Nantucket Shoreline Survey

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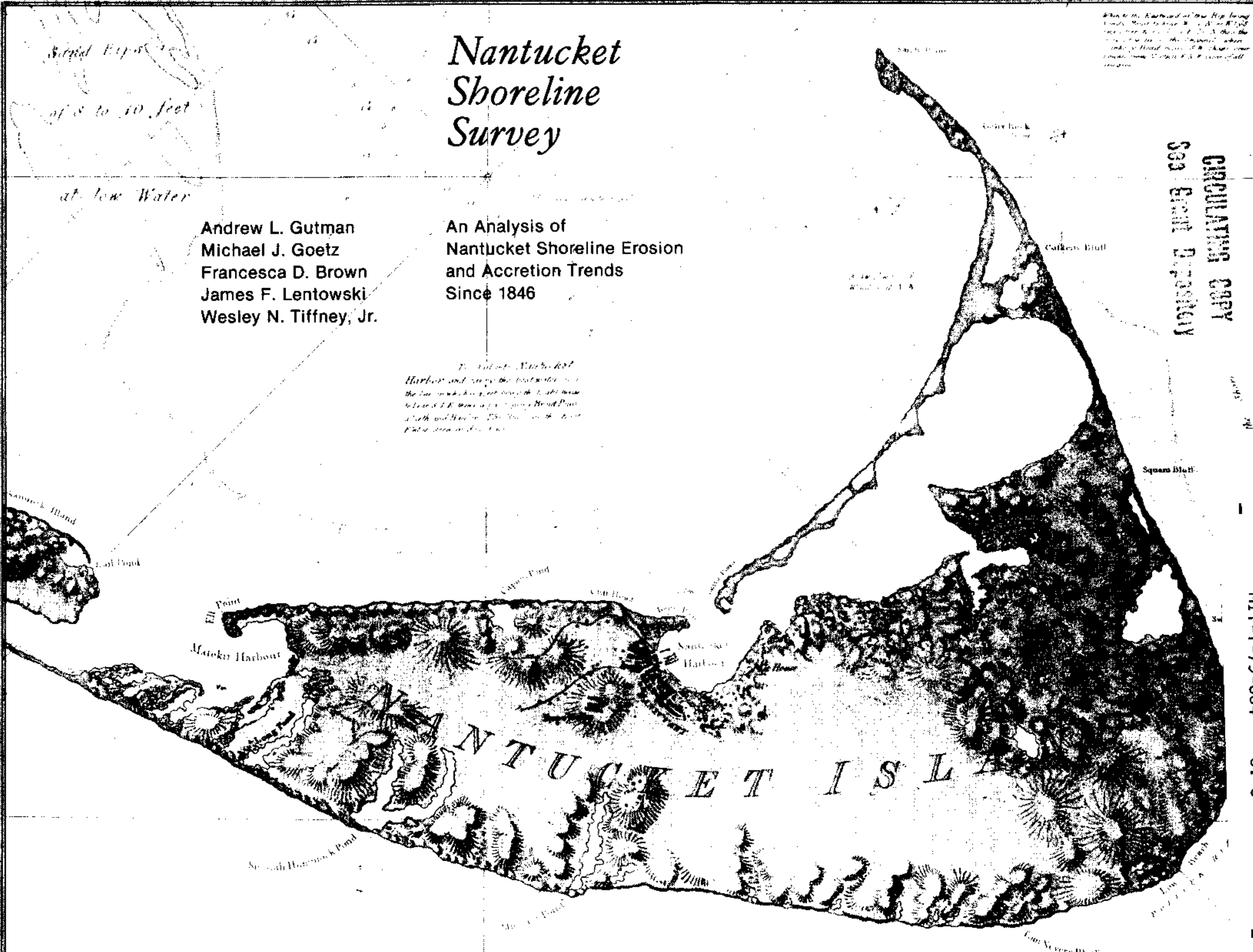
An Analysis of Nantucket Shoreline Erosion and Accretion Trends Since 1846



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Cover: Chart of Nantucket from the Atlantic Neptune. Courtesy of the MIT Hart Nautical Museum.

ACKNOWLEDGEMENTS

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AUTHORS

Andrew L. Gutman, Coastal Engineer with the Extension Sea Grant Advisory Program.

Michael J. Goetz, Coastal Geologist New England River Basins Commission.

Francesca D. Brown, Undergraduate Research Opportunities Program (UROP) student, Massachusetts Institute of Technology.

James F. Lentowski, Executive Secretary, Nantucket Conservation Foundation, Inc.

Wesley N. Tiffney, Jr., Ph.D., Director, Nantucket Field Station.

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SUMMARY

This report documents changes in the Nantucket shoreline over a period of 125 years, from 1846 through 1971. The coastline of the island represents one of its most precious aesthetic recreational, and economically valuable resources. The shoreline, however, is not a static resource. The forces of wind, tides, waves, and rising sea level constantly change and reshape its contours. Sometimes these changes are dramatic. A home, handsomely situated on a bluff, can be literally swept into the sea by the impact of several serious storms. This report has been written to help prospective property owners, developers, real estate agents, regulatory officials and Nantucket residents assess the vulnerability or the stability of individual pieces of property on the island's shoreline. The information can be used to make decisions on the soundness of building new homes or of installing shoreline protection devices to ward off the loss of existing structures, threatened today by an encroaching sea.

Because Nantucket has not been as heavily developed as many other coastal communities, it presents us with an opportunity to learn from past mistakes on and off the island. This report discusses the coastal processes which continually change the shoreline and shows how proper management can ensure the integrity and continued value of a precious resource.

Data covering 125 years are presented to document changes for each 1,000 foot section of the shoreline on the south, east and north shores of the island. Average erosion and accretion rates are presented for the following intervals: 1846-1887, 1887-1955, 1938-1951, 1951-1961, 1961-1970. Using the base maps and the tables of erosion and accretion, the reader of this report can pinpoint individual sites and determine what changes have taken place in the past and estimate what changes might occur to the property in the future. The authors hope decisions on whether to purchase or develop shorefront property will be easier to make. If, for instance, the data show erosion rates of 10 feet/year where a shoreline lot is for sale, then the reader should know that building a house only 100 feet back from the sea is not a wise decision.

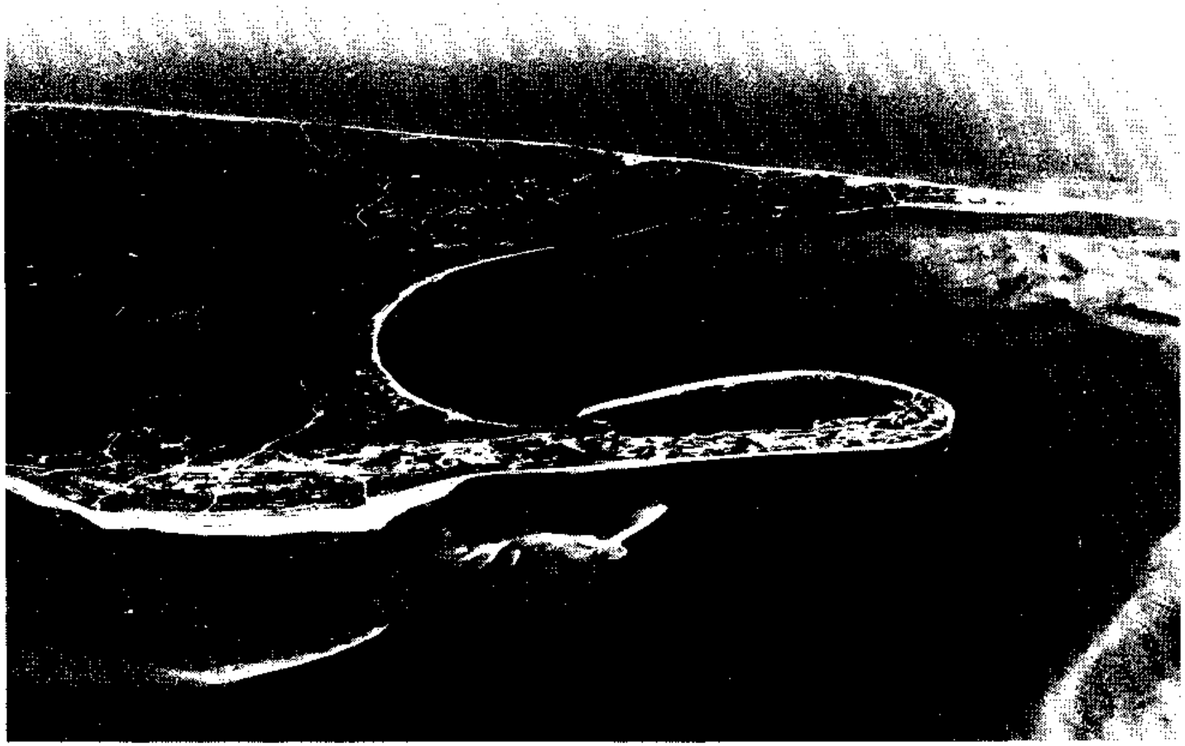
In general, of over 215,000 feet of shoreline examined, only 20,000 feet were constantly depositional over the time period studied. Accretion was observed at many locations over 125 years, but the process was temporary. Codfish Park at Siasconset represents a good example of how a community suffered from not understanding that trends of accretion can reverse themselves with serious consequences. Many years of rapid deposition built out the beach and led to a development of vacation homes. Today that shoreline is eroding leaving many property owners facing serious losses.

This report documents transient shoreline changes like the one in Siasconset to help discourage future development on unstable shorelines. The information should be used as a tool to help effectively manage coastal resources, and avoid the economic and environmental waste that mismanagement of so much of the U.S. coastline has wrought.

INTRODUCTION

The 6 x 13 mile island of Nantucket 30 miles off the shores of Cape Cod is rich in historical, natural, recreational, and commercial values. During the eighteenth and nineteenth centuries the island was the center of the whaling trade and much of this past is reflected in the architecture and character of the area. With the decline of whaling, tourism and construction have become the mainstays of the island's economy; and currently there is a growing emphasis on diversifying the economic development through increased offshore fishing, aquaculture, agriculture, and wine production.

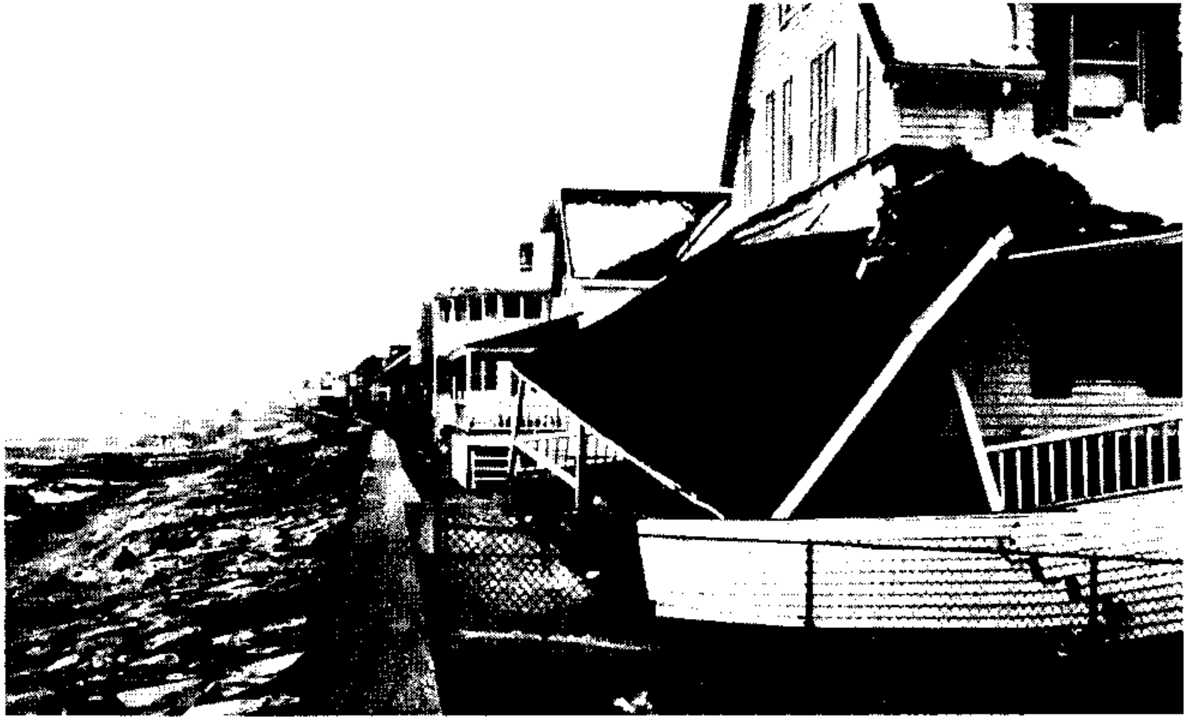
Seasonal or short-term visitors to Nantucket swell the off-season population from about 6,000 to almost 30,000. They are drawn to the island by the historical buildings, museums, and wide-ranging coastal recreational opportunities along nearly 100 miles of spectacular, unspoiled sandy beaches, dunes, and bluffs. Many people who come as visitors decide to buy coastline property and build homes. Increasing coastal development over the years has led to some serious management and land-use problems primarily because much of Nantucket's shoreline is subject to severe storm damage, flooding, and erosion.



Photograph looking southeast over Madaket Harbor.

Typically prospective buyers of waterfront property are shown lots or homes during the calm summer months when the ocean appears deceivingly benign. Usually neither the buyer, developer nor real estate agent understands how the dynamics of coastal processes, the winds waves, currents, and tides, constantly reshape the island. Homes constructed only 100-200 feet back from the sea can rapidly become endangered by the continuing retreat of an eroding dune. Old assessor's maps show that years ago houses were built on narrow, long lots that extended inland from the shore. As the shoreline retreated, the property owners periodically moved their houses inland; unfortunately, today, lots like these would be prohibitively expensive.

One current option for preventing damage to shorefront property is to construct massive concrete and boulder seawalls or revetments to stabilize the shoreline. However, though these protection devices have been successful in other coastal areas, on Nantucket structural shoreline protection -- especially on the ocean side -- is not a feasible alternative, primarily because construction costs are high. The island's isolation from machinery, materials and labor sources, and the intensity of the storm waves and tides, cause effective seawalls to cost in excess of $200-$300 per foot. Protection of one single lot can rise to over $75,000; and this cost borne by the private property owner, in most cases, exceeds the combined value of property and home. In addition, a seawall has a limited lifetime (10, 20 or 30 years) and annual maintenance can be a financial burden.



Even expensive shoreline protection devices will not provide complete protection to property during extreme storms.

Another limiting factor to consider in applying shoreline protection along the exposed sections of Nantucket's shoreline is the effect of the structures on the beach environment. Aesthetically, seawalls and revetments detract from the beauty and tranquility of Nantucket's most precious natural resource, the shoreline. These structures can also interfere and alter the sediment dynamics and equilibrium and cause accelerated erosion. For this reason, state environmental regulations may prohibit their use. It should be noted, however, that these arguments against structural solutions for Nantucket's erosion problems are most relevant to areas with the most exposed open ocean, high wave conditions, like the south shore of Nantucket. In calmer more protected areas, such as harbors, protection techniques can be effective though still expensive.*

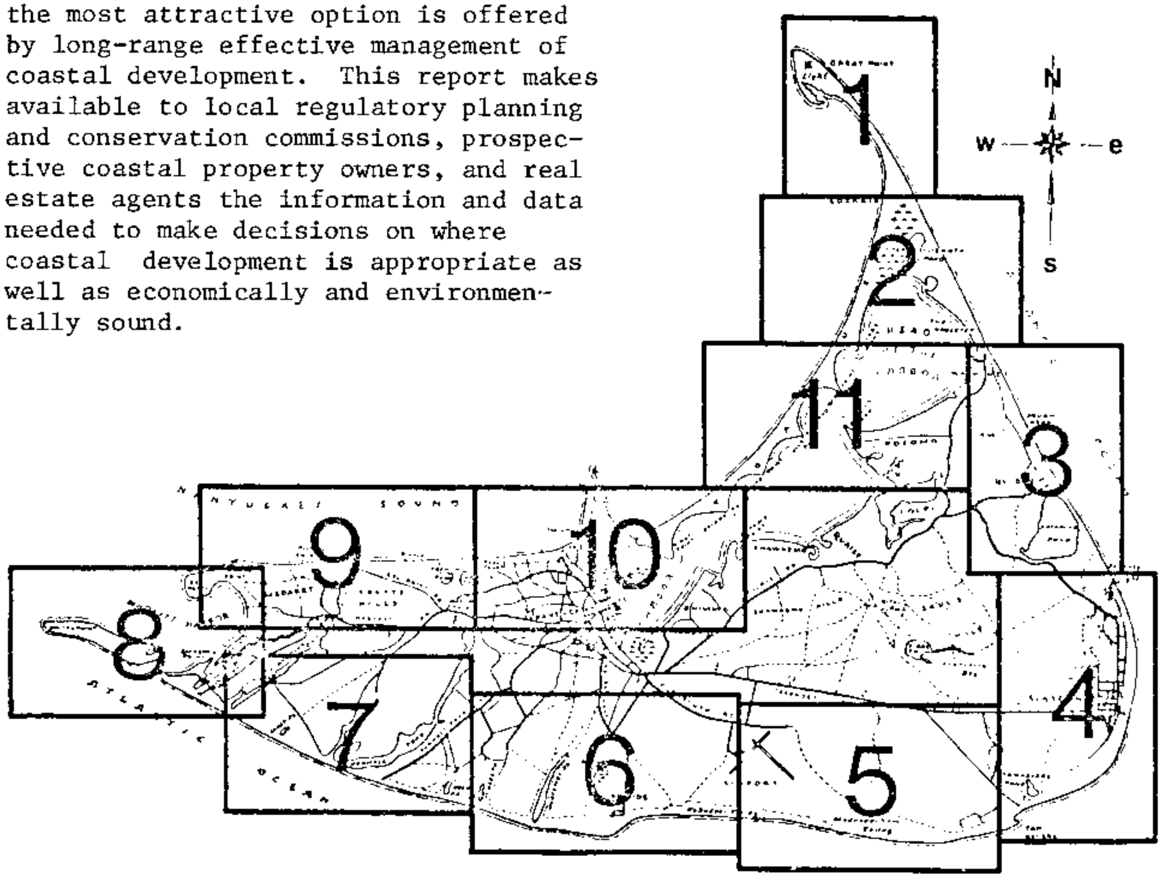
In all instances environmental regulations should be investigated because they may prohibit construction of seawalls and revetments.**

*Comprehensive audio-visual discussions of "Coastal Processes and Shoreline Protection Techniques": "Alternatives and Effects" are available through the M.I.T. Sea Grant Program.

