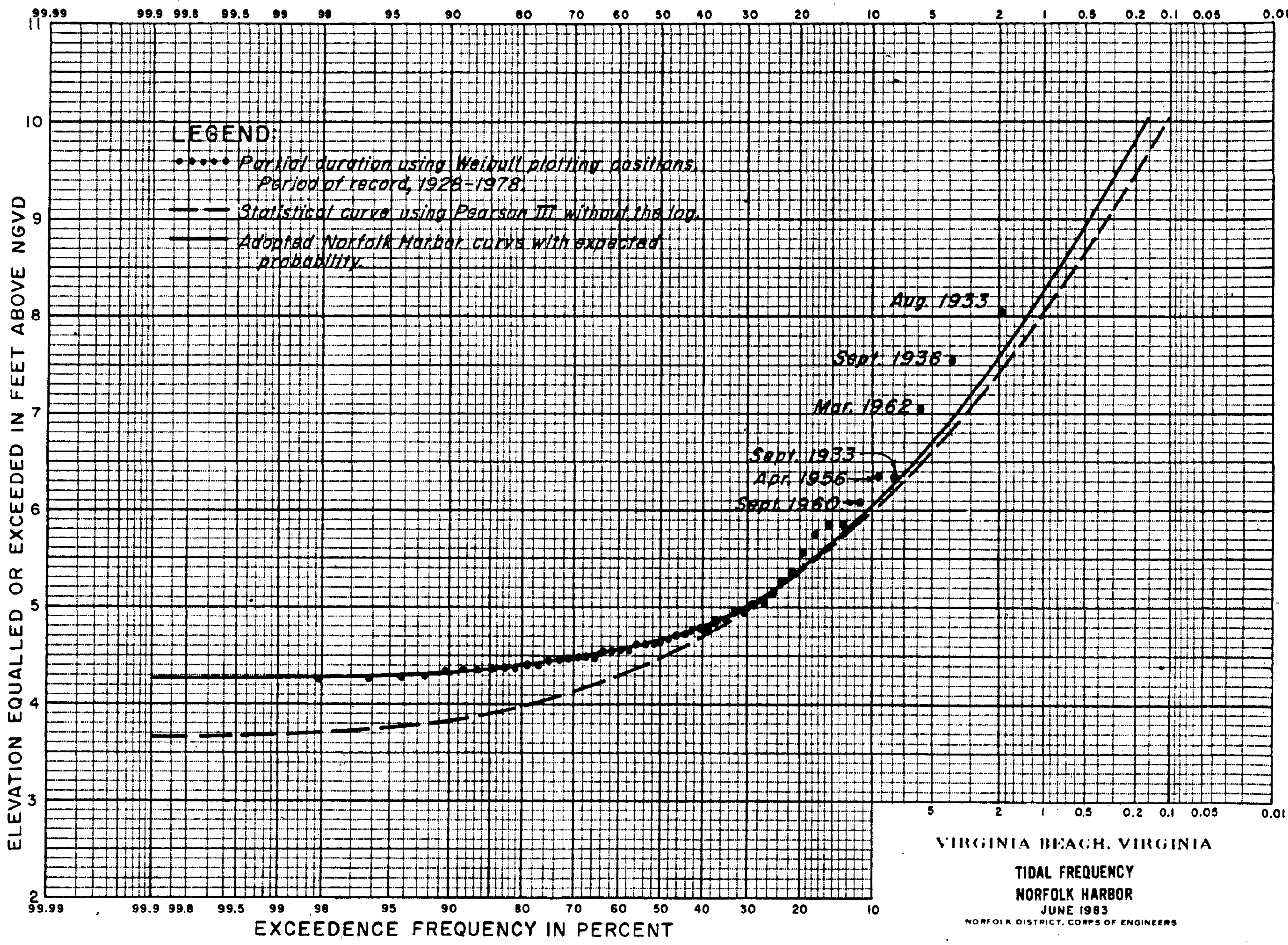
Azimuth distribution based on direction of hurricanes path at its nearest approach to the Virginia Beach area. All hurricanes passing within a 200 mile radius of Virginia Beach were analyzed.

