along the New Jersey Shore, the more significant environmental factors will be discussed without elaboration and the present status of shore preservation summarized with pertinent comment of general interest.

ENVIRONMENTAL FACTORS

LOCATION

The coastline of New Jersey boldly faces the Atlantic Ocean between New York Harbor and Delaware Bay at the northerly end of the eastern seaboard coastal plain. It extends 124 miles from the tip of Sandy Hook Peninsula to the rounded bluffs of Cape May. From about mid-point at Barnegat Inlet, the shoreline runs generally north upcoast and trends southwesterly downcoast.

The coastal frontage is varied in physical form. The mainland coastal plain directly meets the ocean in the northerly frontage creating about 18 miles of marine cliff headland. A narrow, 11 mile long barrier beach including Sandy Hook Peninsula extends northerly from this headland frontage. South of the headland to Cape May are 95 miles of barrier beach broken by inlets and backed by rearward bays, waterways, and salt marshes. The mainland touches the ocean in the form of marine cliffs for a short distance at the rounded tip of Cape May.

In addition to use as location references, the political divisions of the New Jersey Shore have further significance. By New Jersey Law, the state government arranges directly with each municipality for the establishment and execution of cooperative programs within the municipality's borders. While the state functions as a coordinating agency between neighboring municipalities, the New Jersey Shore is not a unit conservation district per se.

The New Jersey Shore lies within four of the 21 counties of the state. These four counties in order downcoast are Monmouth, Ocean, Atlantic and Cape May. The coastline is divided politically at the present time between 45 municipalities and two federal reservations making a total of 47 separate units. The northern mainland 18 mile frontage is in Monmouth County and usually its marine cliffs are termed the Monmouth County Headland. The 11 mile barrier beach to the north is also in Monmouth County. The 95 miles of barrier beaches south from the headland to Cape May are located within the other three Counties.

The 29 mile Monmouth County frontage is divided among 14 municipalities and one federal reservation, Fort Hancock. The Fort and two municipalities, Sea Bright and Monmouth Beach are on the 11 mile northerly barrier beach. The other 12 municipalities closely occupy the headland from Long Branch to Manasquan Beach. The Ocean County 42 miles of barrier beach includes 15 municipalities and Atlantic County's 20 mile barrier beach is divided among 6 municipalities. Nine Municipalities are on the 33 mile Cape May County barrier beach with one, Cape May Point, on the mainland frontage. Cape May Coast Guard base, a federal reservation, is on the barrier beach north of Cape May City.

HISTORIC SHORELINE CHANGES

The New Jersey coast is composed of sand, gravel and clay deposited in ancient times. Wells drilled as deep as 2,300 feet into the earth along the coast do not strike underlying rock. The erodible nature of the mainland soil has led to the commonly held opinion that the marine cliffs of the Monmouth County headland yielded the materials from which the barrier beaches were formed in pre-historic times.

Recession of the New Jersey coastline has been a continuing phenomen of historic times. It can be accepted that the marine cliffs of the Monmouth County headland have been subject to continuous wave-cutting and soil-loss until protected in recent times. It can be taken that the barrier beach shorelines have been formed and reformed by the restless ocean waves and currents and the vital energies of the inlets.

Evidence supporting these conclusions is delineated on special composite maps of shoreline changes along the New Jersey coast which were prepared by the Chart Division of the United States Coast and Geodetic Survey in connection with a report issued in 1922 by the New Jersey Board of Commerce and Navigation. These maps were published in that report and were based on surveys of the New Jersey coast line made during three periods, 1835 to 1842, 1865 to 1885, and 1899 to 1915, by the Survey and a State Board survey made in 1920.

Examination of the comparative shorelines plotted on these maps reveals that measurable shoreline changes did occur at all parts of the 124 mile coastline with recessions overshadowing accretions. The State Board stated in its 1922 Report that comparison of the first survey, 1835 to 1842, with the 1920 survey showed an accretion of 3,025 acres and erosion of 5,220 acres or a net loss of 2,195 acres in about 80 years. The State Board pointed out that this was equivalent to an average recession of two feet per year along the entire 124 mile frontage.