**A guide to the coastal wetlands regulations of the Massachusetts Wetlands Protection Act (G.L. 131, S.40) on file at the Nantucket Conservation Commission and libraries provides a detailed description of regulations which apply to shoreline protection.

PURPOSE OF STUDY

Short of structural solutions to shoreline retreat and storm damage, the most attractive option is offered by long-range effective management of coastal development. This report makes available to local regulatory planning and conservation commissions, prospective coastal property owners, and real estate agents the information and data needed to make decisions on where coastal development is appropriate as well as economically and environmentally sound.



The report first discusses in very general terms the various processes which cause shoreline erosion, and then continues by detailing historical changes of the Nantucket shoreline. The methods, margins of error, summaries for different stretches of the shoreline, and tablulated data are placed within a format so that the reader of this report can pinpoint an area of interest and estimate how much a shoreline has changed -- through erosion or accretion -- over the past 125 years. This information may then be used to predict future changes, but it should be recognized that major shoreline alterations are frequently the result of a single severe storm, which is impossible to predict.

This report then is intended both as an educational, management, and investment tool. For the curious, it will provide background for understanding the processes which shape and change Nantucket. Local officials can use this information to determine management guidelines. And developers or prospective private property owners can apply the data to decide if an investment is justified.

COASTAL PROCESSES

The shoreline, or that unique boundary where the land meets the sea, is changed by coastal processes which constantly reshape and reform it. The shape of Nantucket has and will be influenced by glaciers of the past, changes in sea level, winds, waves, currents, and tides.

About 50,000 years ago, glaciers began accumulating in the Laurentide area of Canada. As the ice sheet grew, it spread outwards (figure 1), eventually reaching as far south as New York City and Long Island. Nantucket is made of materials deposited by these great sheets of ice. Beginning approximately 12,000 years ago, a rapid warming of the world climate melted the great ice sheets. As huge amounts of water were released into the ocean, the level of the sea, which at that time was some 400 feet lower than it is today, began to rise. The rate of sea level rising slowed some 12,000 years ago. However today, sea level is still rising in relation to land at a rate of one to as much as two feet per century. Although an increase of one-tenth of an inch per year may seem inconsequential, a small vertical rise will cause a horizontal shoreline retreat hundreds of times greater than this amount. Figure 2 illustrates a hypothetical cross-section through a typical shoreline. If we assume a shoreline slope on Nantucket of 1:100, and sea level rising three-quarters foot per century, then in 100 years (figure 3) we would expect over 75 feet of shoreline to disappear. (On Nantucket the shoreline slope ranges between 1:100 to much more gradual slopes of 1:1000.) If instead, we assume a shoreline slope of 1:1000, 750 feet of shoreline would be lost in 100 years. Therefore a small rise in sea level relative to land can cause a much larger horizontal change which can range from less than 1 foot per year to greater than 7 feet per year. From a

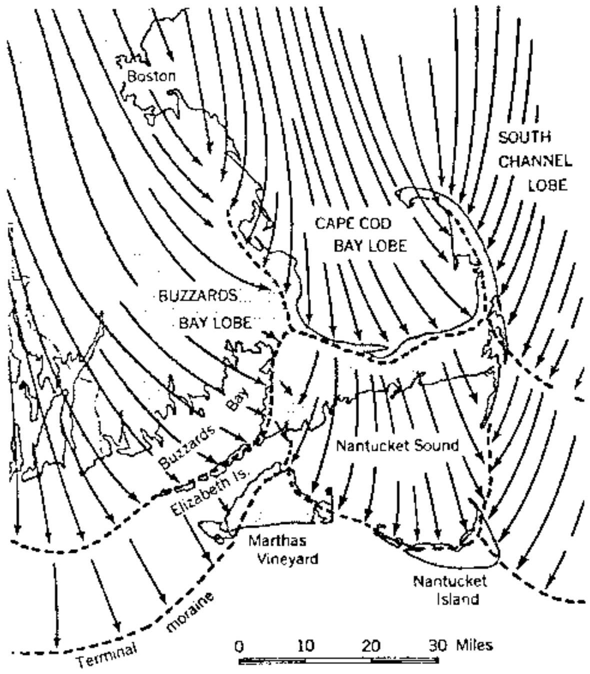


Figure 1. Map of Southeastern New England showing direction of flow of ice 12,000-15,000 years ago. (From Strahler, 1966)

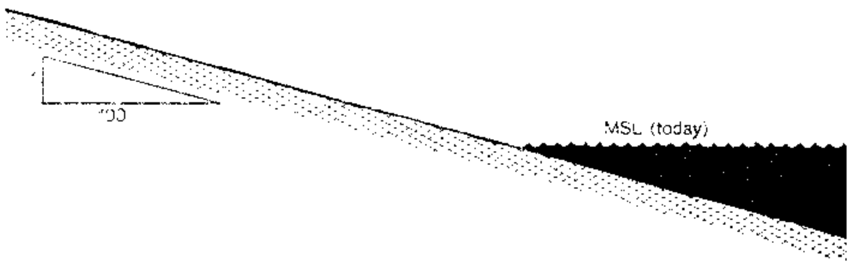


Figure 2. Hypothetical cross-section through a typical shoreline.

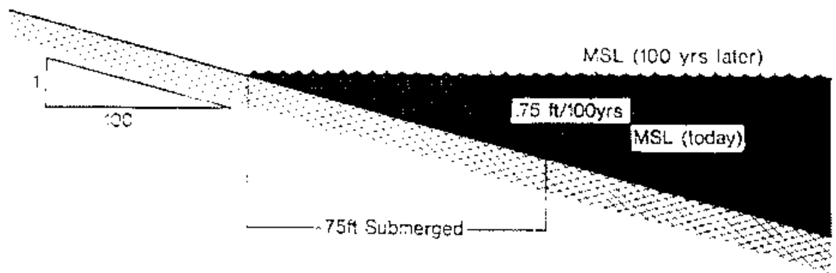


Figure 3. Cross-Section through shoreline 100 years later after sea level rise of .75 feet causing a horizontal submergence of 75 feet.

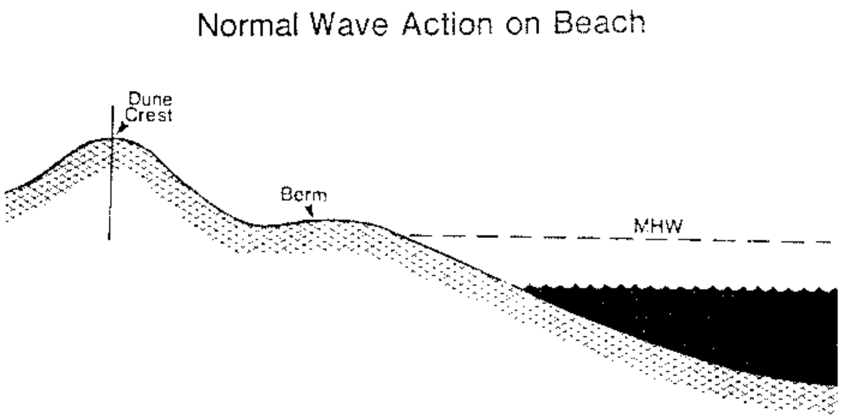


Figure 4. Cross-Section of beach showing that during most of the year little erosion occurs.

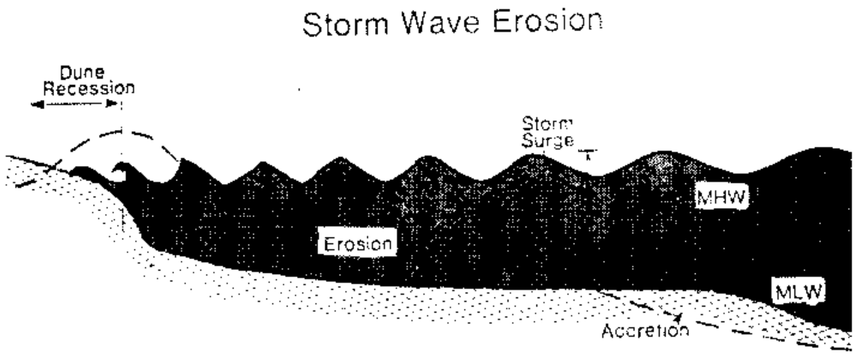


Figure 5. Most beach erosion occurs during storms when large waves attack higher up the beach due to raised water levels associated with a storm surge.

geological perspective of hundreds of thousands of years, the major cause of shoreline retreat is this sea level rising. However, on a time scale of days, months, and years, the coast responds rapidly to the processes of wind, waves, currents, and tides.

It is these forces which carry the beach, dune and bluff material out to sea. If a stretch of shoreline such as the south shore of Nantucket retreats 10 feet in one year, then the sea has eaten away hundreds of thousands of cubic yards of sand. Although waves and tides transport this sand, the loss does not occur grain-by-grain with each incoming wave. Instead, the sand is taken away in great chunks by severe storms. During most of the year, waves break on a beach causing little or no erosion (figure 4). However, during storms (figure 5), much larger waves generated out at sea reach the shoreline and scour sand away causing the dune to recede and the backshore section of the beach to lower. On Nantucket most of these severe storms occur during the fall and winter months. The height of a wave reaching the shoreline increases as the wind velocity and duration increases. The distance of open water offshore over which the wind can blow, known as the fetch, also controls wave height. When high velocity winds during a storm blow from a constant direction for a long time over the open ocean, huge waves can be generated. These great waves reach further up the beach because of a complex phenomenon known as a storm surge which causes water levels to rise dramatically. There are numerous causes of this phenomenon: the passage of a low pressure system over the coast, wave set-up, wind driving water against the coast, the earth's rotation, and runoff from precipitation. All these meteorological and oceanographic factors contribute to the rising water level, coastal flooding and severe wave damage.

The sand eroded from the dune and beach during storms is moved by waves and currents (figure 6). Some, transported offshore, is permanently lost to the beach system. That which is deposited on nearshore bars, generally in water less than 15-20 feet deep, can be transported back onto the beach during the summer when wave conditions are milder. Since most storms, and thus erosion, occur during the fall and winter months and accretion, the deposition of sand, occurs during the summer months, most beaches expand and contract seasonally (figure 7). In winter, beaches tend to be narrow with the sand returning and widening the beach in the summer months.

Sand can also be transported parallel to the beach by wave-induced currents. This movement is know as

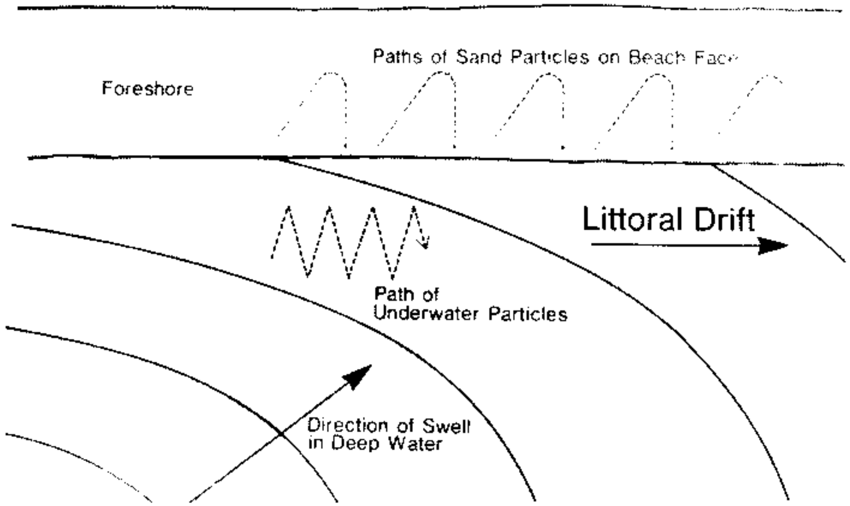


Figure 7. Cross-section through beach showing seasonal changes in beach profile from narrow winter profile (solid line) to wide summer profile (dashed line).

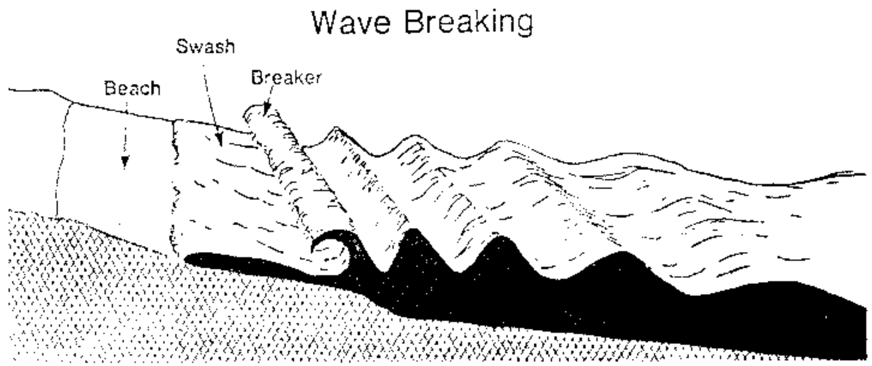


Figure 6. Waves are generated out at sea by wind blowing over the open water. As the waves travel into shallow water they begin to slow and become steeper due to the drag or friction exerted by the bottom on the waves. Eventually, in very shallow water, the waves become unstable and break on the beach, releasing their energy as swash. Most sediment transport by waves occurs in the zone where waves are breaking and rushing up the beach.

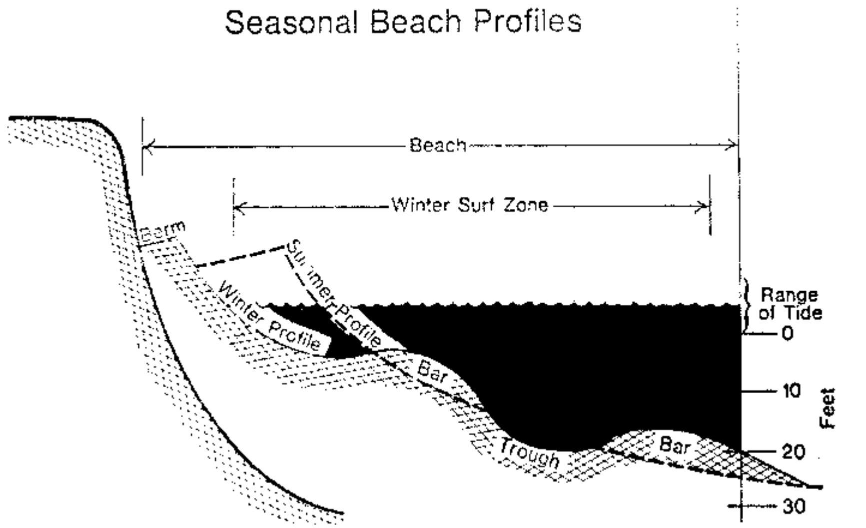


Figure 8. Schematic view from above showing how waves approaching beach at an angle cause, parallel to beach, transport of sand known as littoral drift.