VIRGINIA BEACH, VIRGINIA

AZIMUTH DISTRIBUTION OF HURRICANE PATHS

NORFOLK DISTRICT, CORPS OF ENGINEERS

JUNE 1969 FILE: H-31-10-46



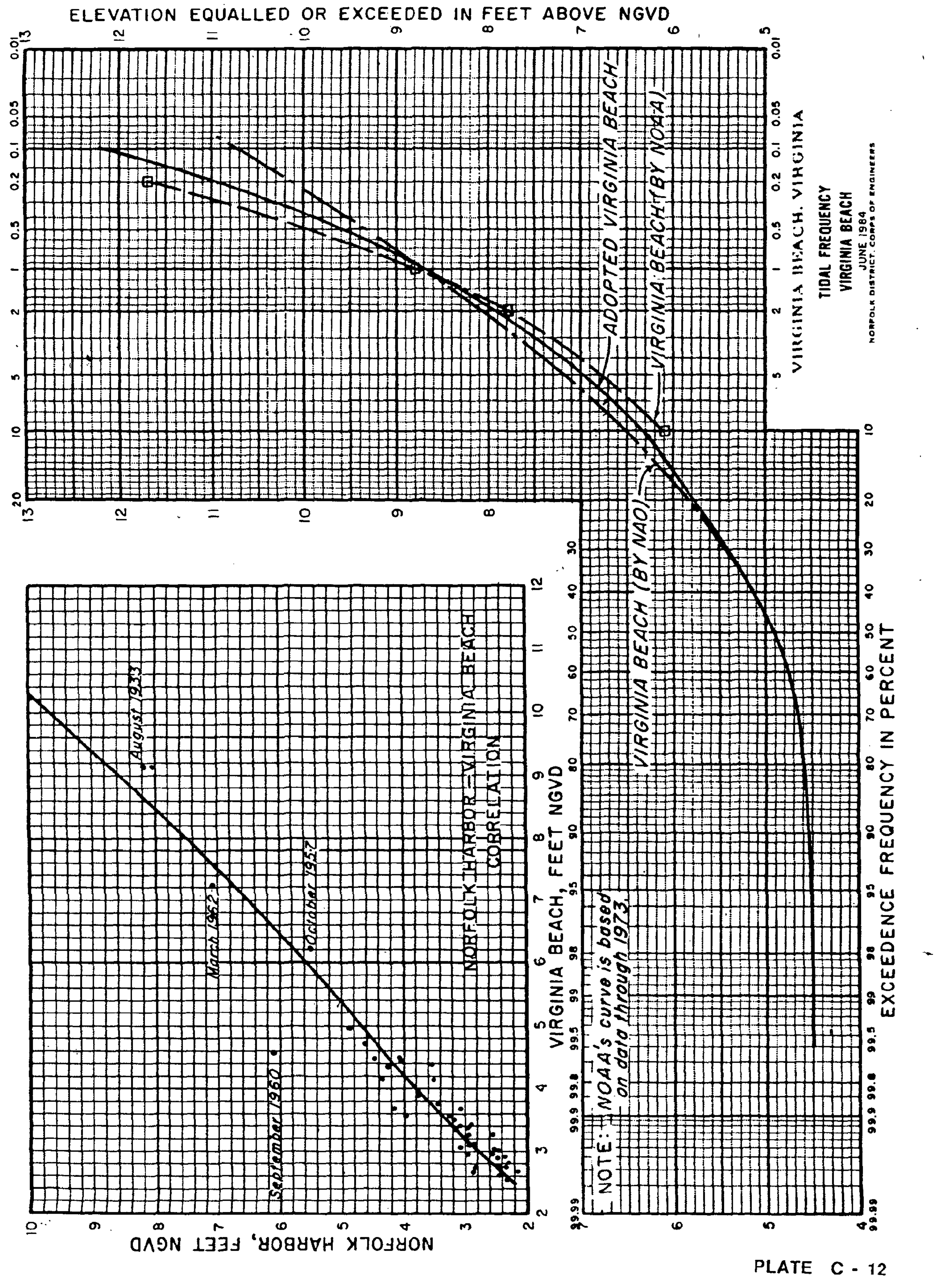
VIRGINIA BEACH, VIRGINIA

TIDAL FREQUENCY

NORFOLK HARBOR

JUNE 1983

NORFOLK DISTRICT, CORPS OF ENGINEERS


ELEVATION EQUALLED OR EXCEEDED IN FEET ABOVE NGVD
ADOPTED VIRGINIA BEACH
VIRGINIA BEACH (BY NOAA)
VIRGINIA BEACH (BY NAO)
VIRGINIA BEACH, VIRGINIA
TIDAL FREQUENCY
VIRGINIA BEACH
JUNE 1984
NORFOLK DISTRICT, CORPS OF ENGINEERS
EXCEEDENCE FREQUENCY IN PERCENT
NOTE: NOAA's curve is based on data through 1973.
NORFOLK HARBOR—VIRGINIA BEACH CORRELATION
VIRGINIA BEACH, FEET NGVD
NORFOLK HARBOR, FEET NGVD
August 1933
March 1962
October 1957
September 1960

APPENDIX D

PERTINENT CORRESPONDENCE

APPENDIX D

PERTINENT CORRESPONDENCE

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COMMONWEALTH of VIRGINIA

Virginia Port Authority
600 World Trade Center
Norfolk, Virginia 23510
Cable Address Vastports
Telephone (804) 623-8000
Telecopier (804) 623-8500
TWX 710 8811231

J. Robert Bray
Executive Director

April 12, 1988

Colonel J. J. Thomas
District Engineer
U.S. Army Corps of Engineers
803 Front Street
Norfolk, Virginia 23510-1096

Dear Colonel Thomas:

Based on correspondence received on April 7, 1988, from the City of Virginia Beach, I hereby request, on behalf of the Virginia Port Authority and the Commonwealth of Virginia, that Section 933 (of the Water Resources Development Act of 1986) studies be initiated for the placement of sand as requested by the City, as part of the 55-foot Outbound Channel Project. I would ask that you evaluate Thimble Shoal Channel as the sand source for the beach west of Ocean Park, the Resort Strip and the Fort Story stockpile site and the Atlantic Ocean Channel as the sand source for the Resort Strip, Sandbridge Beach and the Fort Story stockpile site.

It is my understanding you will provide a cost and time analysis for each proposed study site so that Virginia Beach may consider whether to proceed with any or all of the studies.

Sedimentological and survey data is available for most of the Virginia Beach sites. Jack Frye shall forward the most current data shortly.

If you have any questions, please feel free to call.

Sincerely,

J. Stanley Payne, Jr.
Deputy Executive Director
and General Counsel

cm

City of Virginia Beach

OFFICE OF THE CITY MANAGER
(804) 427-4242

MUNICIPAL CENTER
VIRGINIA BEACH, VIRGINIA 23456-9002

June 27, 1988

Mr. Jack E. Frye
Shoreline Programs Manager
Post Office Box 1024
Glouster Point, Virginia 23062

Dear Jack,

Thank you for your recent letter concerning Section 933 evaluations. The City wishes the Corps of Engineers to proceed with the three studies mentioned in your letter. These are as follows:

Beach Segment	Estimated Study Costs
Resort Strip	$ 43,000
Sandbridge Beach	$213,000
Chesapeake Bay Bridge-Tunnel to Ocean Park	$176,000

As your letter stated, Section 933 of the Water Resources Development Act 1986 and Corp's policies and regulations would allow for Corps participation in 50% of the cost of sand placement on these beaches. This would be in lieu of overboard disposal, and the cost would be the incremental cost above overboard disposal. Further, we understand if the studies do not result in placement of material on the beach, study costs will be absorbed by the Federal Government.

I believe under the current schedule, the studies will take approximately eighteen months and it will be 1990-1991 before the dredging begins.