These general observations included mixed accretion and erosion at the inlets. The State Board pointed out that, on the unbroken coastline, recessions varied from 100 feet to 1,000 feet with median of 500 feet. The latter, on the basis of an 80 year period, indicates an average recession of 6 feet per year.

Further evidence of general recession along the entire coastline is that in the last thirty years protective structures have been built in 45 of the 47 political units along the coast embracing 111 miles or 90% of the 124 mile frontage. The exceptions are the 10 mile undeveloped frontage of Island Beach in Ocean County and the 3 miles of isolated island frontages in the vicinity of the Ocean-Atlantic county line.

There is no present evidence of shoreline changes due to subsidence of the coastal plain in New Jersey. The only change in vertical relationship between land and sea, is the slow progressive rise of sea level along the Atlantic Coast, since 1930, which is reported by the United States Coast and Geodetic Survey as approximately one-

third of a foot to date.

THE INLETS

The historic surveys previously cited and more recent observations reveal the major influence of ocean inlets on adjacent shorelines. In the past, a number of inlets were closed to obliterate unwelcome features of the shoreline. The policy, today, is to maintain all existing inlets in the interests of navigation. This requires that the objectives of both navigation and shore protection must be integrated in planning and offers great opportunities to achieve maximum benefits in both fields. As will be noted later by direct reference, the improvement of inlets for navigation in some instances has created difficult shore preservation problems.

Formerly 19 rivers and streams cut through the Monmouth County headland and emptied into the ocean. Two rivers, the Shrewsbury and the Navesink, had inlets through the now unbroken northerly barrier beach. Today, all but two streams have either been diverted or confined to seaward drainage through conduits. Only Shark River and Manasquan River, important seaports, have jetty-controlled inlets. There is some thought that the closing of historic headland inlets diminished sand supply along parts of that frontage. More material is the fact that these land-locked streams are available as borrow areas of sand to augment natural supplies.

The barrier beaches of Ocean, Atlantic and Cape May Counties were cut through formerly by at least 17 inlets. By combination of natural and artificial means, seven of these have been closed. The ten remaining inlets, gateways to valuable seaports, represent particular opportunities to serve both navigation and shore preservation.

From time to time, it is suggested that the two great inlets at either end of the New Jersey Coast, New York Harbor and Delaware Bay, may greatly influence the entire intervening coast line. The idea usually springs from the observation that the dominant littoral drift in the north half is upcoast to New York Harbor and in the south half is downcoast to Delaware Bay. The nodal point has never been fixed being usually considered as just north of Barnegat Inlet. This suggested theory has not progressed beyond the conjecture stage.

OCEAN STORMS

Ocean storms have had and will continue to have a leading role in the field of coastal engineering. These awesome, always dramatic outbursts of natural forces underline the need for coastal engineering and provide full-scale tests of protective works. Every storm has its importance, but in particular, two widely separated storms of extreme intensity greatly influenced the practice of coastal engineering in New Jersey.

The three successive severe storms of Winter 1913-1914 provided critical tests of protective works existing at that time. The first

struck at Christmas, the second at New Year, and the third in mid-February. Mountainous seas driven by gales exceeding 100 MPH lashed the entire coast line. The wide spread land loss, property damage, and destruction of protective structures during these storms made clear the need for community action in the common defense and led to greater municipal participation in coastal engineering. The interest of the State at large was also awakened. Engineering evaluation of the protective structure failures led to new concepts of design and planning which many consider the start of modern coastal engineering in New Jersey.

The hurricane of September 14, 1944, is of more recent memory. It roared the full length of the coast. Shorefront damage ran into millions of dollars. Ocean piers were destroyed. Boardwalks and adjoining buildings were torn apart. The barrier beaches were flooded. Homes were destroyed. Lives were lost. The Governor ordered the State Police to take custody of many stricken communities. The New Jersey Shore was termed a disaster area. This critical testing of the New Jersey Shore's ocean defenses, aroused concerted popular support. Sample activity was the formation of an Emergency Erosion Committee in 1944 by Atlantic City's civic and business organizations. Later, in 1948, the State created the State Beach Erosion Commission to advise the Governor and the Legislature on this major public problem. Such broader support permitted enlarged planning concepts which advanced the maturity of coastal engineering practice in New Jersey. This coming of age was featured by the initiation of continuing State-Municipal programs which are in progress today.