Figure 10. Photograph showing the effect of a groin on a beach. Net littoral drift is from the left to right.

littoral drift (figure 8) which is particularly pronounced during severe storms when waves break on the beach at a sharp angle, generating stronger currents. And though different storms, generating waves at different angles, will move the sand both up and down the beach, there is generally a net transport in one direction as a result of the area's "prevailing storms." Figure 9 shows the net direction of sediment movement around Nantucket.

Littoral drift is extremely important in the balance and equilibrium of the shoreline. Sand transported parallel to the beach partially renourishes downdrift beaches which have been eroded by storm waves. Without this partial renourishment, erosion of the shoreline is accelerated. Obstructions, such as groins that are poorly placed (figure 10) can interfere with the littoral drift and consequently increase the erosion of another property owner's beach.

Erosion caused by rising sea level, waves, tides, storm surge and the resulting sediment transport causes the shoreline to retreat landward. The shoreline may be defined by the edge of a retreating low dune or towering bluff, or by the location of high water on a low lying beach. In many cases, without reference to a fixed object, for instance a house or telephone pole, erosion would be unnoticed because the shoreline retreats, or is submerged, without any visible change in profile or shape. However, when references are available, a retreat can be documented quantitatively over a fairly long period of time. This report presents the results of an ongoing study which documents the retreat of Nantucket's shoreline since 1846.

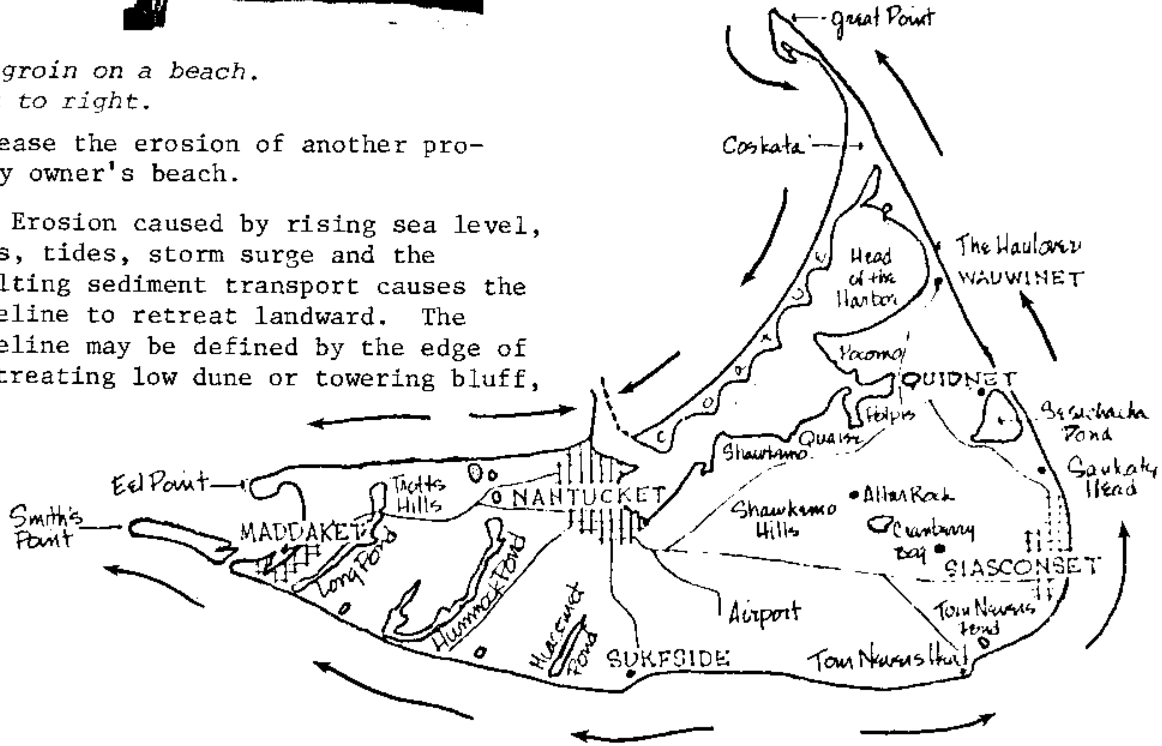


Figure 9. Map of Nantucket showing a generalized picture of the net direction (arrows) of littoral drift around island. At specific locations on coast, net direction may be the opposite of indicated or from both directions.

TECHNIQUES FOR DOCUMENTING SHORELINE RETREAT

Three basic methods are available to study erosion of a shoreline over time. The application, accuracy, and technical difficulty of each technique varies. This survey of historical and present day changes in Nantucket's shoreline incorporates all three methods to provide a comprehensive data base for a variety of applications.

Field Survey

Perhaps the simplest method for documenting shoreline trends is to periodically measure the distance between a reference marker and the shoreline. Approximately 20 sites on Nantucket, representing critical areas of erosion or management concern, were selected for field measurements. At each site a reference marker -- concrete post, telephone post, house corner -- was selected and a profile perpendicular to the shoreline was run using standard surveying techniques (transit and tape method). For a number of years, measurements will be taken at most sites at the end of each winter and summer; though a few locations will be observed more frequently. Each year the newly compiled data will be made available as an appendix to this report.

This study used three different methods to document dune and bluff erosion such as that shown in this photograph.

Trained local citizens will do much of the actual surveying to ensure that the project will be continued for a fairly long period and to provide flexibility for surveying immediately after extreme storms. At the same time, these Nantucket residents will have an opportunity to understand more completely the dynamic nature of their island's shoreline.

Field measurements offer the advantage of accuracy. Fairly simple equipment will yield information on changes in the shoreline within plus or minus .05 feet vertically and plus or minus .5 feet horizontally. For the purposes of this study, the horizontal measurements -- shoreline retreat -- are the most important.

The disadvantage of field surveys is that they cannot cover very large areas, and are limited to the study of discrete points along the shoreline. Two methods for measuring shoreline changes were used in this project to fill this gap.

Aerial Photographs

Vertical aerial photographs (figure 11) taken from specially equipped aircraft can be used to make shoreline comparisons, if pictures of the same locations are taken over a period of time. Although considerably less accurate than field measurements, aerial photographs are valuable for studying long stretches of shoreline. On Nantucket, photographs have been taken at intervals of 13 years or less since 1938, and the second of the three parts of this shoreline study makes use of this information. At the University of Rhode Island, Mike Goetz, under the supervision of Dr. John Fisher, conducted an historical photogrammetric survey of the patterns and rates of shoreline change on the island from 1938 to 1970 for his Master's thesis.

The aerial photographs used in this study were of differing scales ranging from 1:20,000 to 1:40,000. An instrument known as a Zoom Transfer Scope was used to produce a precise scale match from this different imagery. The base map was derived from the largest scale photographs. Cliffs, dunes and high tide lines shown in other aerial photographs were traced on overlays and compared with the base map. The shoreline of Nantucket was then divided into 1,000 foot segments (figure 12). Changes in the shoreline were measured along each segment

Figure 11. Example of one vertical aerial photograph (April,1961) used in this study to measure shoreline changes. This particular photograph covers the area around Siasconset.

for 1938-1951, 1951-1961, and 1961-1970 by superimposing the appropriate overlays. Appendix II presents aerial data for the entire Nantucket shoreline. We will describe how the reader can use the base map as a key to locate a particular site and determine the rates and total amount of change for each individual period and for the whole 32 years.

Allowance must be made for errors that are intrinsic to the photogrammetric techniques employed for this study. These errors include: imprecision of the microrule and Zoom Transfer Scope, operator variability, cartographic distortion in producing overlays, imprecision of ruled grid, and scale variability. Field measurements for scale correction and "ground truth" indicate an accuracy of plus or minus 2.5 percent for measurement of area (length times width) changes. For the measurements listed in the tables in Appendix II the reader should assume an accuracy of about plus or minus 1.0 foot.

The photogrammetric technique described above provides information on shoreline trends for the entire coastline of Nantucket. These data are limited to the years after 1938 when the first imagery became available. However, to accurately and completely describe longer term shoreline trends, data going further back in time are required.

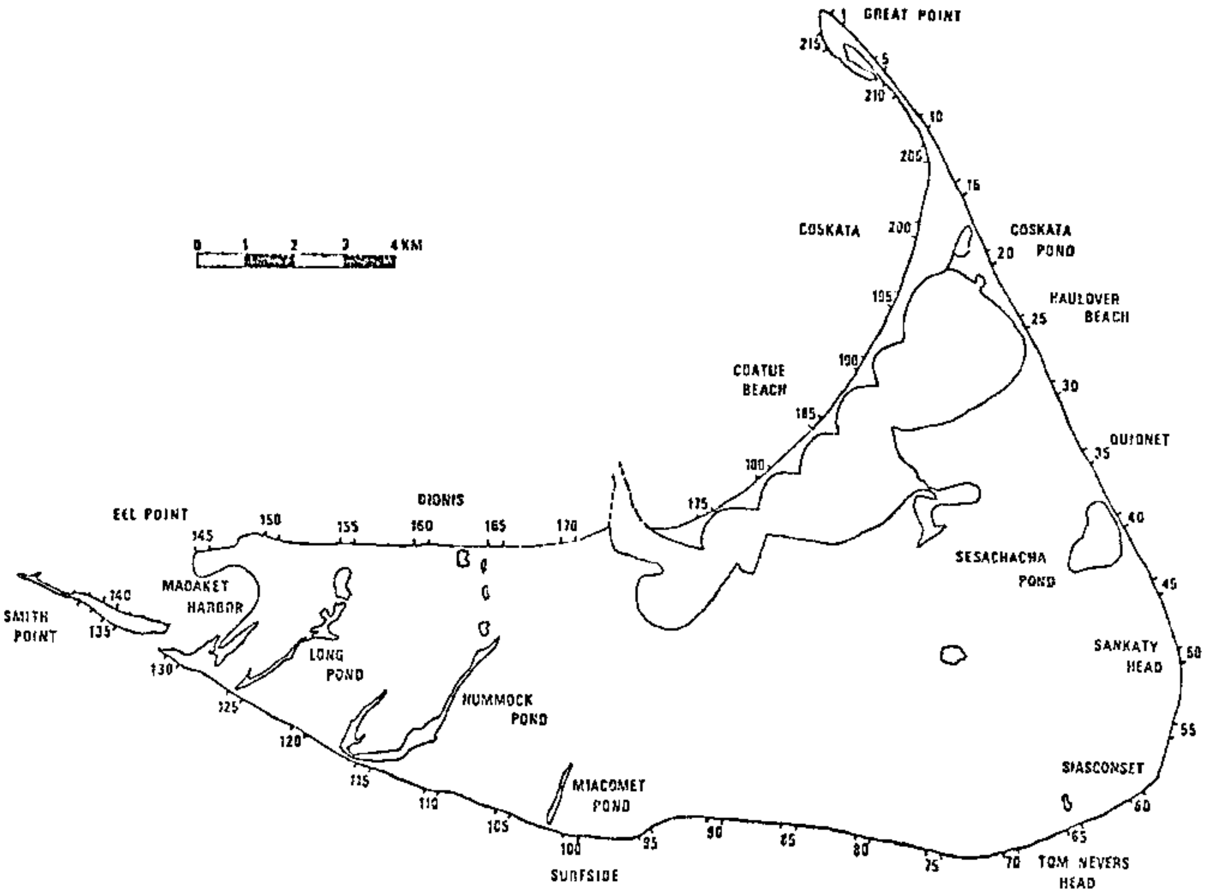


Figure 12. Map of Nantucket showing location and number of shoreline segments from vertical aerial photographs. Each segment equals 1,000 feet of shoreline.

Comparison of Maps and Charts

The third source of data for this report comes from the maps and charts prepared by the government for many years. Since the middle of the nineteenth century, reliable and precise maps and charts have been periodically prepared for most areas of the country. Since surveys were repeated at varying intervals, it is possible to consult different maps to make comparisons. This data offers the advantage of providing information over a long period of time, but it is less accurate than the other two techniques employed in this study. Although a brief description of this method of comparing historical charts is presented here, the reader is encouraged to study the references listed at the end of this report for further information.

In 1961, cartographers at the U.S. Army Corps of Engineers Beach Erosion Board (BEB) compiled charts covering periods, often of more than 100 years, for many sections of the United States coast. On Nantucket, United States Coast and Geodetic Survey charts for 1846, 1887, and 1955 were available. The BEB transferred the Mean High Water (MHW) shoreline for each of these charts onto one map at a common scale. The MHW shoreline is defined simply as the location on the beach or coast where the still water rests at the time of Mean High Water.

Francesca Brown, as a research assistant, took these compiled BEB charts to compare shoreline changes over a 109 year period. Transect lines were drawn perpendicular to the shoreline at intervals of 1,000 feet (figure 13). Measurements of the shoreline changes between 1846 and 1887, 1887 and 1955, and 1846 and 1955 were taken at each transect. These data are listed in the tables of Appendix III. As with the photogrammetric data, the reader can locate a site of interest on the base maps and derive shoreline trends from the tables. With the addition of these data, the reader will have available information covering 125 years.

The data listed in Appendix III are subject to several types of errors. Very small distances cannot be measured on most charts, and another source of error is the accuracy of the map itself. For the charts used in this study, the combined error from these two sources amounts to about plus or minus 3 feet per year. Shoreline changes less than 3 feet per year were ignored because they cannot be accurately measured. Therefore, this phase of the study was limited to the section of Nantucket between Smith Point and Sesachacha Pond, where shoreline changes were large enough to be measured using historical charts.

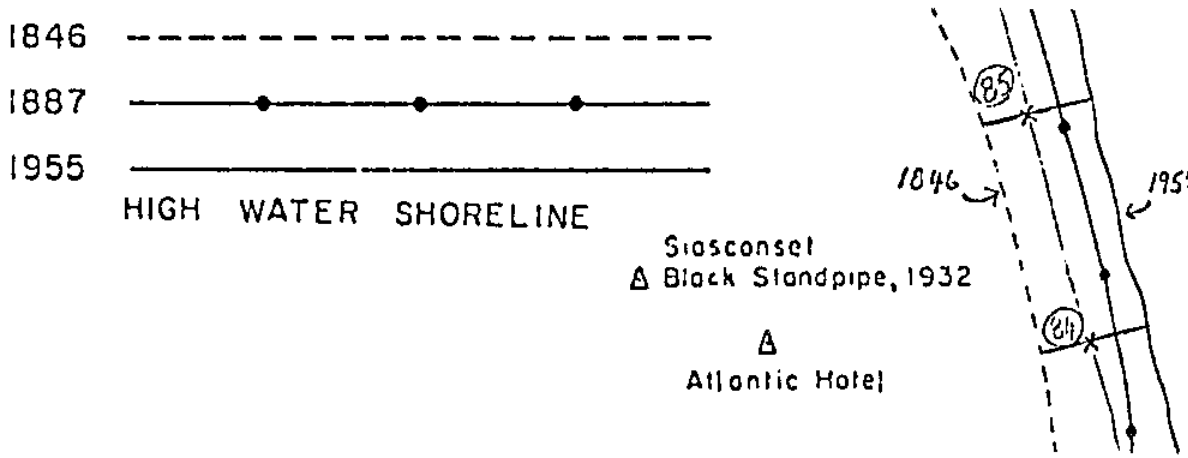


Figure 13. Example of historical charts used in this study to measure shoreline changes. The section shown is in the Siasconset area. Measurements of shoreline change were taken along the numbered lines perpendicular to the shoreline (transects).

ORGANIZATION AND SUGGESTED USE OF DATA

The aerial photographs and charts provide data on shoreline trends covering a 125 year period. These data are presented in tablular form in the appendices of this report. A series of base maps (Appendix I) is provided for locating areas of particular interest. The numbers on the base maps refer to the transect data in the tables. Two sets of numbers appear on these maps: One set refers to data from the aerial photographs (Appendix II); while the other derived from the charts (Appendix III). To locate a site of particular interest, the reader should use a street or an assessor's map. Then going to the base map, he or she should find a nearby landmark, for instance a road, pond, or lighthouse, and note the number of the closest transect. Because transects mark every 1,000 feet, it is possible to accurately identify any area within 500 feet of a transect. Using the transect number, consult the tables in the appendices to estimate the rates of change in the shoreline. Along the south and east shore between Smith Point and Sesachacha Pond there are data listing shoreline changes from both historical charts (1846-1887, 1887-1955), and from aerial photographs (1938-1951, 1951-1961, and 1961-1970), while along the north shore, only photogrammetric data are available. To determine total erosion or accretion for a specific shoreline point over a given time period, consult the tables, which show the average change in feet per year, then multiply this change by the number of years involved.

Photograph of the West Jetty and Jetties Beach.

The detailed data compiled in the tables at the end of this report provide information on the historical erosion and deposition of a specific location.