Thank you for your assistance in rebuilding the beaches of the City. Please contact me if I can provide you with any further information.

Your truly,

Aubrey V. Watts, Jr.
City Manager

AVW/RRM:pah

cc: The Honorable Mayor
Members of Council
Robert Matthias
E. Dean Block
C. Oral Lambert
Carl Thoren
Don Williams

COMMONWEALTH of VIRGINIA

Virginia Port Authority
600 World Trade Center
Norfolk, Virginia 23510
Cable Address Vastports
Telephone (804) 623-8000
Telecopier (804) 623-8500
TWX 710 8811231

J. Robert Bray
Executive Director

June 30, 1988

Colonel J. J. Thomas
District Engineer
U. S. Army Corps of Engineers
803 Front Street
Norfolk, Virginia 23510-1096

Dear Colonel Thomas:

Based on the enclosed letter received June 29, 1988 from the City of Virginia Beach, I hereby request, on behalf of the Commonwealth of Virginia, that Section 933 (of the Water Resources Development Act of 1986) studies be initiated for the placement of sand on the Resort Strip, Sandbridge Beach and on the beach between the Chesapeake Bay Bridge-Tunnel and Ocean Park.

Please feel free to call me if anything further is required.

Sincerely,

Jack E. Frye
Jack E. Frye
Shoreline Programs Manager

enclosure

cc: Aubrey V. Watts, Jr., City Manager,
City of Virginia Beach
Robert R. Matthias, Intergovernmental Relations Coordinator,
City of Virginia Beach
J. Stanley Payne, Deputy Executive Director and General Counsel,
Virginia Port Authority
B. C. Leynes, Jr., Director,
Department of Conservation and Historic Resources
Roland B. Geddes, Director,
Division of Soil and Water Conservation
Suzette M. Kimball, Marine Scientist,
Virginia Institute of Marine Science

APPENDIX E

FISH AND WILDLIFE COORDINATION ACT PLANNING AID REPORT

FISH AND WILDLIFE COORDINATION ACT

PLANNING AID REPORT

ENVIRONMENTAL EFFECTS OF BEACH NOURISHMENT AT NINE SELECTED VIRGINIA BEACHES

ANALYSIS OF THE ARMY CORPS OF ENGINEERS PLANS

Prepared for:

U.S. Army Corps of Engineers
Norfolk District
Norfolk, Virginia 23510

Prepared by:
Elizabeth Block, Wildlife Biologist

Under Supervision of:

John P. Wolflin, Supervisor
Annapolis Field Office
U.S. Fish and Wildlife Service
Annapolis, Maryland
and
Karen Mayne, Assistant Supervisor
Gloucester Point Field Office
U.S. Fish and Wildlife Service
White Marsh, Virginia

July 1989

Title: Fish and Wildlife Coordination Act Planning Aid Report, Environmental Effects of Beach Nourishment at Nine Selected Virginia Beaches, Analysis of the Army Corps of Engineers Plans

Elizabeth Block
July 1989

Abstract: The Army Corps of Engineers plans to dredge the Thimble Shoal and Atlantic Ocean Channels, Virginia between October 1990 and September 1993. The Commonwealth of Virginia has requested that suitable beach quality material be placed on up to nine Virginia beaches under Section 933 of the Water Resources Development Act of 1986. This act creates provisions for one-time use of dredged material for beach nourishment. The purpose of this report is to assess potential impacts of nourishment at these beaches to fish and wildlife resources and to make recommendations which would reduce impacts.

The nine beaches are located on the western shore of the mouth of Chesapeake Bay and on the Atlantic coast, south of the Bay, Virginia. Existing information was used to document past and current conditions and uses of beaches, and likely impacts to fish and shellfish resources, endangered species, and the nearshore ecosystem in general.

Probable impacts to nearshore biota include burial, lethal or sublethal effects of increased turbidity (reduction of dissolved oxygen, light penetration, and photosynthesis; disruption of predator-prey interaction; and clogging of gills and filter feeding structures), possible exposure to contaminants in dredged material, and changes in physical conditions such as beach slope, and particle size. Previous research indicates that most negative effects of beach nourishment are temporary, and the community would be expected to recover within a few years. Bioassay tests showed that toxicity of sediment from the two channels is not a concern. In general, effects to fish and wildlife at several of the proposed nourished beaches is of less concern because the beaches have been periodically nourished in the recent past.

Effects to endangered species are of concern for a few of the beaches. Loggerhead and Atlantic ridley turtles are summer residents of Chesapeake Bay. Loggerhead nesting is known to occur infrequently at two of the beaches. A nesting colony of piping plovers is adjacent to another proposed nourishment beach.

Times of year and specific nourishment methods were recommended for reducing effects to nearshore biota. We also recommended that one beach, Grandview Natural Preserve, not be nourished so that the ecological integrity of this natural area can be maintained.

Key words: Beach nourishment, dredging, turbidity, loggerhead turtles, piping plovers, Sandbridge Beach, Virginia Beach, Ocean Park Beach, Willoughby Beach, Buckroe Beach, Salt Ponds Beach, White Marsh Beach, Grandview Natural Preserve, Yorktown Beach, Thimble Shoals Channel, Atlantic Ocean Channel.

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INTRODUCTION

The Commonwealth of Virginia has requested that the U.S. Army Corps of Engineers (Corps) place dredged material on nine Virginia beaches to reestablish beach area lost to erosion and to provide storm protection for coastal developments. This report outlines the U.S. Fish and Wildlife Service's (Service) concerns for impacts to fish and wildlife resources which can be expected as a result of beach nourishment. This planning aid report has been prepared in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) which requires the Service to assess potential impacts of proposed Federal projects on fish and wildlife resources. Impacts were assessed based on existing information and qualitative on-site examination.

Dredged material for beach nourishment will come from the deepening of the Thimble Shoal and Atlantic Ocean Channels (Figure 1), and dredging is scheduled to occur between October 1990 and September 1993. Probable impacts of dredging for borrow material to fish and wildlife resources in the vicinity of the Atlantic Ocean Channel have been documented by U.S. Fish and Wildlife Service (1982), and similar impacts would occur during dredging of the Thimble Shoal Channel. Effects to aquatic resources at dredge sites will not be considered in this report.