PRESENT STATUS OF SHORE PRESERVATION

Evaluation today of the New Jersey Shore's defenses against the ocean requires ratings from critical to reasonably secure. The degree of protection varies from locality to locality and remains to be improved as funds for further work are made available principally by the state and local governments.

State law in New Jersey requires each municipality to finance one-half the cost of local state-municipal programs so that the completion rate of such programs depends first, on the financial ability of the muncipality and secondly, on the ability of the State to match available municipal funds. This leads to extended construction periods of several years to complete planned work, and in some instances, to the inability of the state and municipal - ity to execute any work due to the latter's financial inability.

Starting at Sandy Hook and proceeding downcoast, a review of the present status of shore preservation supplemented by pertinent references to future work and special problems will permit a comprehensive understanding of coastal engineering in New Jersey.

MONMOUTH COUNTY

The Monmouth County barrier beach north of the headland has

attained a high degree of security against direct frontal assult by the construction of heavy seawalls and bulkheads marginal to the oceanfront. In Sea Bright alone, two miles of stone seawall were constructed in 1946 and another quarter mile was completed this year. Groin protection of the barrier beach is minimum and the need is urgent.

The Monmouth County headland frontage, occupied by 12 closely grouped municipalities, provides a variety of conditions. Extensive marine cliff frontage is secure behind seawalls and bulkheads, but there is equally long frontage exposed at this time due to deterioration of former structures and their destruction by storms. It is the universal policy among these highly developed resorts to hold the present margin of the land. Further anticipated construction includes bulkheading of the now open bluff frontages.

Groin construction along this frontage is well advanced. The groin patterns, while representing local conditions in each municipality, collectively present a coordinated grouping for the whole frontage. The task for the future is to fill in the missing units so as to complete the grouping. In the majority, the existing groins were constructed originally of a minimum length to provide emergency protection with the available construction funds. The extension seaward and maintenance of such structures are being carried out as rapidly as funds will permit. Lateral broadening of the groin field will permit establishment of wider beaches more generally than now exist. In this connection there is some question as to the adequacy of natural sand supply to create and continue beaches of desirable width. Natural sand movement has produced many admirable sections of beach along this frontage, but the question of artificial supply is being given serious study. The headland rivers are being weighed as prime sources of material by hydraulic pipe line transportation. Offshore dumping by hooper dredges from New York Harbor is also being considered.

The construction of navigation jetties at Shark River and Manasquan River inlets created special problems. Navigation jetties at Shark River Inlet were completed first in 1918 under a state project. Shore erosion developed both north and south of the Inlet. The situation was corrected in Belmar on the windward side by extension of the south inlet jetty in 1923. A fine broadbeach was created. The beach recession in Avon by-the-Sea, leeward of the Inlet, became very serious and required bulkheading of the shorefront and the construction of a series of groins. In 1948, the Inlet north jetty was redesigned and constructed to complement the groin field. Recently, the groins were extended to further the relationship and the results have been very favorable.

The completion of the Manasquan Inlet navigation jetties by the Federal Government in 1933 provided a very wide beach along the windward frontage at Point Pleasant Beach. This security permitted the development of this locality which previously had

been retarded by extreme exposure to storm damage. On the leeward side of the Inlet, the beaches of Manasquan began to disappear. Remedial action was taken immediately by the Federal Government adjacent to the Inlet, but the municipal frontage generally receded until a timber groin field was constructed by Manasquan in 1939. The sea ends of a number of these groins were exposed and destroyed by currents of a deep, longshore slough which featured this frontage. This situation was corrected by construction of a heavy stone-portected groin across the slough so as to reduce its effectiveness and lead to its ultimate shoaling and closure. Future similar reconstruction of several groins to safeguard present gains is anticipated.