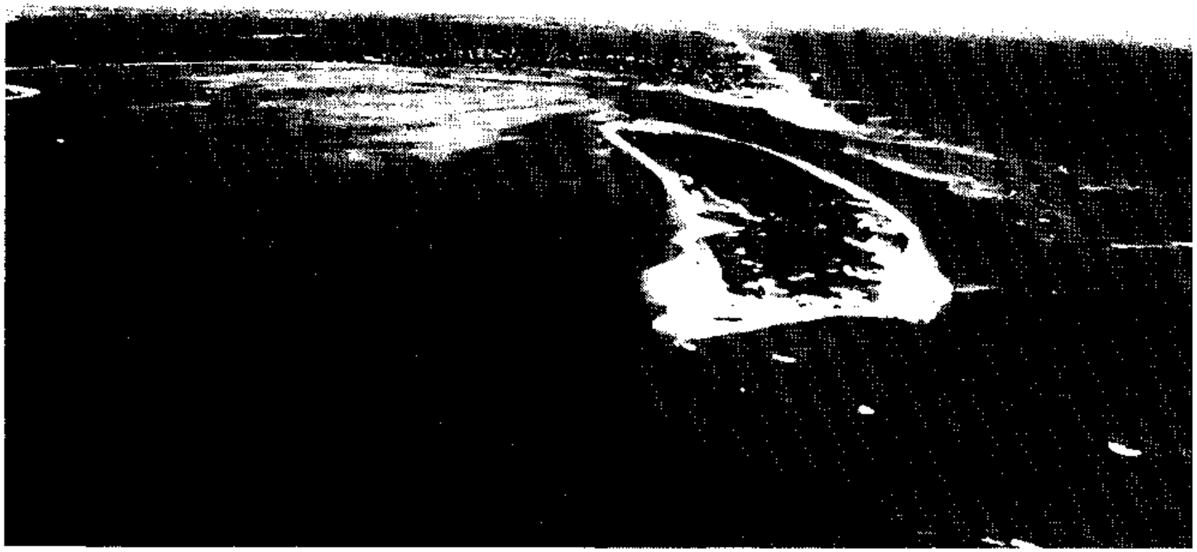
The following section of this report describes in more general terms the erosion/accretion trends of the shoreline of Nantucket over the past 125 years. This summary will help differentiate those critical areas that are least appropriate for development versus those where erosion is minimal or, where in fact accretion is occurring.

SUMMARIES OF SHORELINE TRENDS

SOUTH SHORE

Esther Island

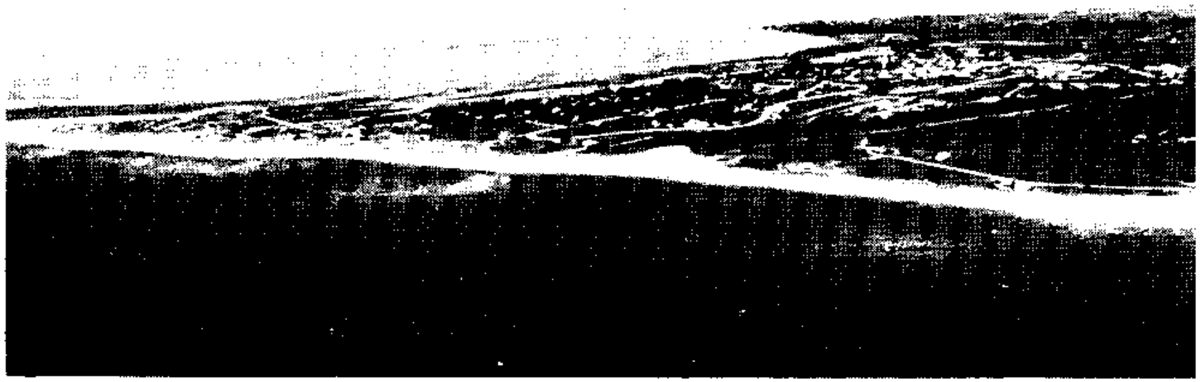
Prior to the breaching of the shoreline west of Madaket in December of 1962, Esther Island and Nantucket formed one continuous stretch of shoreline. At present however, the breached area is submerged by 15-18 feet of water. Between 1846 and 1887 erosion averaged about 19 feet/year, and though this rate appears to have slowed to about 11 feet/year during the 1900's, this area is still unstable and unsuitable for development. Besides exhibiting high rates of erosion on its southern flank, Esther Island changed dramatically between 1887 and 1955 through a westward accretion of 1100 feet at Smith Point. This indicates a net westerly direction of littoral drift along the south shore.



Photograph looking southeast over Smith Point and South Shore.

Madaket

The area just east of the breach into Madaket Harbor has been eroding at an average rate of about 13 feet/year. This is a particularly critical erosion problem because this area, especially to the west of the Ames street bridge, is low lying and subject to flooding and overwash during severe hurricanes and northeasters. Although the data indicates the area is not stable and is therefore unsuitable for development, this is one of the rapidly developing areas of Nantucket.

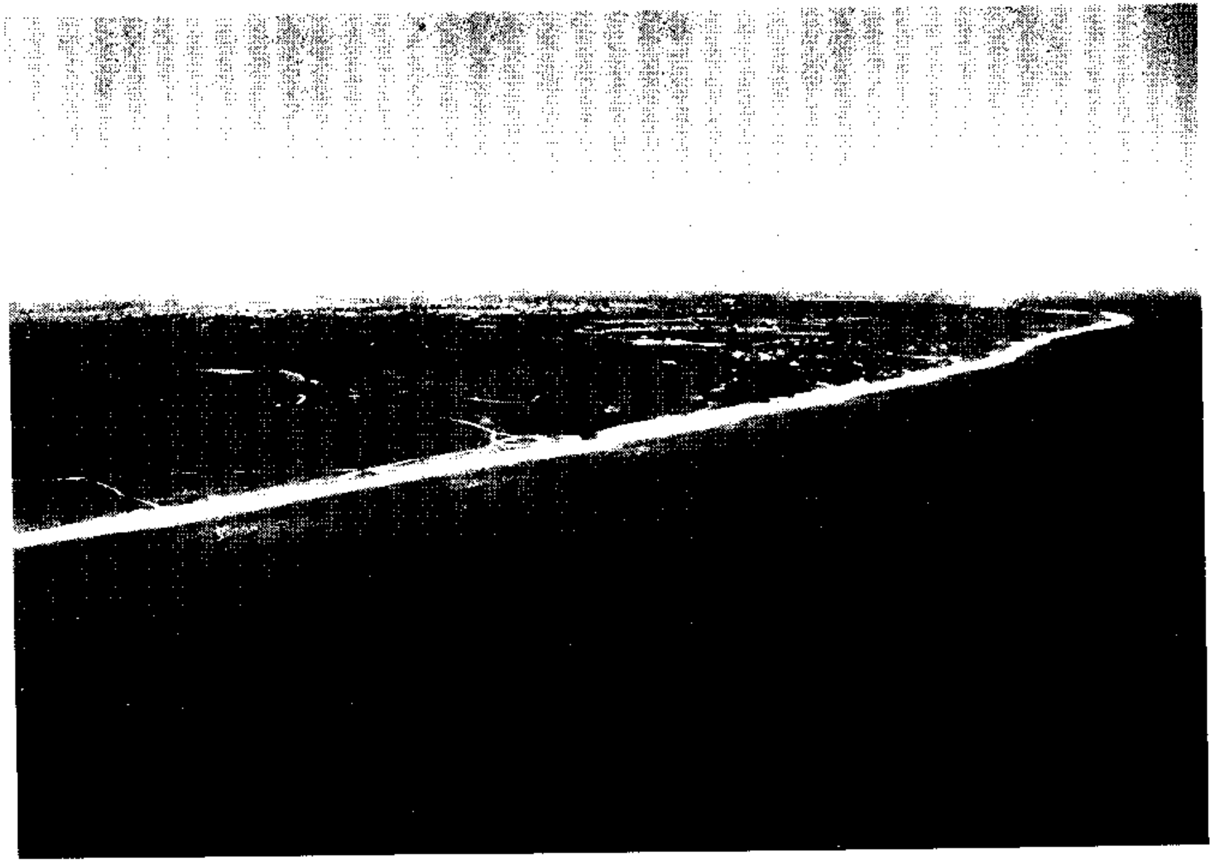


Photograph looking north at Madaket and Long Pond.

Madaket to Surfside

The area between Madaket and just west of Miacomet Pond has eroded, though not at any consistent rate, during the time records have been kept. Between 1846 and 1887 the rate averaged about 6 feet/year, while between 1887 and 1955 it was some 11 feet/year. Between 1961 and 1970 erosion along this section ranged from about 3 feet/year to nearly 30 feet/year.

These erosion rates contrast sharply to the accretion trends between Miacomet Pond and Surfside. Between 1846 and 1887, accretion was rapid, ranging from 1 to 25 feet/year. Between 1887 and 1955, this accretion rate was much lower and confined to a more narrow area. Between 1961 and 1970 the accretion rate ranged from less than 1 to over 8 feet/year. The material deposited in this area, known as Point of Breakers, probably comes from material eroded from the cliffs to the east and west and then deposited here because Miacomet Rip, a nearshore shoal, interrupted the long shore sediment transport. Although the accretion trends might indicate that this is a stable area suitable for development, close examination of the data shows the area is very unstable, accreting during one period and heavily eroding during another.

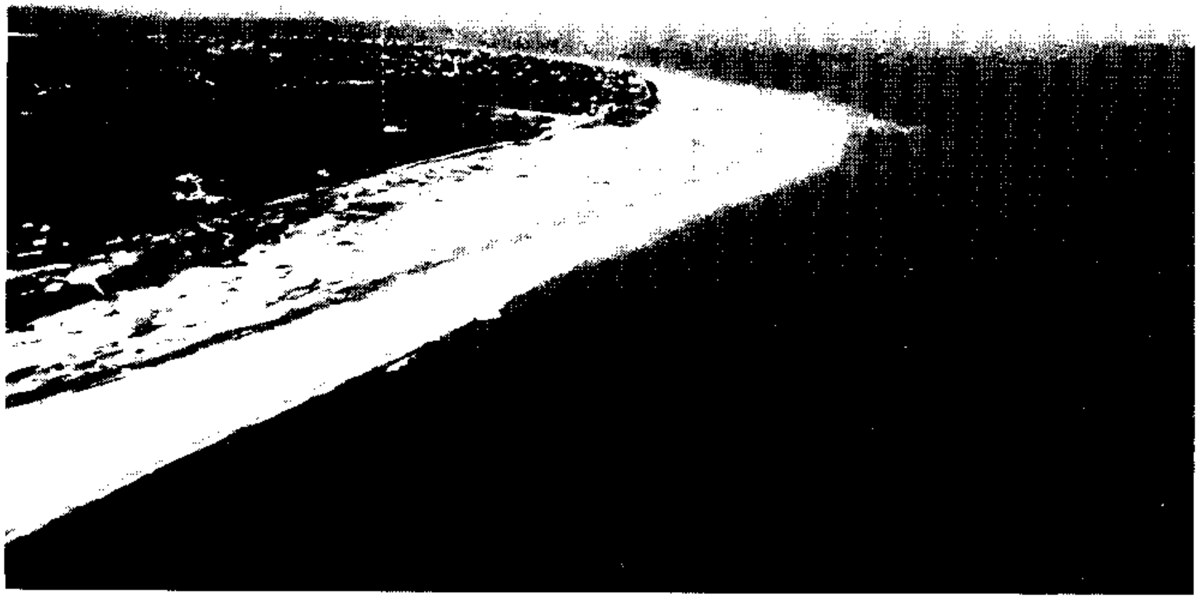


Photograph looking northeast at the South Shore from Madaket to Surfside. This section of shoreline, taken as a whole, is the most rapidly eroding area on Nantucket.

Surfside to Tom Nevers Head

This section of the Nantucket shoreline has historically also been subject to severe erosion. Between 1846 and 1887 erosion averaged about 3 feet/year except near Tom Nevers Head where the shoreline accreted at a rate of about 5 feet/year. Then after 1887 until 1955, the entire area eroded, though at a slightly lower rate.

Sediment transported to the Tom Nevers Head area from eroding shorelines to the north and west has resulted in a net deposition of beach here over time. However, accretion here has been punctuated with periods of comparatively rapid erosion. Variation in accretion-erosion is probably related to shifts of the highly mobile on and offshore shoals that characterize Nantucket's southeastern shore. The present pattern of accretion suggests the presence of protective shoals. When and if they move on, transported by littoral drift, this same shoreline area will be left more exposed and subject to erosion.



Photograph looking northeast from Tom Nevers Head to Siasconset.

Summary South Shore Trends

The sections of the south shore which have been described exhibited very similar, though erratic, shoreline trends. This entire section has been eroding at an average rate of about 7 feet/year -- standard deviation is 6 feet/year -- though in several cases erosion rates have exceeded 15 feet/year. In the immediate vicinity of the headlands at Surfside and Tom Nevers Head, the pattern has been one of shifting areas of accretion, suggesting a convergence of littoral drift from both directions and/or extensive shielding of these sections from wave attack by offshore bars.

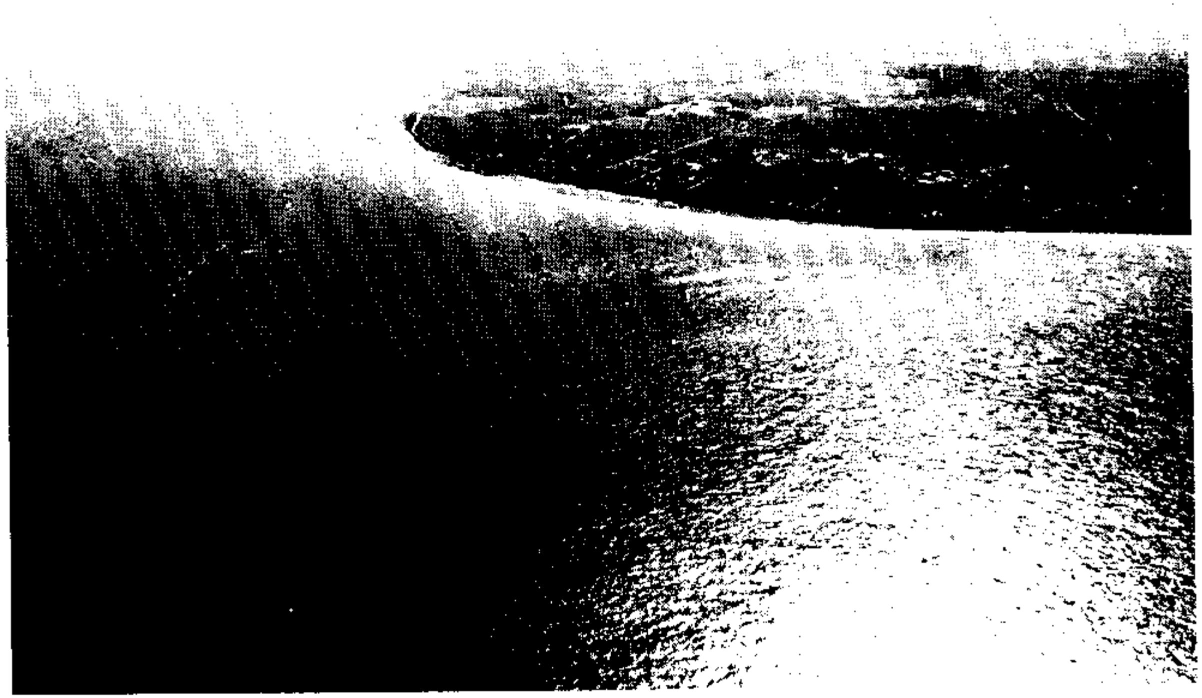
Of 75,000 feet of shoreline on the south shore, over 55,000 feet were erosional between 1846 and 1887. Of this 55,000, 40,000 feet were eroding at less than 10 feet/year, with the remainder eroding at a rate greater than 10 feet/year. Between 1887 and 1955, only 5,000 feet of shoreline were accretional, indicating a general decrease in deposition. During this period over 30,000 feet of shoreline were eroding faster than 10 feet/year. Between 1961 and 1970, accretion spread to a slightly wider area covering about 10,000 feet of shoreline. The south shore, taken as a whole, has historically been the section of the Nantucket shoreline that has eroded most.

EAST SHORE

Tom Nevers Head to Sankaty Head Lighthouse

This section of Nantucket between the southerly-facing south shore and the northeast-facing section shows some surprisingly non-characteristic trends. Along the section between Tom Nevers Head to just south of Siasconset, the shoreline was erosional between 1846-1887, but to the north of this area, the shoreline was rapidly accreting. Between 1887 and 1955, this area of accretion extended 2,000 feet further to the south. Accretion rates during this period averaged nearly 8 feet/ year and the MHW shoreline advanced some 300-450 feet seaward. This rate of accretion was greatest towards the south and was slowly reduced to zero towards the north, eventually becoming slightly erosional just north of the lighthouse.