Much of the dredged material will be released at the Dam Neck Ocean Disposal Site (Figure 1). The Commonwealth of Virginia has requested that dredged material of suitable beach quality be placed on nine Virginia beaches under Section 933 of the Water Resources Development Act of 1986. This act creates provisions for one-time use of dredged materials for beach nourishment with the following stipulations. The project must be requested by the State, be environmentally acceptable, and the beach must be open to the public. The added cost of beach disposal must be justified by the benefits associated with protection of the beach, and 50% of the added cost must be paid for by local interests. The nine beaches are (from south to north, Figure 1):

- Sandbridge Beach - Dam Neck Naval Station to Back Bay National Wildlife Refuge
- Virginia Beach (Resort Strip) - Rudee Inlet to 49th Street
- Ocean Park Beach - Chesapeake Bay Bridge Tunnel to Lynnhaven Inlet
- Willoughby Beach - Mason Creek Road to Lea View Avenue
- Buckroe Beach - Buckroe Fishing Pier to Pilot Avenue
- Salt Ponds Beach - private property line north to Salt Ponds Inlet
- White Marsh Beach - Salt Ponds Inlet to Grandview Fishing Pier
- Grandview Natural Preserve - private property line north to Factory Point
- Yorktown Beach - Post Office 1,330 feet to existing stone breakwater

The first section of this report gives background information on the dredge sites. As the nearshore habitats at all of these beaches are similar, the next two sections consider impacts from beach nourishment activities in general, and impacts to fisheries specifically. The sections following give specific information on each beach considered for nourishment including special considerations such as endangered species. The final

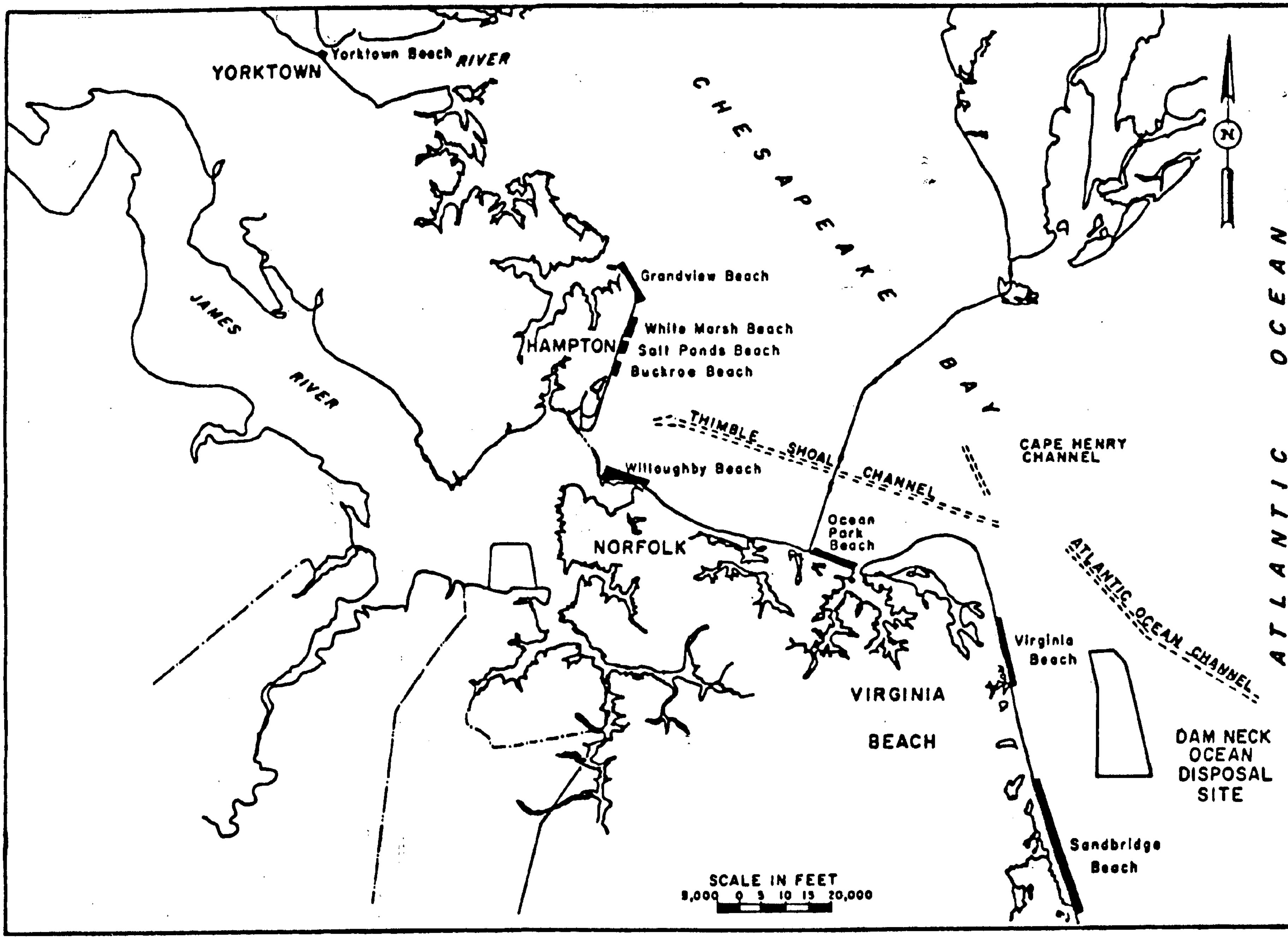

Figure 1. Location of nine beaches proposed to receive one-time nourishment during dredging of Atlantic Ocean and Thimble Shoal Channels.

section gives recommendations for reducing or avoiding impacts to wildlife resources.