OCEAN COUNTY

The erosion tendency along the Ocean County barrier beaches has been restrained only at the older settled locations such as Bayhead and Beach Haven. It is anticipated that control will be extended to more localities and longer frontages as a result of the unprecedented boom in home building since World War II. Concentrated occupation and ownership diversity traditionally have created demand for shoreline stability and protective works. The Ocean County ocean-front includes, also, the untouched, natural 10 miles of barrier beach just north of Barnegat Inlet which is the site of a proposed state seashore park. The Legislature has appropriated funds for purchase and negotiations with the private owner are in progress.

There are several isolated oceanfront islands in the vicinity of the Ocean-Atlantic county line. This region is dominated by the large and powerful Little Egg Inlet with complementary action by the lesser Beach Haven Inlet to the north. The most exposed of these islands, Tucker Beach, formerly was sparsely occupied. This island and surrounding waters have been the scene of natural forced operating without restraint. There has been drastic erosion and reshaping in process for many years. These islands presently are not valued and corrective work is not required. The situation has not gone unremarked, however, since it affords opportunity to study a critical erosion location within a highly valuable coastal area.

ATLANTIC COUNTY

Directly south is Brigantine Island, the large oceanfront island that forms the northerly part of Atlantic County's barrier beach. The changing shoreline has been controlled by groins at only a few locations. A general program would be of great value, but lack of funds has prevented action beyond the planning stage.

Absecon Island comprises the southerly part of the Atlantic County shorefront between two major inlets, Absecon Inlet to the north and Great Egg Inlet to the south. The four municipalities which occupy the island represent the greatest concentration of values on the New Jersey Coast. Atlantic City occupies the north end of the island with Ventnor, Margate and Longport in order to the south.

Practically from the founding of Atlantic City in 1854, erosion

has been a problem on Absecon Island. At this time, the entire shoreline is protected either by bulkheads and seawalls or by groin controlled beaches. These structures represent very large investments in protective works and provide a large measure of security.

The Atlantic City shores lie within the influence of Absecon Inlet, one of the largest on the New Jersey coast. The city has beaches along the Inlet channel as well as on the oceanfront. These beaches have been maintained for many years by judicious use of groins. Unfavorable relationships between the Inlet and the City's beaches resulted in shoreline recessions of alarming proportions about 1944. The hurricane of that year, cited previously, served to accentuate the situation.

A previously designed major program of protective work was set in motion. This program has been considered overly ambitious in some quarters but now received universal support indicating a maturity in planning for the future. The program was in two parts:-First, to provide direct local protection to the City's beaches including restoration of recreational areas; Second, to divert the Inlet channel away from the City's beaches.

A one thousand foot long groin was constructed to separate the north end of the oceanfront beach from the Inlet with a group of shorter groins on both sides in support. It was originally intended to construct a complete groin field along the oceanfront and inlet beaches before depositing artificial beachfill, but due to the necessity of establishing recreation areas, the order was reversed. Favorable changes in the Inlet's behavior gave support to this decision.

In a ten week period in the Spring of 1948, 1,500,000 yards of sand were placed on the City's beaches to provide berms 300 to 400 feet wide outside the Boardwalk. The sand was dredged inside the Inlet and distributed through pipelines. Erosion losses were considerable on the open beaches thus provided, so that a series of timber groins were constructed in 1950 along the oceanfront. Further groin construction was deferred by decision in 1951 to proceed immediately with the second part of the program.

The second phase consists of constructing a 4,200 foot long jetty on the northerly ocean bar of Absecon Inlet parallel to the Inlet channel and the City's beaches. The jetty is located 2,000 feet from these beaches and is intended to shelter them from open ocean exposure. Its further purpose is to act as an inlet training jetty and permit diversion of the Inlet channel away from the City's Inlet beaches. At present the Inlet channel, about 25 feet deep, undercuts these Inlet beaches requiring difficult and expensive protection. Construction of this jetty is in progress with 25% completed to date and the halfway mark projected for late in 1953.

Longport at the south end of Absecon Inlet has been waging a running conflict for years with Great Egg Inlet. It is estimated that the Inlet cut away 4,000 feet of barrier beach prior to 1920. Efforts by individual owners to half the encroachment proved ineffective and

it remained for the municipality to make a stand in the common defense. The investment by the municipality about 1920 in a major groin and heavy seawall stopped the land loss but had serious effect on the town's financial history. Only recently, has it been possible for this small community to undertake further necessary work with state aid. As pointed out previously, state-municipal projects can be executed only when the municipality can finance one-half the cost. The value of the Inlet to navigation may lead to an inlet improvement project including features beneficial to the adjoining Longport coastline.