Recently, however, photogrammetric data indicate a dramatic reversal of this pattern towards an increased rate of erosion along this section. Much of the shoreline between Sankaty Head and Siasconset became erosional during the 1950's and 1960's with the exception of the area immediately south of Siasconset which was accretional between 1961-1970.



Photograph looking west from Sankaty Head to Tom Nevers Head.

The implication of this data is particularly serious near Siasconset. Residential development along this section of shoreline in the past was limited to the area landward of the cliffs and bluffs. However, the rapidly accretional shoreline here provided a new beach for development. The deposition of sand building up the beach led to a false sense of security and eventually the construction of seasonal homes on this low lying accretional beach. Unfortunately, the sea has played this same trick over and over again. A seemingly stable and building beach can rapidly become unstable and erosional due to changes in wind, wave, and offshore bar conditions. This is what happended at Siasconset and many of the homes built here are now endangered by an encroaching sea. Unless the pattern reverses, these homes will either have to be removed, or they will be carried off to sea. What the sea gives, it can very easily take back.

Sankaty Head to Great Point

This section of the Nantucket shoreline faces directly into the northeast and the reader might assume the section would be eroding rapidly. This assumption would be reasonable considering that the most severe storm conditions in New England occur during a "noreaster" when winds and waves come from the northeast. Surprisingly however, much of this section of shoreline has been relatively stable with the exception of the area near Great Point. Between 1846 and 1887, erosion was less than 1 foot/year and between 1887 and 1955, the rate was less than 2 feet/year. It should be noted that these rates cannot be considered statistically significant since they are less than the level of accuracy of the charts themselves. Between 1938 and 1951, erosion ranged from near 0 to about 3 feet/year, but between 1951-1961, the vast majority of the beach, over 24,000 feet, remained unchanged. Between 1961-1970, erosion rates were generally less than 3 feet/year and averaged about half this rate.

Photograph looking north from Sankaty Head to Great Point.

The only exception to this general trend of very low erosion rates has been the area in the immediate vicinity of Great Point. From Great Point south about 4,000 feet, erosion rates have ranged between 4-20 feet/year since 1938. Some of this material eroding from the dunes and glacial cliffs at Great Point was transported around the spit and deposited to the west causing accretion of the shoreline and formation of sandbars parallel to Coatue Beach. Although most of the littoral drift moves to the north along the eastern shore, a portion of the sand eroding from Great Point was probably also transported to the south and contributed to the fairly stable shoreline in this area.

In general the east shore of Nantucket, with the exception of Great Point, has historically retreated at rates much lower than would be expected given the area's northeast orientation. The presence of extensive offshore shoals may account for this fact. Large storm waves are broken by the shoals and the wave energy is dissipated before reaching shore. The east shore cannot, however, be considered stable, especially the narrow section north of Wauwinet, because it is vulnerable to storm induced flooding and overwash. For example, in 1897 a strong northeast storm caused a breach between the Atlantic Ocean and Nantucket Harbor at a point called the Haulover, just north of Wauwinet. At that time, fishermen commonly dragged their small boats across the narrowest part of the beach to go codfishing on the shoals to the east of the island. Destruction of vegetation and the creation of a track through the dunes promoted by the fishermen's activities weakened the spit at the Haulover and led to the development of an overwash channel at this point. Under the influence of the prevailing northward longshore current, the channel migrated north over nearly a mile of beach until finally closing when it reached the Coskata upland in 1908. This cut, open for nearly 12 years, drastically altered the current patterns in Nantucket Harbor and promoted development of sandbars within the harbor (figure 14).

More recently, the February 6, 1978 "noreaster" caused extensive overwash and sand transport along the entire sand spit from Wauwinet to Great Point. Overwash is particularly common on the Gauls, a narrow stretch of beach. Buildings on this spit would be particularly vulnerable to frequent flooding, and construction activities themselves would damage the dunes and the dune vegetation, making the sand strip even more fragile.

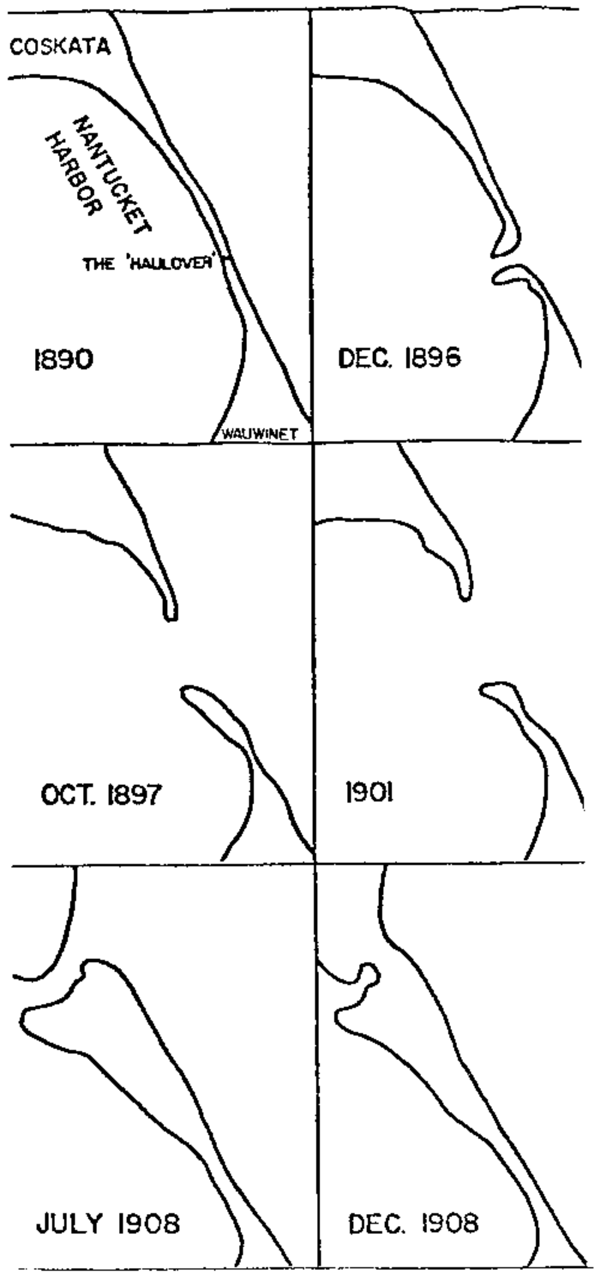
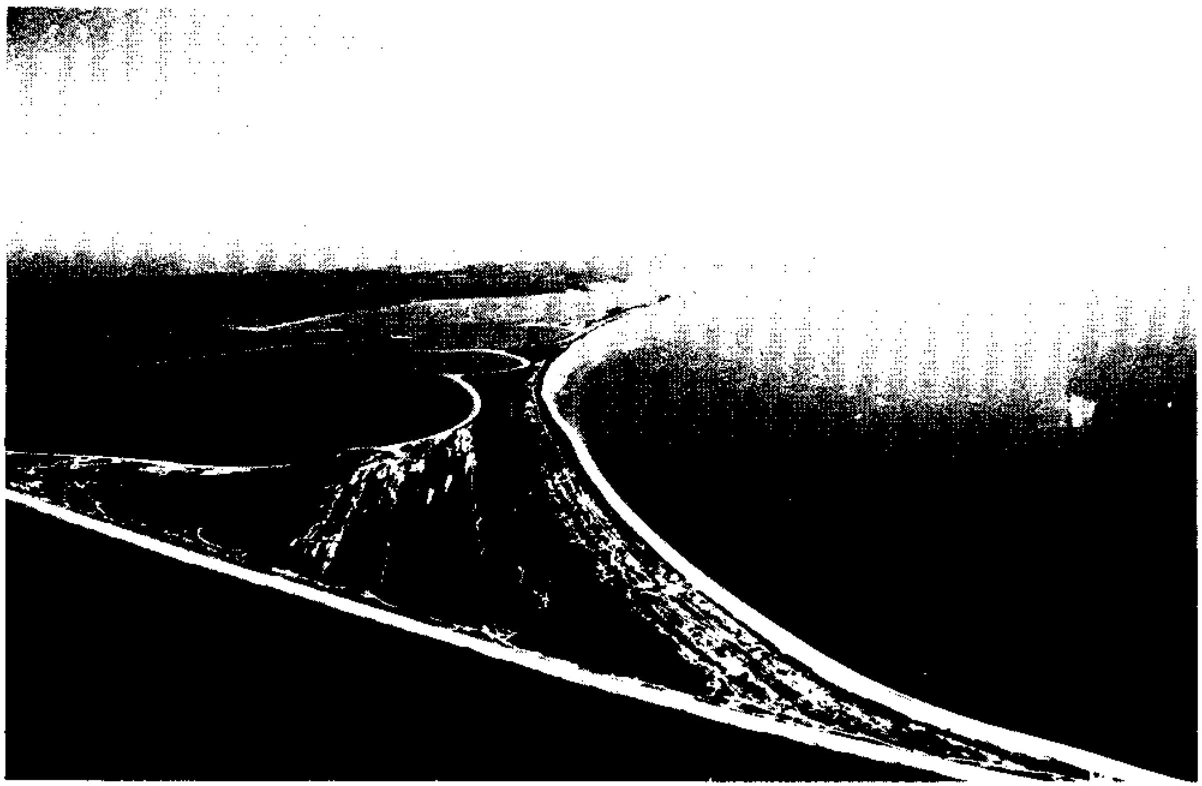


Figure 14. Schematic representation of changes at the haulover between 1890-1908. (From Rosen,1972)

NORTH SHORE

The north shore of Nantucket differs greatly from that to the east and south. At the beginning of this report the discussion of coastal processes told how storm wave activity scouring sand away from the dunes, bluffs, and beach is a major cause of erosion. The height of waves reaching a shoreline during a storm, and thus their ability to chew away sand, is in part limited by the fetch (distance of open water offshore), and water depth offshore. On the south and east shore, an unlimited fetch, open ocean, and deep water offshore permit the generation of huge waves during storms. However, north of Nantucket there are only 30 miles of open water, all of which is quite shallow; and both factors limit the height of waves reaching the north shore of Nantucket. Since waves of much reduced height and energy reach the north shore, erosion occurs at correspondingly lower rates. While the south and east shore of Nantucket are known as high energy open ocean shorelines, the north shore is affected by a lower energy restricted fetch, though still subject to fairly intense storm conditions.

*Between Great Point and Eel Point only photogrammetric data since 1938 is available due to the small shoreline changes along the north shore.



Photograph looking southwest over Coatue and Nantucket Harbor.

Great Point to East Jetty (Coatue Beach)

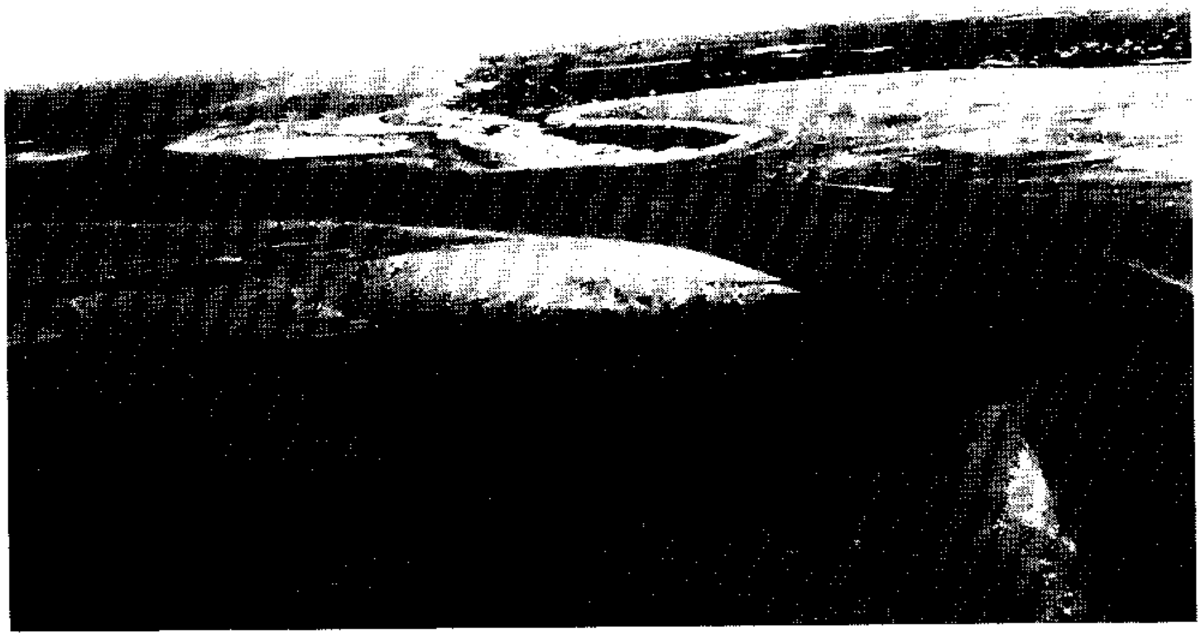
From 1938-1970 this section of shoreline, between the harbor-protecting east jetty and Great Point, experienced a net accretion of over 2 feet/year. One should note however, that most of this accretion occurred on the west side of Great Point and on the shoreline of Coskata. Of about 40,000 feet of shoreline in this section, about 30,000 were accretional or remained stable between 1938-1951. From 1951-1961, only 4,000 feet of shoreline was erosional and between 1961-1970, only 5,000 feet of shoreline, out of a total of 40,000 feet, were erosional.

In general erosion occurred primarily along the western section of Coatue Beach. Between Coatue Beach and Coskata, there was very little change over the 32 year period. Accretion was most pronounced along the west side of Great Point with rates reaching over 15 feet/year.

The shape of the shoreline between Great Point and the east jetty, longshore bars parallel to Coatue Beach and accretion on the east side of the east jetty suggest an east to west littoral drift along this shore. The net trend of this shoreline has been toward accretion which contrasts sharply with the severe erosion on the south shore. However, the Coatue barrier sand spit is subject to the same type of overwash flooding as described for the eastern shore. Its continued integrity is vital to maintaining Nantucket Harbor in its present configuration. The spit exists in delicate equilibrium among wind, waves, sand, and vegetation.

West Jetty to Smith Point

A net erosion rate of less than 1 foot/year was measured along this remaining section of the Nantucket shoreline between the west jetty and Smith Point. Most of the accretion occurred in the immediate vicinity of the jetty, 1 foot/year, and on the foreland at Eel Point, 6-12 feet/year. The 10-30 foot dune and glacial cliffs between Eel Point and the west jetty were eroding at 1-3 feet/year over the 32 year period. Although this erosion rate is more severe than on the other section of the north shore, it is still much lower than along the south shore.



Photograph looking east from Eel Point to the west jetty.

The glacial cliff segments on the north side of Smith Point generally had higher rates of erosion at the west end, about 5 feet/year, than at the east end, about 1.5 feet/year. Much of the erosion at the west end of Smith Point may be due to strong tidal currents moving between Tuckernuck Island and Smith Point.

CONCLUSION AND MANAGEMENT IMPLICATIONS

The vast majority of the Nantucket shoreline is being eroded by rising sea level, wind, waves, and tides. The most severe rates documented in this study were on the south shore with average rates on the order of 6-10 feet/year, but sometimes exceeding 12-15 feet/year. Erosion was much less severe on the east and north shorelines with the section between Great Point and the east jetty perhaps the most stable section of the entire Nantucket shoreline. Of over 216,000 feet, 41 miles, of shoreline examined, less than 20,000 feet were accreting during the 125 years studied, though during particular time intervals many areas were building. Characterized as a whole, the Nantucket shoreline has been, and remains, largely erosional with rates varying in different locations.

The shoreline trends documented by this study should provide potential purchasers of coastal property, real estate agents, banks, and regulatory officials with the information needed to properly manage development of Nantucket's coastal resources. For the first time, data is available which details rates of shoreline retreat around the entire island.

In addition to the historical data, the ongoing field monitoring program will provide accurate supplemental data on seasonal shoreline changes at twenty specific locations on Nantucket. The information from this phase of the study will allow corroboration of the historical trends documented in this report and a more detailed examination of twenty specific areas of critical coastal resource concern. As this field data is compiled and analyzed, it will be issued as an appendix to this report.

As an example of the utility of this data, consider two hypothetical, previously undeveloped, shoreline building sites being considered for purchase by a family. It is determined through reference to the base maps and appendices that Site A on the north shore has had an average erosion rate of 3 feet/year and a range of 1-5 feet/year. Site B is on the south shore and erosion here has averaged 11 feet/year with a range of 9-16 feet/year. Both sites have lots with the same dimensions and a maximum setback distance of 140 feet from the dune's edge. Both lots list for about the same price and the family is trying to choose which one to purchase. They will also go to a bank to investigate the chances for securing a 30-year mortgage for each. The shoreline data provided in this report would clearly indicate the consequences of the purchase of Site B. With a setback of only 140 feet/year, the home built here would in all likelihood fall into the ocean within fewer than 13 years. Hardly an attractive investment for a 30-year mortgage! On the other hand, the property owner could be reasonably certain that the home built on Site A would remain safe from ocean damages for over 45 years. The reader should remember that on Nantucket, which is isolated from sources of heavy machinery, building materials, and labor, shoreline protection is in almost all cases <u>not</u> an economically or environmentally viable solution. The remaining option for prospective property owners is to avoid, development in flood, storm damage, and erosion prone areas of the shoreline.