DREDGE SITES

Channel deepening will proceed under the U.S. Army Corps of Engineers, Norfolk District, Norfolk Harbor and Channels Project scheduled to take place between October 1990 and September 1993. The Atlantic Ocean Channel will be constructed to a depth of 60 feet. Preliminary investigation of the sediments show that sand suitable for beach nourishment projects are located in the eastern two-thirds of the channel. The area was recommended as one of the most likely borrow areas in a previous study (U.S. Army Corps of Engineers 1984). Fines contained in the coarse grained sediment vary from 0.8 to 38.0 percent with an average of 12.4 percent. It is estimated that over 10,000,000 cubic yards of sandy material is located in this area of the channel (Swean 1986a). Geotechnical investigations have determined that the Atlantic Ocean Channel material has a high degree of similarity to the material on the berm and nearshore areas of the Virginia Beach oceanfront. Information on the degree of similarity with sand at other proposed locations is unavailable at this time.

The Thimble Shoal Channel was deepened to 50 feet in 1988 and may be further deepened to 55 feet under the Norfolk Harbor and Channels project. During an earlier maintenance dredging of this channel, dredged material from the eastern portion was stockpiled at Fort Story in 1974 and then hauled to Virginia Beach oceanfront. Later channel maintenance did not remove sufficient quantities of beach quality sand for economically feasible nourishment, and dredged material was taken to the Dam Neck Disposal Site. Swean (1986b) estimated that 3,000,000 cubic yards of suitable material is located in the eastern portion of the channel containing an average of 29.3 percent fines. Sand from the east end of the Thimble Shoal Channel (east of the Chesapeake Bay Bridge Tunnel) is exceptionally compatible with original material from Ocean Park, Virginia Beach, Sandbridge, Buckroe, and Ocean View (near Willoughby) beaches (Suzette Kimball, personal communication). The extreme eastern area of the channel is characterized by fine grained sediments (Swean 1986b) and is not appropriate for beach nourishment.

IMPACTS OF BEACH NOURISHMENT

The sandy beach is an inherently unstable system. The face of the beach is constantly changing in response to the ebb and flow of tides. Changes in current, wind, and wave energy or direction can move sand to or from any part of the beach and offshore area. Natural beaches are generally backed by dune systems which are said to stabilize the beach. However, the dunes are also part of the shifting equilibrium of sand on a longer time scale.

Sandy beaches and associated nearshore areas are quite inhospitable. Living creatures in these habitats can be exposed to wide ranges of temperature, moisture, and salinity in addition to the mechanical impacts of pounding surf. Cover is limited, and the sandy substrate is unstable. These areas were once considered to be relatively devoid of life. While the number of species is low, the organisms which have adapted to the difficult conditions often occur in high numbers.

The sandy beach can be divided into three habitats on the basis of physical conditions. The beach zone is above the reach of the high tide and inhabitants include ghost crabs (Ocypode quadrata) and sand fleas (Talitridae). The area of the beach zone habitat would be most extended by nourishment activities.

The surf zone starts at the high tide mark and includes the areas of breaking waves. Dominant organisms are mole crabs (Emerita talpoida) and coquina clams (Donax spp.). Species are generally small and well adapted to burrowing or digging. One of the physical characteristics of this habitat, the profile (slope), is created by wave and tide energy and direction. The profile is perhaps most susceptible to alteration by beach nourishment. Filling activities should attempt to recreate the profile to maintain similar habitat areas. More natural beach profiles can also be maintained by reducing or avoiding the use of heavy earth moving equipment and allowing the material to redistribute naturally.

The nearshore zone beyond the surf is more stable and supports a correspondingly greater diversity of organisms including those that migrate from deeper water to feed. Sport fish and shellfish can be abundant, and the area is used for migration by some species of juvenile fish. Organisms in this zone are less well adapted to disturbances, so may be more adversely impacted by beach nourishment.

The immediate effect of beach nourishment would be burial by transported sand. Fish and other more mobile creatures would probably leave the area and so would be less affected. As most of the surf zone species are adapted to burrowing, effects of burial would be somewhat minimized. Maurer et al. (1978) found that some benthic animals were able to migrate vertically through more than 30 cm of sediments. The smaller organisms and interstitial dwellers would be most affected by burial. As these creatures form the base of the detrital food chain in this area, reduction of higher order consumers is also a possibility. Effects from burial can be minimized by applying dredged material in the winter after adult clams and mole crabs have migrated offshore (Reilly and Bellis 1978).

Increases in turbidity are a major concern for the health of the biota. The effects of turbidity will depend on the mechanical methods used to spread sand on beaches, the amount of fines in the dredged material, and other conditions which modify settling rates including water currents. Increased turbidity has been shown to have several effects on physical conditions in the water column. Reduction in light penetration will affect photosynthetic organisms. Results from studies with phytoplankton have ranged from no effect to both reduced and increased photosynthesis, the latter can possibly be attributed to increased nutrient availability (Priest 1981). Most previous research found that drastic reduction in primary productivity was seldom observed and was short-lived in duration (reviewed in Morton 1977). Changes in light penetration may also change the temperature of the water column.

Decreases in dissolved oxygen in the water column result from physical rearrangement of sediment from a deposited to a suspended state (U.S. Fish and Wildlife 1987) and from the exposure of previously buried anoxic sediments. Suspension of organically rich sediments may also decrease dissolved oxygen. At open ocean dredge disposal sites, decreases in dissolved oxygen due to turbidity have been found to be small and relatively short-lived, but some studies reported substantial decreases of 1-2 milligrams per liter which might affect species with a narrow tolerance range (Priest 1981). During beach nourishment, wave action and dispersion by currents and tides will quickly reduce effects of depleted oxygen.

Resuspension of sediment and organic matter in the dredged material will result in increased nutrient levels in the water column. Increased nutrient availability can result in biotic stimulation or overstimulation and associated problems such as plankton blooms. Changes in physical conditions of the water column can produce synergistic effects. In a worst case scenario, dissolved oxygen could be reduced by suspended sediments, further decreased by the biological oxygen demand of bacteria stimulated by excess nutrients, and not replenished by photosynthetic organisms inhibited by reduced light penetration.