CAPE MAY COUNTY

The Cape May County barrier beaches are in the form of a series of long narrow islands separated by inlets of which only the most southerly one is improved. Localized protection has been installed in every municipality to prevent shoreline recessions and to cope with unfavorable inlet effects. Such work has been extensive at some locations and minimum at others. Present indications are that increased general use of the County's oceanfront will provide the opportunity to meet the evident demand for remedial work on a much larger scale. Inlet improvements for navigation may also be a source of aid in the future by inclusion of protective features beneficial to adjacent communities.

In recent times, the principal work has been at Ocean City and Cape May City. Some construction also has been performed at Sea Isle City and Stone Harbor. Serious situations at Strathmere, Avalon, and North Wildwood exist without correction due to financial difficulties. Wildwood and Wildwood Crest enjoy ample protective beaches and do not have a current problem.

Ocean City, the most northerly municipality of Cape May County, falls within the influence of Great Egg Inlet. The northerly City shorefront adjacent to the Inlet about 1932 began a period of recession in contrast to favorable accretion during the previous 30 years. As the situation became marked, a groin system was planned to control the northerly two miles of oceanfront. This program was started at the south end in 1939 and was completed in major part by spring of this year.

It has been planned to complete the groin field before pumping in artificial beach fill. The extended construction period, however, had permitted beach depletion, despite favorable action by the groin field, to such an extent that the proposed beach fill became mandatory and further groin construction was deferred in its favor. Between April 7, and August 4, of this year, 2,500,000 cubic yards of sand was dredged from the rearward bay, transported 4,000 feet across the island and distributed through pipeline along the southerly 1.5 miles of the groin field. Beach berms of 200 to 300 feet in width were created outshore of the Boardwalk. Completion of the groin field is being undertaken immediately in order to assure maintenance of the newly created beach.

Both Cape May City and Cape May Point are located leeward of the Cold Spring Inlet Jetties. These jetties were completed in 1909 and extended 4,500 feet seaward of the shoreline. In the early 1900's, Cape May City's beach was the Daytona Beach of that time. Early automobile makers, including Henry Ford, raced their new mechanical marvels on the City's wide open beach.

Sand diversion by the Inlet Jetties set in motion serious recession of the shorelines of both municipalities. Very heavy investiments in protective structures during the 1920's and 1930's provided temporary security. Since those times deterioration of structures and lack of funds for maintenance and new construction have diminished defensive values. In 1946 Cape May City initiated a groin construction program which it hopes to continue to completion and supplement with artificial beach fill. A second portion of the groin program was completed this year, and further work is planned for 1953. Financial difficulties have prevented any recent work at Cape May Point.

OTHER SHOREFRONTS

It should be stated parenthetically at this point that shore preservation is also extremely important at locations other than the coastline. Erosion problems exist along Raritan and Sandy Hook Bays, Delaware Bay and River, and inside the ocean inlets. These regions have equal status with the coastline in all particulars and are omitted only to avoid extended exposition.

THE STRUCTURES

In the foregoing status summary, reference has been made to the several classes of structures employed in coastal engineering. It is of interest to describe these structures in some detail and to point to changes and evolution in designs and use dictated by growing experience.

BULKHEADS AND SEAWALLS

In the New Jersey, bulkheads and seawalls have been used to barricade the upland face and mark the line of defense against the ocean. Since the cited 1913-14 winter storms, the emphasis in design has been on great strength and durability. Bulkheads of timber or steel predominate although in recent times steel has not been used where sand abrasion exists. At difficult locations, such as the Monmouth County headland, stone embankment is provided as frontal defense of such bulkheads.

Reinforced concrete seawalls were used in the 1920's along the Absecon Island frontage, but are rare elsewhere. Massive seawalls constructed of large rough stones have received wide preference. The usual design is frequently described as rubble-mound construction. Emphasis is placed on dense, compact construction by individual placement of stones having a density of 165 to 185 pounds per cubic foot. Stone sizes range from two to twelve tons. Top berm widths are usually 10 to 12 feet at elevations of 6 to 13 feet above high water.