The data in this study were compiled to help accomplish this goal. However, the accretion and erosion rates presented represent <u>averages</u> from charts and photographs covering intervals ranging from 10-68 years. At any particular site there may be no appreciable erosion for many years, then many feet of dune or bluff may disappear in a single severe storm. Many fall and winter storm seasons may pass with little hurricane or "noreaster" activity. Then in one year particularly severe storms could occur. For example, a severe hurricane has not struck Nantucket in many years. The average erosion rates (derived from extremes) presented here cannot predict specific future trends but are intended as a comparative historical chronicle of coastal change on Nantucket. Only through proper management of the shoreline can this coastal resource be preserved to provide economic and recreational benefits, while avoiding the waste and losses incurred from unconsidered, inappropriate development.

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The reader is encouraged to refer to the references listed below for more detailed information on techniques used in this study, geology of Nantucket, and coastal processes.

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APPENDIX I

Base Maps with Key to Data Tables

(Appendix II and III)

The base maps (appendix I) and tables (appendix II and III) have been organized to make them easy to use.

We hope that any prospective property buyer, real estate agent, developer, regulatory official or Nantucket resident will be able to locate specific sites and determine average annual and total shoreline changes.

The procedure for using these data starts with locating the piece of property of interest on a street or assessor's map, noting the distance from the property to a nearby landmark such as a road, pond, or lighthouse. Then consult the index to base maps which divides Nantucket into 11 blocks that define individual sections of the shoreline. Find the block into which your property falls and turn to the appropriate base map (the base map number is located in the lower right hand corner of each of the 11 base maps). After turning to the correct base maps the reader should locate the same landmark originally identified on the street or assessor's map and measure the equivalent distance from the landmark to the property. The detailed base maps are scaled to 1:24,000; each inch being equivalent to 2,000 feet. Next the transect numbers closest to the property should be noted and the reader could next turn to the tables and read off the erosion-accretion rates of the shoreline. Here is a detailed example which will illustrate how to access this data.

A hypothetical family is interested in property near Hummock Pond. They have found the lot on an assessor's map and noted that the site is approximately 1,000 feet east of the intersection of Massasoit and Clark Cove Roads. They would turn first to the index to the base maps and find that the Hummock Pond area is on base map #7. Turning to this detailed map, they would locate the street intersection and then with a ruler measure ½ of an inch (½" = 1,000' on these charts) to the east (to the right) to locate their property.

Having now located their lot, the family would note the transect numbers nearest to their property for use in consulting the tables. On base maps 3-8 there are two sets of identifying transect numbers while on base maps 1, 2, 9, 10, and 11 there are only one set of numbers. The solid bars on the base maps refer to the aerial photograph sequence numbers in appendix II. The distance between each numbered bar (only every fifth bar is numbered for clarity) is 1,000 feet so the property should be no more than 500 feet from the nearest bar. The family would note the aerial photograph sequence number nearest their property; in this case #117.

The second set of numbers on the base maps are the circled historical chart transect numbers. The family would again note the number of the closest transect, #23.

With the two transect numbers the family would be ready to turn to the tables listing historical shoreline changes for each transect numbers.

Appendix II (aerial photographs) is divided into three parts; cliff line segments, dune line segments, and high tide line segments. Since some sections of the Nantucket shoreline are cliffs while others are low dunes measurements of cliff and dune shoreline changes from the aerial photographs are listed separately. Some of these segments were also measured a second time using location of mean high water as the shoreline. This is because accretion along coastlines with cliffs can be measured best by the movement of the high water line seaward.

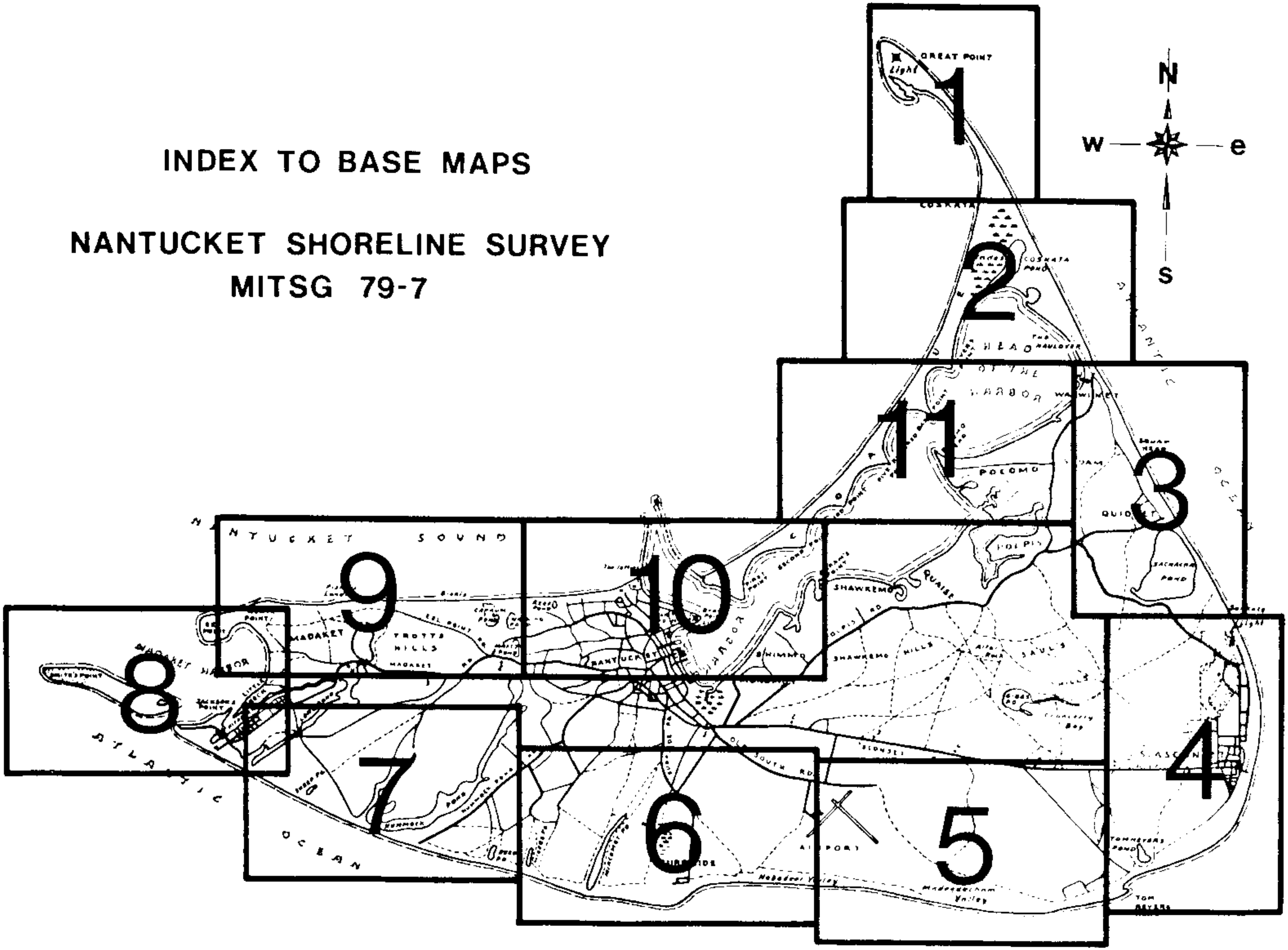
The family referring to appendix II would find data listing average annual erosion or accretion rates for three intervals (1938-1951, 1951-1961 and 1961-1970). Accretion in all cases is indicated by a plus (+) sign. For segment #117 the table lists an erosion rate of 14.8 feet/year between 1951-1961. Total shoreline change car be determined simply by multiplying the annual rate times the number of years in the interval.

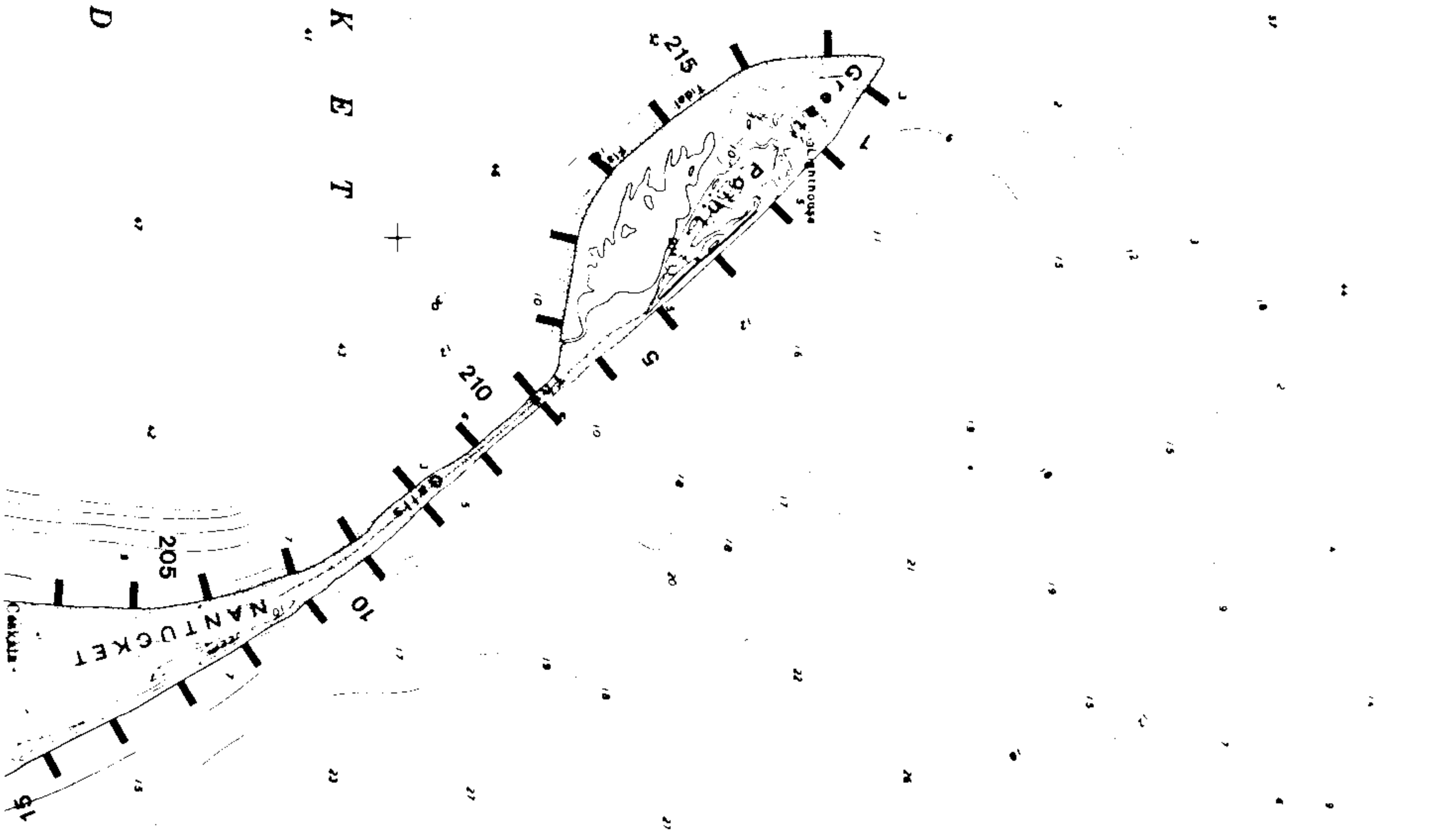
The family could next refer to appendix III and determine erosion-accretion rates for the intervals 1846-1887, 1887-1955 and 1846-1955. The annual or total shoreline change can be found by simply finding the appropriate historical chart transect number and reading off the rates listed to the right of the transect number. Between 1946-1955 erosion of transect #23 averaged 9.5 feet/year.

The family interested in property near Hummock Pond would now have available data on erosion rates at their property to aid an investment decision. Any reader interested in a particular site could follow the procedure outlined in this example to determine historical shoreline trends. It should be noted however, that the average erosion-accretion rates presented in these appendices cannot predict specific future trends but are intended as a comparitive historical chronicle of coastal change on Nantucket.

INDEX TO BASE MAPS

NANTUCKET SHORELINE SURVEY
MITSG 79-7





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95 Aerial photograph segment number

NANTUCKET SHORELINE SURVEY
MITSG 79-7

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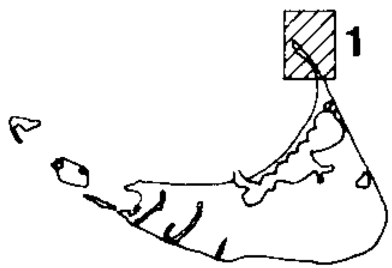

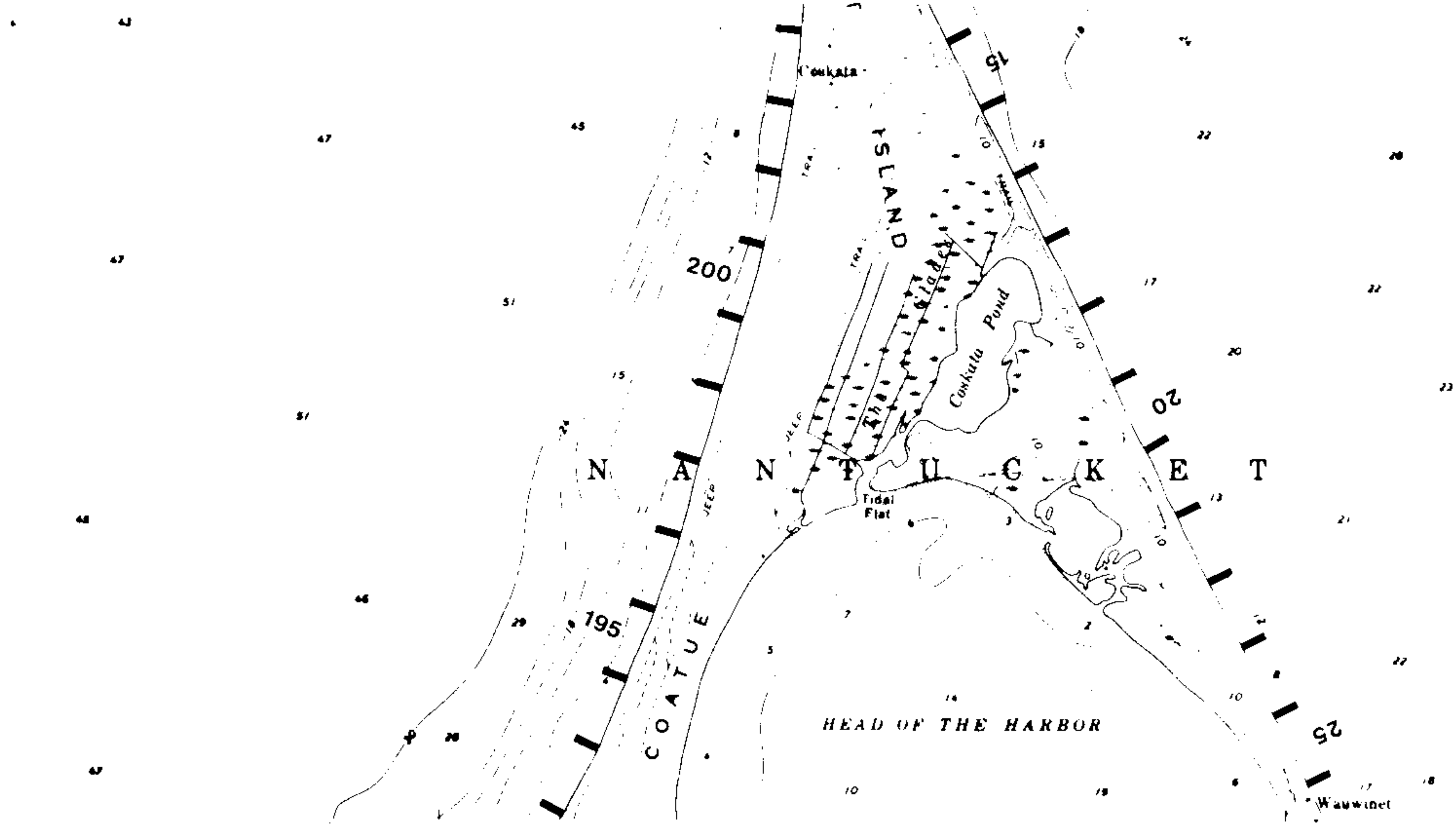

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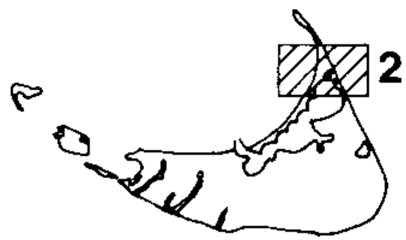