Turbidity may affect organisms in several ways. Settling of sediments may bury sedentary nonburrowing species. Suspended matter can clog gills and filter feeding structures which could directly cause death or reduce energy efficiency and cause indirect effects such as reduced reproduction or ability to avoid predation (Sherk 1971). The migration of larvae from the planktonic to the benthic community is disrupted by high turbidity (Reilly and Bellis 1978). Post-nourishment community recovery time would be slowed and possible effects to higher order consumers may occur. Suspended or settled sediments may also adversely impact spawning of certain commercial and recreational fish species. Turbidity could affect predator/prey behavior by reducing effectiveness of vision and other senses. The Federally threatened loggerhead turtles (Caretta caretta) may have an increased likelihood of becoming entangled and drowned in pound nets in high turbidity conditions. The loggerhead is a summer resident to Chesapeake Bay and the Atlantic coast. The Federally endangered Atlantic ridley turtle (Lepidochelys kempi) is also a summer resident and may be adversely affected by increased turbidity.

Tests with several life stages of oysters (Crassostrea virginica) and hard clams (Mercenaria mercenaria) indicate that lethal levels of suspended solids are much greater than levels found during most dredging projects (Haven et al. 1981). Four species of fish were exposed to high levels of turbidity. The effects to adults were minimal, eggs experienced a slight delay in hatching, and the lethal concentration of suspended particles for fish larvae were in excess of anticipated dredging levels (Priest 1981). In studies reviewed by Morton (1977), fish tolerance to turbidity varied widely by species.

Effects from increased turbidity will be less for a beach nourishment project than for open ocean disposal, as material suitable for placement on the beach is necessarily larger grained and contains fewer fines. During beach nourishment, dispersal by currents and tides act to reduce effects of turbidity. Water quality effects are generally quickly diluted, but Naqvi and Pullen (1982) caution that cellular circular patterns in nearshore areas may extend recovery time. Several authors believe that turbidity effects will be short-term and of minor impact (Thompson 1973, Naqvi and Pullen 1982).

An additional consideration in resuspension of sediments is increased bioavailability of metals and a variety of other persistent contaminants. Very low levels of contaminants may not directly and immediately affect adults but could cause chronic problems. Developmental stages of all organisms are especially sensitive. Rule (no date) tested sediment samples from the Thimble Shoal Channel for metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn). Levels of all metals were below or only slightly above average crustal abundance, although the inner channel did have consistently slightly higher levels than the outer channel. Bioassay tests have been performed with sediment from the Thimble Shoal Channel by Alden and Young (1984), and results indicated that toxicity was not a concern.

Changes in grain size and makeup as a result of beach nourishment may affect substrate specific species, possibly resulting in community level changes, particularly of the interstitial community. Currently, little is known about how sand quality affects the loggerhead turtle's choice of nesting beaches. Naqvi and Pullen (1982) suggested that compactibility of sand may be important, and Keinath (personal communication) believes that sand which is too coarse or too fine would discourage nesting. A study in Imperial Beach, California found that sediments were rapidly sorted and that grain-size distribution was comparable to pre-nourishment conditions after about four months (Parr et al. 1978).

Recovery of the communities of nearshore organisms will depend on factors such as time of year, size of the nourishment project, amount of time between subsequent nourishment projects, and type of community. Naqvi and Pullen (1982) stated that communities are likely to recover rapidly due to high reproductive potential and recruitment from planktonic larvae and mobile macrofauna from nearby unaffected areas. However, Reilly and Bellis (1979) found that recovery was affected by failure of adult intertidal organisms to return from offshore overwintering areas, reductions in organism densities on adjacent unnourished beaches, and inhibition of pelagic larval recruitment. Reports on recovery rates vary from several tidal cycles to up to 18 years for small, nonmotile meiofauna (Rogers and Darnell 1973). Hayden and Dolan (1974) found that the mole crab population at a nourishment site recovered within a few tidal cycles. However, mole crabs are perhaps the best adapted of the beach community to recover from such disturbances. Reilly and Bellis (1979) concluded that recovery should take place within one or two seasons. Several studies found that no long-term damage to fauna had occurred after four to seven years of recovery time (reviewed in Naqvi and Pullen 1982). The community might not recover but change type, from a filter-feeding community to a deposit-feeding community or vice-versa. Repeated nourishment will prevent communities from ever fully recovering.

IMPACTS TO FISH AND SHELLFISH RESOURCES

The Chesapeake Bay, like other estuaries, is very productive, and a variety of finfish, clams, and crabs are harvested commercially according to season and size limits. The area also supports extensive recreational fisheries from public fishing piers, and private and charter boats. Species, numbers, and estimated catch levels for the Hampton Roads area and the lower Chesapeake Bay have been previously reported for the area (Mayne 1979, Hedgepeth et al. 1981, Birdsong no date, Birdsong et al. 1984, no date).

Currently, there are two permanent shellfish closures associated with sewage treatment plants. Little Creek, east of the Willoughby Beach site, is closed for marketing of all shellfish except blue crabs (Callinectes sapidus). Closure extends in a one-mile radius into the Bay. Two square miles off the coast at the U.S. Naval Fleet Anti-Air Warfare Training Center, north of Sandbridge Beach, is closed to shellfish marketing due to effluent from the Atlantic sewage treatment plant. The lower portion of the Chesapeake Bay is closed to crabbing between mid-May and mid-September due to the large number of spawning females in the area.

The nearshore area is important to fish for a variety of reasons. For some species, it provides a nursery area and migration route for juveniles. Anadromous fish also migrate through to reach upstream spawning grounds. Many species come in from deeper water to feed. While fish probably escape the more direct effects of beach nourishment, longer term disruptions to life cycles or movement patterns may take place. Beach nourishment will remove a segment of the prey population for a short time. This could be especially damaging to resident species with specific dietary requirements. Effects to fish resources would be minimized if nourishment took place on smaller segments of beach over a longer time period.