GROINS

In earlier times groins were essentially timber baffles, either open or sand-tight, constructed normal to the shoreline. The cited winter storms of 1913-14 illustrated the need for permanent designs. This led to the first construction of stone groins which today are the most poplar. Between 1921 and 1928, stone groins were built at Sea Bright, Monmouth Beach, Long Branch, Allenhurst, and Asbury Park, all in northern Monmouth County, and at the south end of Ocean City in Cape May County. These first stone groins were of rubble-mound construction and were placed at an acute angle of 30 to 60 degrees from the littoral windward shoreline. This permitted the leeward groin face to act as a breakwater defense of the beach entrapped within the acute opening. The arrangement provided satisfactory results in some instances, but later general practice has been to construct groins normal to the beach to minimize the leeward-groin effect.

Until the early 1940's, the stone groins were essentially sand-tight timber or steel walls supported by stone embankment. In many cases, the quantity of stone used was limited for the purpose of economy so that the corewall was exposed to direct sea action. Deterioriation of the groin core-walls was followed by loss in effective action and by need for maintenance. In the usual design to-day, the core-wall feature has been replaced by a compact center mass of small stones contained within an enveloping large stone cover and side supports thus producing an all stone groin. Where timber groins are considered appropriate, stone embankment is used only to support and secure the seaward end. It has been found that timber groins in exposed locations are subject to extensive damage without such stone protection.

Stone groins are constructed with a flat berm top, 14 to 18 feet wide, with elevation 2 to 4 feet above high water. These dimensions permit use of the completed portion of the groin as a working platform and facilitate organization of equipment to individually handle and securely place the large, rough quarry stones which weight from two tons each to in excess of eight tons each and form the bulk of the groin. Location of operations directly at the working face assures the close attention required to obtain a dense, compact structure and provides the best opportunity to judge and meet the changing conditions and emergencies, which are recurrent and characterize this class of construction.

ARTIFICIAL BEACHFILL

Although placement of artificial beachfill was executed largely without groins at Atlantic City in 1948 and with a partial groin field at Ocean City this year, it is felt that groins and beachfill are complementary. The groin field provides the necessary pattern and physical change within the subject area to receive the artificial beachfill and to assure maximum benefits. The attitude of Ocean City at this time may be cited as in point. Dispite the fact that the beachfill was not completed until mid-summer, the City reports the largest beach populations in its history and a 25% better resort income than last year. The City attributes these gains directly to its investment in the newly created beaches and considers it good judgement to conserve its new

asset by completion of the groin field. Atlantic City in similar vein constructed groins to protect its 1948 beachfill.

The expanding development of the New Jersey Shore has created a wider interest in the augmentation of natural sand supply along all parts of the coastline. As mentioned previously, the headland rivers are being considered as supplementary sources for the Monmouth County frontage. Along the barrier beaches fringing the inland waterways, the interest is two-fold. Navigation on the inland waterways is an important feature of the New Jersey Shore. Channel and harbor developments beneficial to navigation are being considered as sources of beachfill material. In general the justification for beachfill goes beyond the basic need for security and defense into the field of extremely valuable recreational and economic benefits.

SUMMARY REMARKS

In summation, the historic conflict between seashore development and ocean encroachment along the New Jersey coast is being resolved in favor of the New Jersey Shore by unceasing vigilance and the will to hold the sea frontiers.

While security is the keynote, it is recognized that enlarged economic and recreational benefits also have important inter-relationship with direct protective values. Rising curves of population growth, new highways unfolding shoreward, unprecedented investment in summer homes, all portend unabated shore development and expanding concepts for coastal engineering in New Jersey.

Once the problem of the individual property owner along, shore protection in general has become large scale public works executed cooperatively by the state and the municipalities in the common interests. The need for shore preservation receives popular understanding and support, not only among shore residents, but also within the growing ranks of summer visitors and home owners.

While the problem of shore preservation in New Jersey still remains large in scope, the record of accomplishments permits a strong sense of achievement and furnishes confidence for the road ahead.