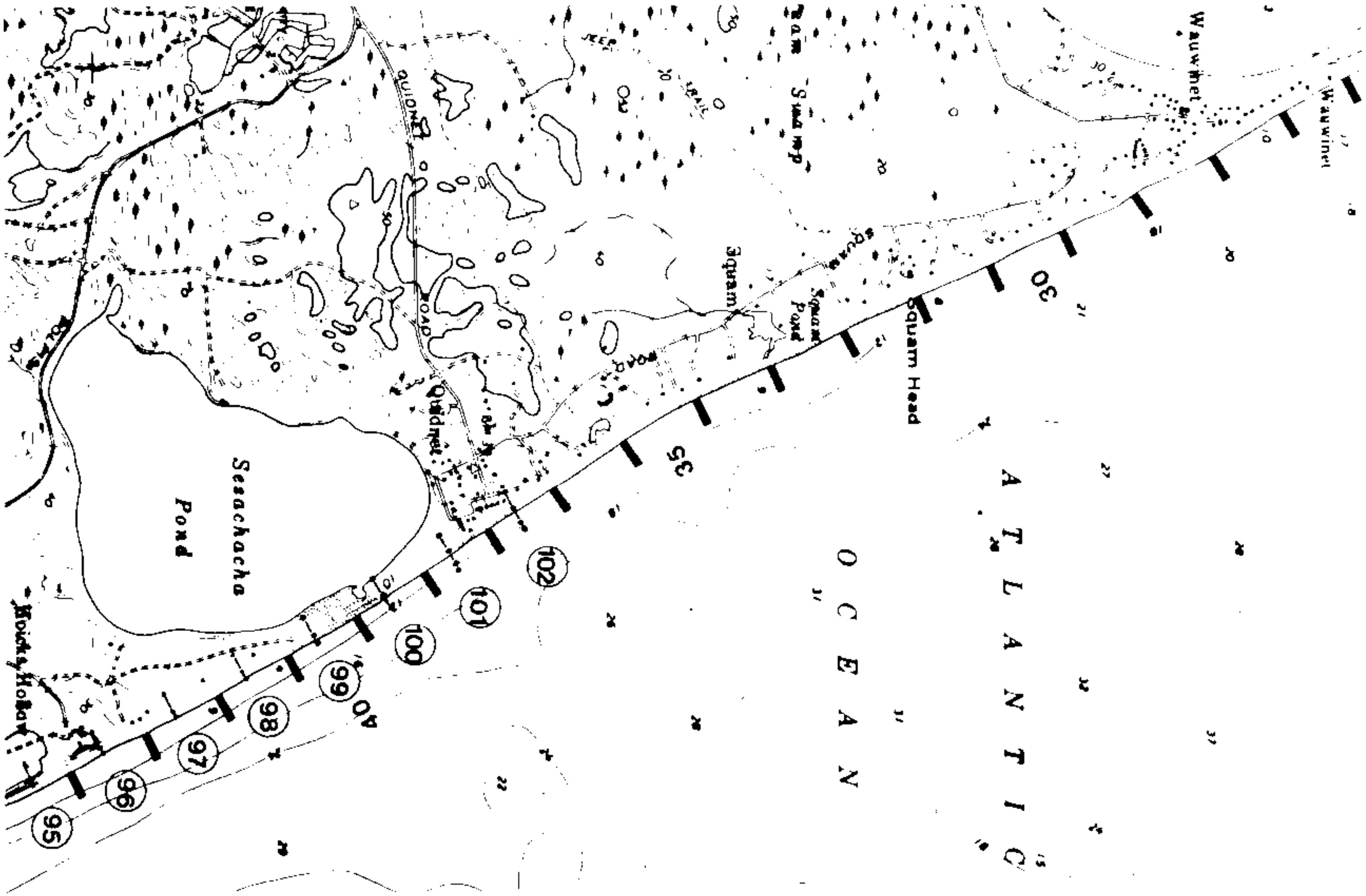

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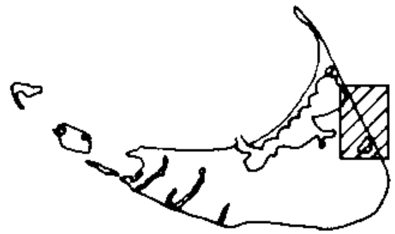

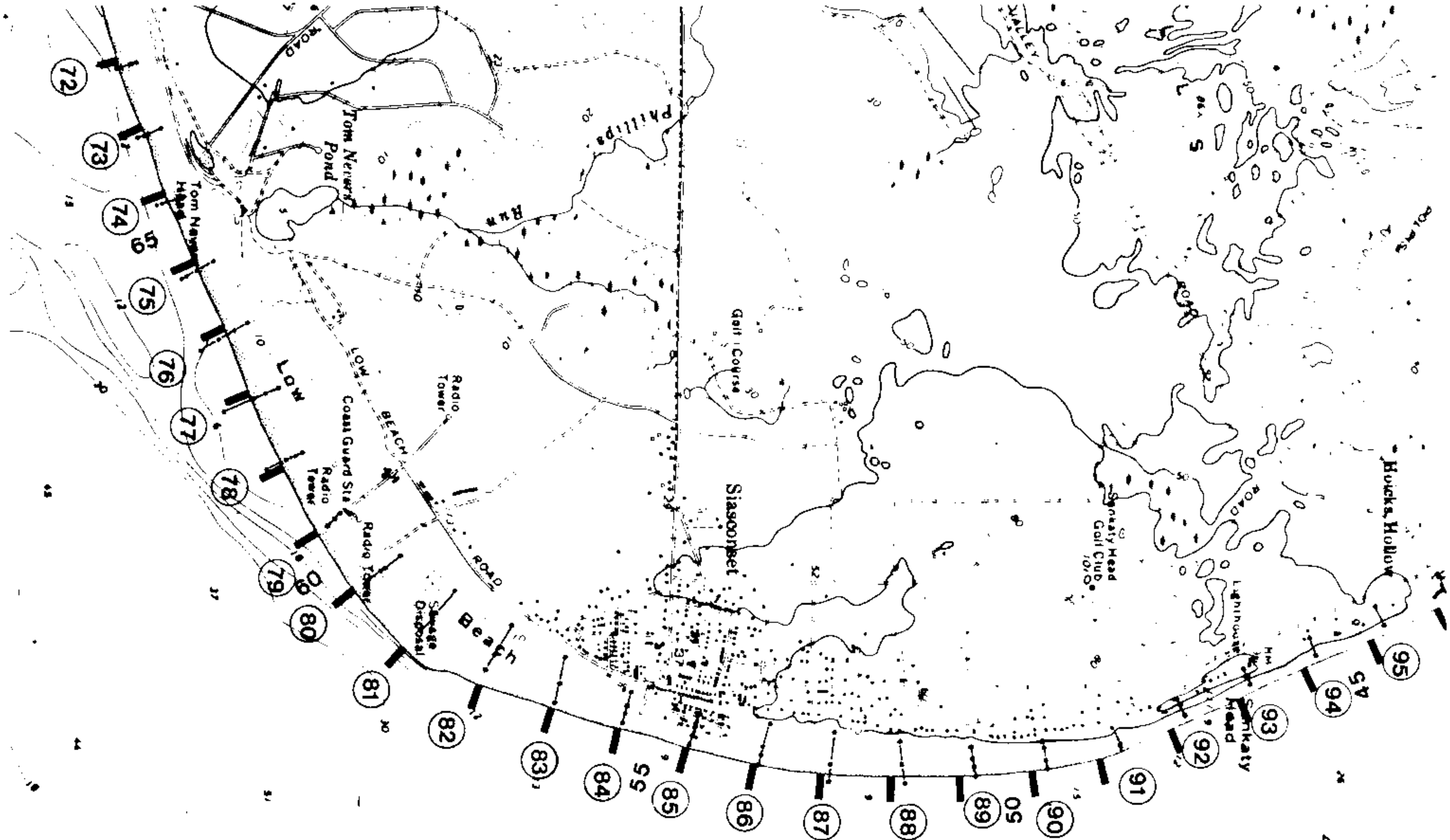

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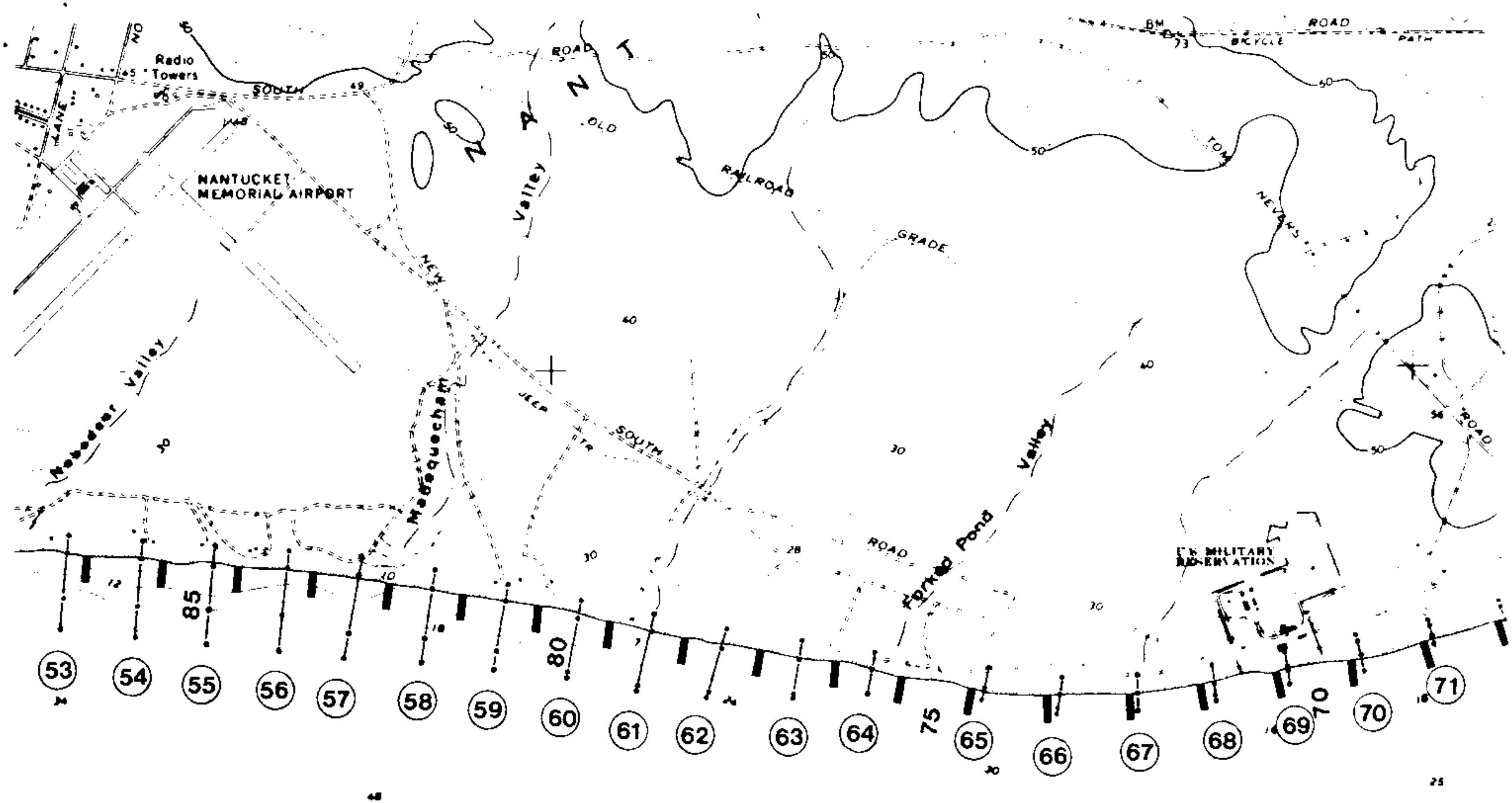

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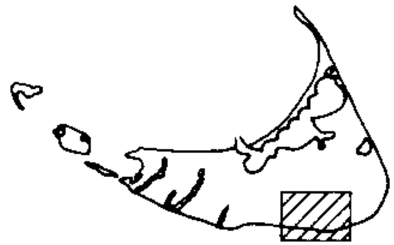

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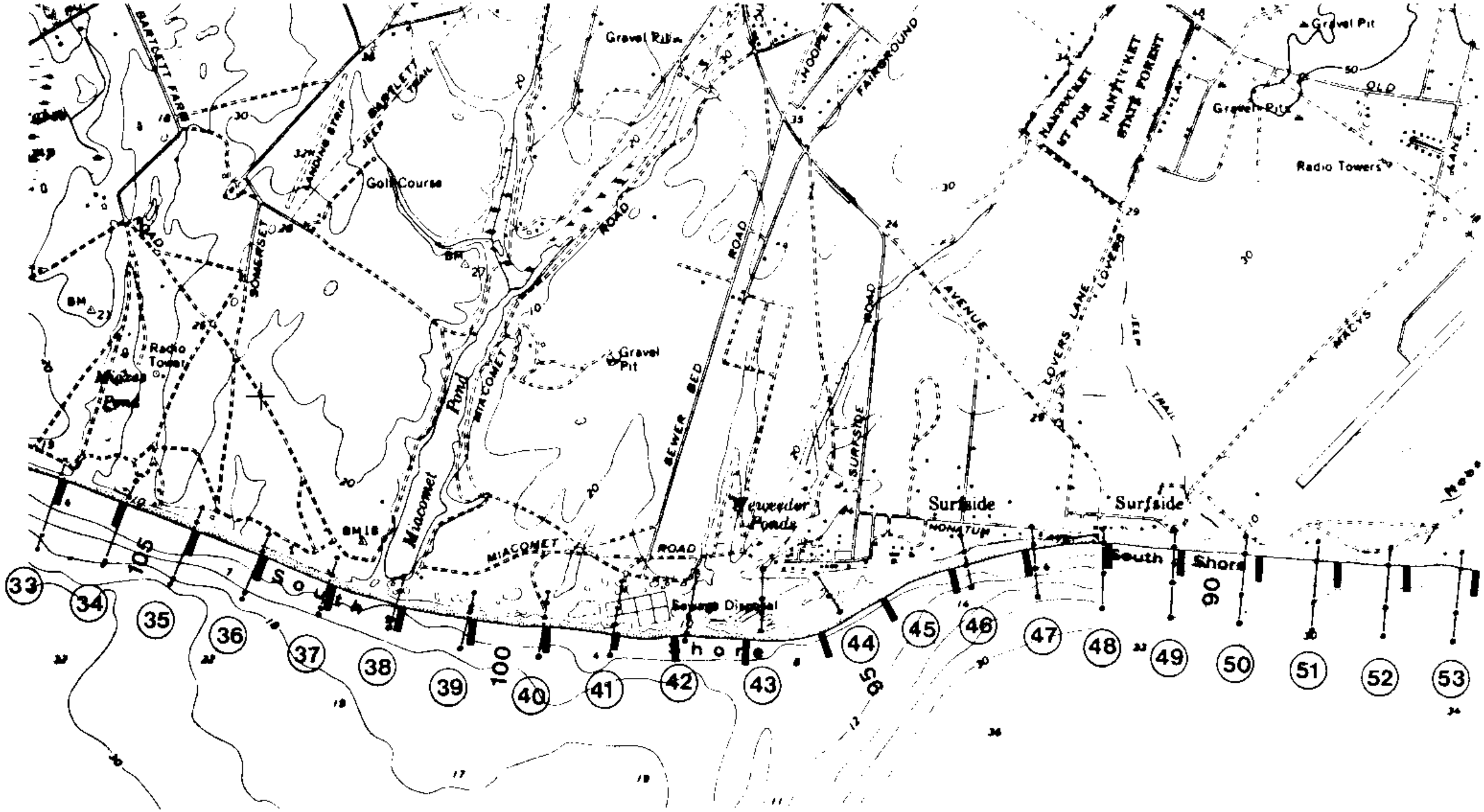

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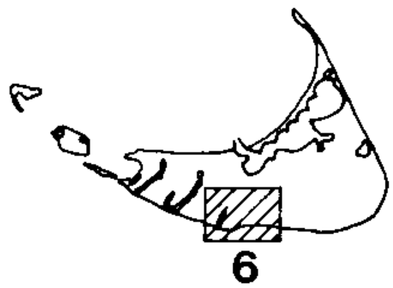