Hard clams are one of the important commercial species in southernmost Chesapeake Bay. Clam beds off the coast of Buckroe Beach had a reported value of $90 per acre at 1981 market prices (Hobbs et al. 1982). Clams could be detrimentally affected by beach nourishment if turbidity was prolonged over the clam beds or if substrate surface conditions were altered to affect larval clam settlement.

PROPOSED BEACH NOURISHMENT PROJECTS

The following sections give the location, description, beach nourishment history, estimated area and volume of added material (provided by the Corps), and specific biological considerations and recommendations for each project location. Previous beach nourishment periods and sources of material have been reported as available, and should not be considered to be complete.

Sandbridge Beach

The project area is located south of Virginia Beach, Virginia between the U.S. Naval Fleet Anti-Air Warfare Training Center and Back Bay National Wildlife Refuge (Figure 1). A permanent and summer residential neighborhood has developed on the narrow neck of land between Back Bay and the Atlantic Ocean. Dunes were destroyed during housing construction or by storms, and current storm protection includes a narrowing beach, and bulkheads and riprap placed by individual homeowners. Recreational use of the beach is fairly heavy during summer months.

Sandbridge Beach has been "nourished" periodically by the bulldozing of sand from the intertidal zone and beach face. Material was placed to rebuild the shoreline after the March 1962 storm. The volume and design of beach nourishment at this area has yet to be determined.

A species of concern in this area is the loggerhead turtle. A nest was found in the Sandbridge area in 1980 and in 1989. The Virginia Beach section below contains more detailed information on concerns for the turtle.

Virginia Beach, Resort Strip

The project area is located in the City of Virginia Beach, Virginia along the Atlantic Coast (Figure 1). The specific area to be nourished is 3.3 miles of oceanfront between Rudee Inlet and 49th Street. The area has a high density of commercial and recreation-oriented development including many high rise hotels, restaurants, and specialty shops catering to a large tourist trade. The beach is heavily used in the summer.

Artificial placement of sand to protect publicly owned portions of Virginia Beach was deemed justifiable as early as 1952. The Corps plan involved placing approximately 1,100,000 cubic yards of sand to widen the beach berm approximately 100 feet at an elevation of seven feet above mean low water and to construct a groin system. Beach restoration was accomplished by local interests in 1953 but the groins have not been constructed to date. The shoreline was also rebuilt after the March 1962 storm. The River and Harbor Act of 1962 authorized Federal participation in the form of one-half of the cost for periodic nourishment of the beach. Local interests acquired dredging equipment and borrow areas, and the beach was nourished annually between Rudee Inlet and 49th Street (U.S. Army Corps of Engineers 1984). Rudee Inlet has also been dredged annually since 1968, and sand bypassed to the downdrift side of the jetties. In 1970, a Corps feasibility report recommended extending protection to include the area between 49th and 89th Streets. Federal participation in this project expired in 1987 and was subsequently extended another 10 years.

The nourishment design calls for 900,000 to 1,200,000 cubic yards of sand to be used to extend the width of the beach berm 100 feet. Biological impacts of nourishment are not a strong concern at this location, as adding material will only continue previous periodic disturbances. Also, the very heavy summer recreational use of the area greatly reduces its value to wildlife.

A species of concern in this area is the federally threatened loggerhead turtle. Virginia Beach is at the northern edge of the breeding beach distribution. The 60-mile stretch of Virginia Atlantic Ocean coastline has an average of two or three nests per nesting season, and two turtles have nested right in front of the hotels on Resort Strip (Musick, personal communication). If material is to be added to beaches during the turtle nesting period, beaches should be examined carefully by trained experts to locate and remove eggs to more suitable beaches. As mentioned previously, sand quality may also be important in maintaining breeding beaches. This is a concern for the Atlantic coastline rather than just at the nourishment sites, as material will be moved with the currents. As with all species, developing turtle eggs are especially sensitive to contaminants which may occur in small amounts in the dredged material. Also, adult loggerheads are particularly sensitive to hydrocarbons, which could be resuspended in the water column during dredging or nourishment activities.

Ocean Park

The project area is located east of U.S. Navy Little Creek Amphibious Base in Norfolk, Virginia (Figure 1). Nourishment would take place along the shoreline between the Chesapeake Bay Bridge Tunnel and the Lynnhaven Inlet. The area is mostly residential with a few small commercial establishments, and the beach is used fairly heavily for recreational purposes in the summer months. Structural protection is provided by a groin system built in 1939. Information on previous nourishment activities was not located for this site. The nourishment design calls for 100,000 to 700,000 cubic yards of material to be placed to create a beach berm 50 to 150 feet wide.

Willoughby Beach

The project area is in the westernmost coastal part of Norfolk, Virginia (Figure 1). The residential area is located on a neck of land extending westward between Chesapeake Bay and Willoughby Bay. Nourishment will take place between Mason Creek Road and Lea View Lane.

Material was first placed on the beach in 1928 during the dredging of the Little Creek Inlet when over 800,000 cubic yards from the Little River was placed to the east and southeast of the new channel. Almost all material placed on the beach has come from dredging of the Little Creek entrance and forebay area with the exception of 20,000 cubic yards of sand from an upland site placed just west of the jetties (Hobbs et al. 1982). A recent city-initiated small fill project was conducted at the eastern extreme of the project area where 22,000 cubic yards of fill was placed in front of a public parking lot threatened with undermining. The volume and design of beach nourishment for this project has yet to be determined.

A location of concern is Sarah Constant Park, to the east of the project area. This preserved natural dune area contains the locally rare live oak (Quercus virginiana) and the only remaining extensive stand of the Virginia pinweed (Lechea maritima var. virginia) in the state. The park probably provides habitat for a variety of nesting birds and other wildlife as well. Beach nourishment would help protect the dunes from storm damage.

Buckroe Beach

The project area is in the City of Hampton and extends from the Buckroe Beach Fishing Pier to Pilot Avenue. Surrounding development is residential with apartment buildings and single family homes. Historically, recreational use was once augmented by an amusement park which was torn down several years ago. This area receives heavy use by beachgoers during the summer.

Buckroe Beach has been nourished periodically in the past. Sand dredged from Willoughby Bank adjacent to Fort Wool was placed here after it was no longer needed for the construction of the second Hampton Roads tunnel (Hobbs et al. 1982). The City of Hampton was issued a permit to place lines of sandbags below the mean low tide in 1983 to facilitate sand accretion and has recently been issued a permit (Army Corps of Engineers Permit #88-1787-12) to place sand along 7,950 feet of beach including Buckroe, Salt Ponds, and Grandview Beaches between 1989 and 1992. The nourishment design considered in this report calls for placing 40,000 to 140,000 cubic yards of sand along a distance of 3,470 feet of beach to create a berm 50 to 150 feet wide.

Salt Ponds

The project area is in the City of Hampton and extends from the Salt Ponds Inlet south to the private property line (Figure 1). Current development consists of single family homes, and future development is restricted by the limited area of the neck of land between the Salt Ponds and Chesapeake Bay. Commercial use consists of a few small fishing boats moored in the Salt Ponds.

The Salt Ponds area has been improved previously with the construction of jetties and the dredging of an inlet. Modification and maintenance of the inlet has involved placing sediment dredged from the inlet on surrounding beaches and bypassing sand from above the updrift jetty to below the downdrift jetty. The currently considered beach nourishment design calls for 50,000 to 250,000 cubic yards of sediment to be placed along 3,330 feet of beachfront to create a berm 50 to 150 feet wide.

White Marsh

The project area is in the City of Hampton and extends between the Salt Ponds Inlet and the Grandview Fishing Pier to the north (Figure 1). This stretch of beach is undeveloped along the proposed nourishment area. Recreational facilities to the north are the fishing pier and a campground. Low density single family homes are found beyond the pier. The wetlands just inland provide substantial wildlife habitat. Beach nourishment of White Marsh would involve the placement of 25,000 to 300,000 cubic yards of material along 4,500 feet of beachfront to create a berm 50 to 150 feet wide.

Grandview Natural Preserve

The project area is in the City of Hampton to the south of the mouth of the Back River. Nourishment would take place along a stretch of 15,350 feet between Factory Point to the north and the private property line to the south and would include the majority of the Preserve shoreline. The Preserve is currently undeveloped, with no parking facilities. Access to the beach is by a mile-long dirt road. Plans are under consideration by the City of Hampton to improve public access to the beach.

The Grandview Natural Preserve contains a wide variety of relatively undisturbed wetlands, beach/dune habitats, and associated wildlife species. It is one of the few remaining examples of undeveloped Chesapeake Bay shoreline. The U.S Fish and Wildlife Service has placed the Grandview area in Resource Category 1, meaning that the habitat is high value, unique, and irreplaceable in the ecoregion and nationally. The Service's goal for Resource Category 1 is no loss of existing value. In addition to many uncommon birds which can be observed, several colonial shorebirds nest at the northern tip of the peninsula, including the Federally threatened piping plover (Charadrius melodus). The Virginia listed endangered Wilson's plover (Charadrius wilsonia) was observed foraging on the beach in May 1989. The northern beach tiger beetle (Cicindela dorsalis dorsalis), a Category 1 Federal candidate, was observed here in July 1989. The Service is currently in the process of preparing documentation for proposing endangered status for this species. The area is used by numerous waterfowl and songbirds during migration or for overwintering. The beach is backed by a substantial dune system which will provide sand so that the beach will reach equilibrium with the physical conditions, such as sea level and wave energy. The beach is an example of a healthy, dynamic system. In the absence of development, beach nourishment would provide only minor benefits while disrupting a food web which supports the piping plover and many other wildlife species.

Yorktown

The project area is in Yorktown, York County just to the east of George P. Coleman Memorial Bridge (Figure 1). The historical area contains several museums, restaurants, and other tourist-oriented concessions. Nourishment would extend from in front of the post office southeast to an existing stone breakwater. The nourishment design consists of placing 11,000 to 17,000 cubic yards of material along 1,330 feet of shoreline to create a beach width of 40 to 60 feet.

RECOMMENDATIONS

Beach nourishment will initially cause extensive damage to the shoreline invertebrate community and less extensive effects to the offshore inhabitants due to turbidity. The damage is expected to be temporary, and recolonization and recovery of the communities should take place rapidly. The following recommendations will help minimize damage, specifically to invaluable wildlife habitat and endangered species.

1. The biological quality of most of the sites has previously been compromised by heavy recreational use and periodic nourishment and is less of a concern. However, this is not true of Grandview Natural Preserve. We strongly recommend that nourishment not take place on the Grandview Natural Preserve so that the integrity of the habitat and the food web will be maintained.

2. If nourishment is to take place on Grandview Natural Preserve, it should be scheduled to avoid the piping plover nesting period (mid-March through the end of July).

3. If nourishment is to take place on Virginia Beach and Sandbridge during the loggerhead turtle nesting season (June to August, but incubation can last until October), beaches should be searched for nests by trained professionals with appropriate permits (Virginia Institute of Marine Science staff under Jack Musick or Service personnel at Back Bay National Wildlife Refuge) so that eggs can be removed before material is placed on the beach.

4. Nourishment should only be conducted using material that is compatible in grain size with the original material on the beach. Fine grained material from the extreme eastern area of the Thimble Shoal Channel should not be used.

5. Material should be placed on the beach so that the profile created on the seaward side of the berm is similar to the original profile to maintain habitat types in similar proportions.

6. As much as possible, reduce or avoid the use of heavy earth moving equipment and allow waves, tides, and currents to distribute the material. The more natural habitats created will allow accelerated recolonization of species. Avoid excessive mounding of the material by moving the discharge pipe at appropriate intervals.

7. The beginning and end of the widened nourished area should be tapered gradually to the unnourished area to reduce erosion.

8. As much as possible, schedule dredging and nourishment for fall and winter months to reduce impacts during the time of year with higher levels of biological activity.

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