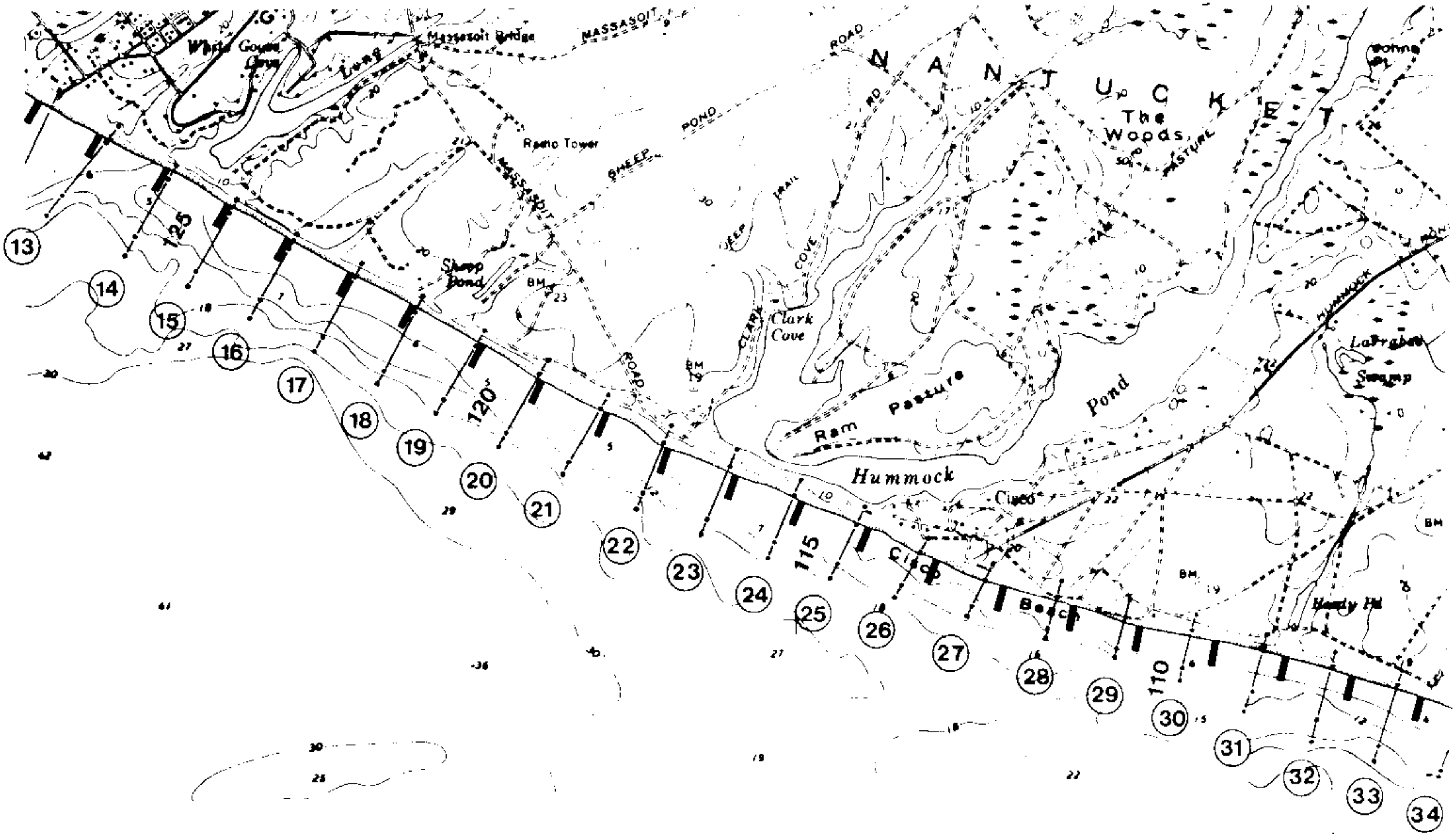

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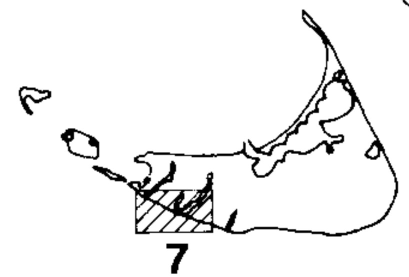

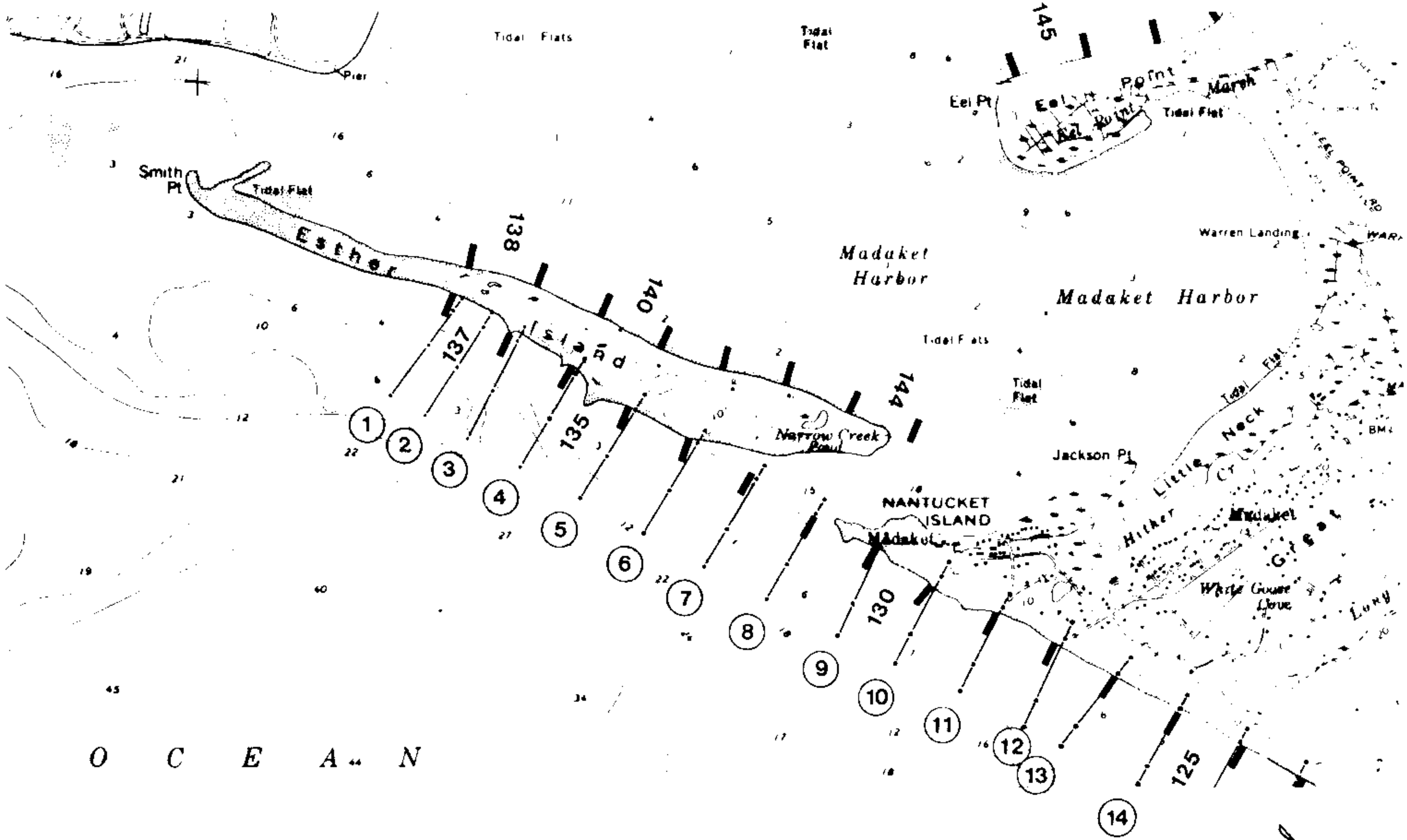

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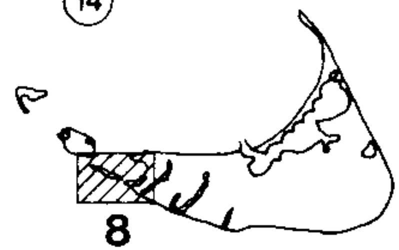
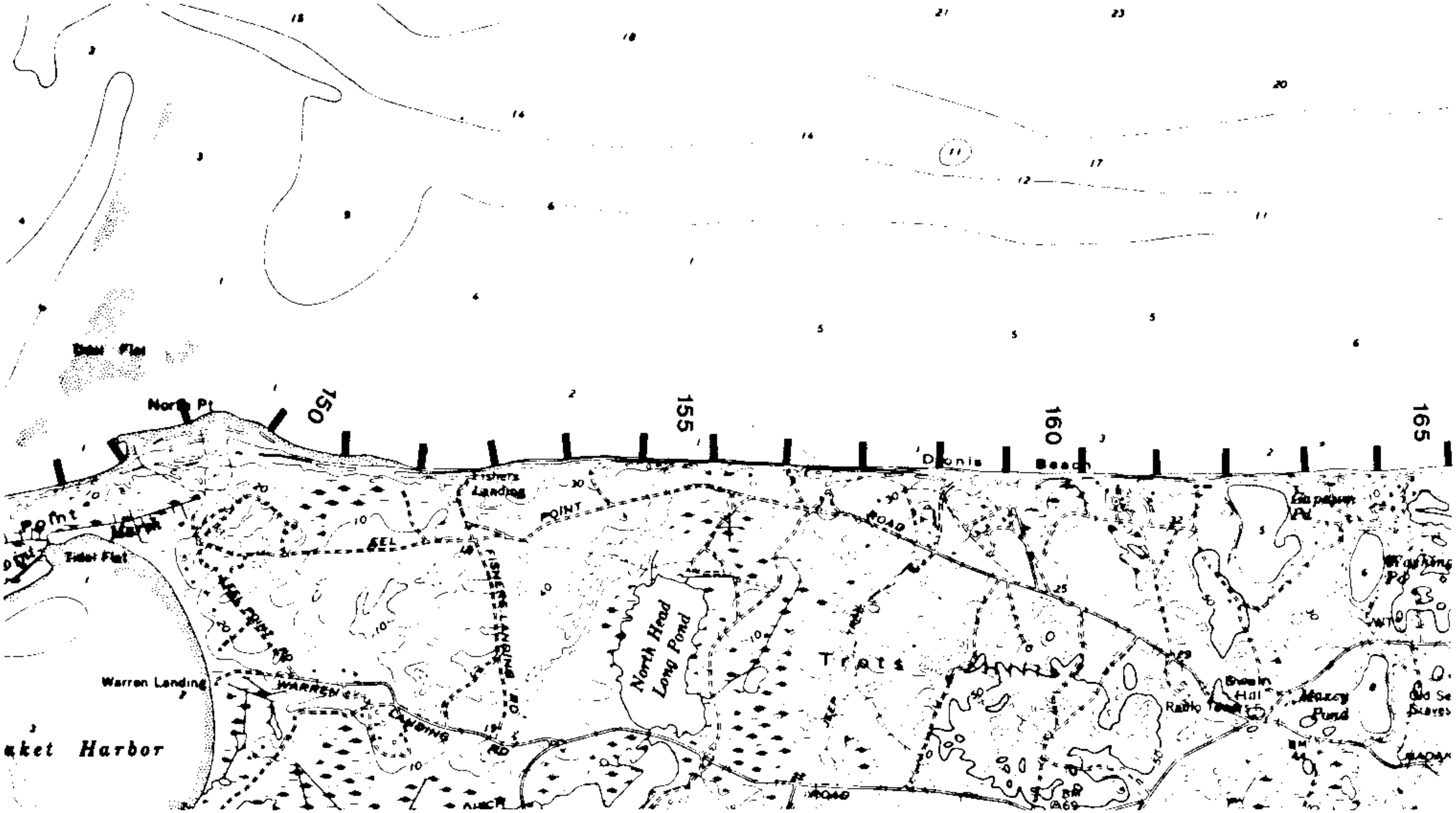
NANTUCKET SHORELINE SURVEY
MITSG 79-7

BASE MAP: USGS 1972 **SCALE 1:24000**





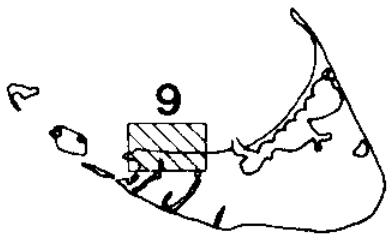
95 Historical chart transect number

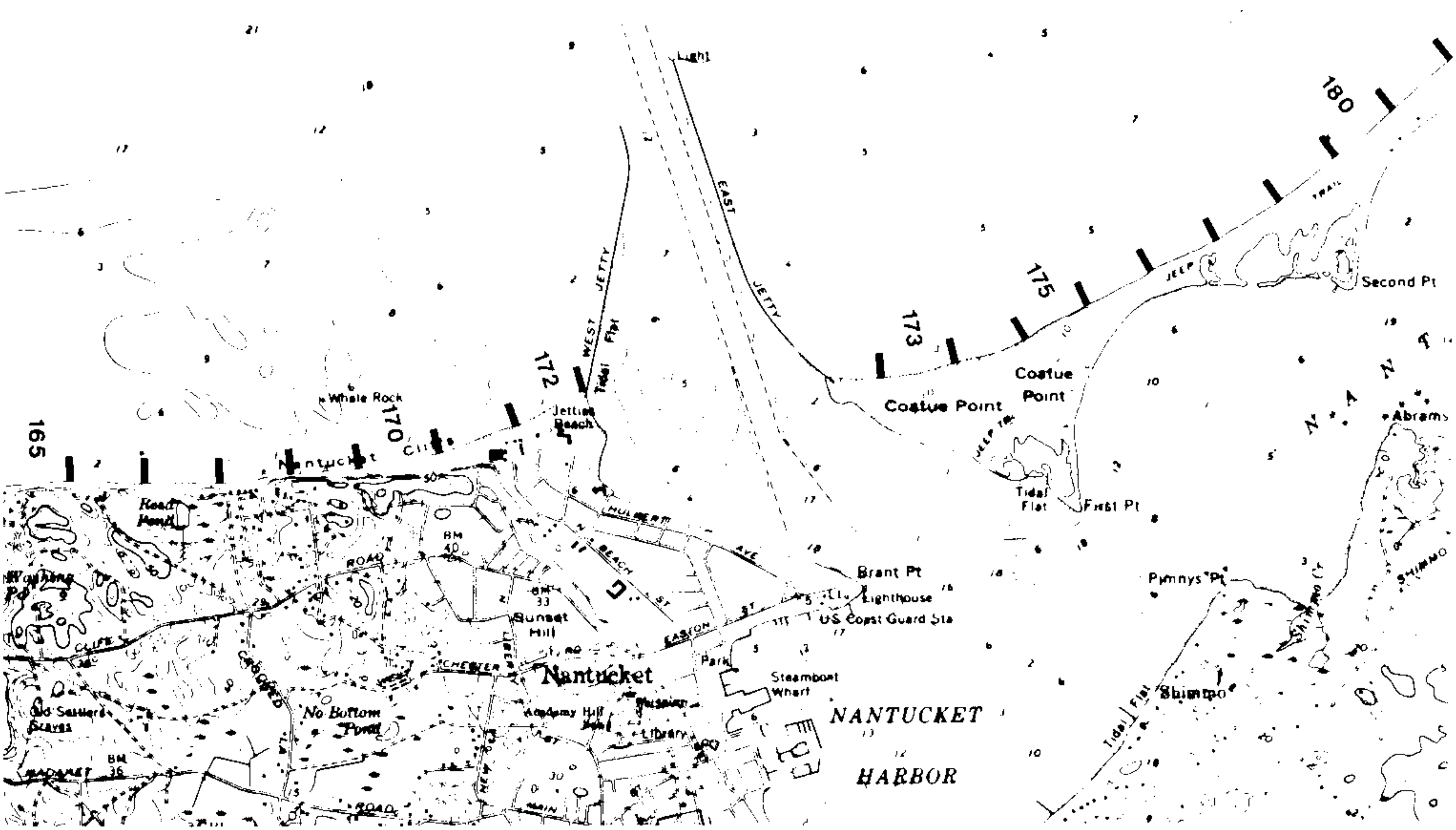
95 Aerial photograph segment number

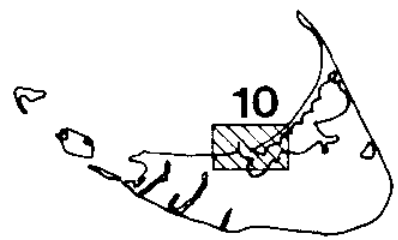
NANTUCKET SHORELINE SURVEY
MITSG 79-7

BASE MAP: USGS 1972

SCALE 1:24000







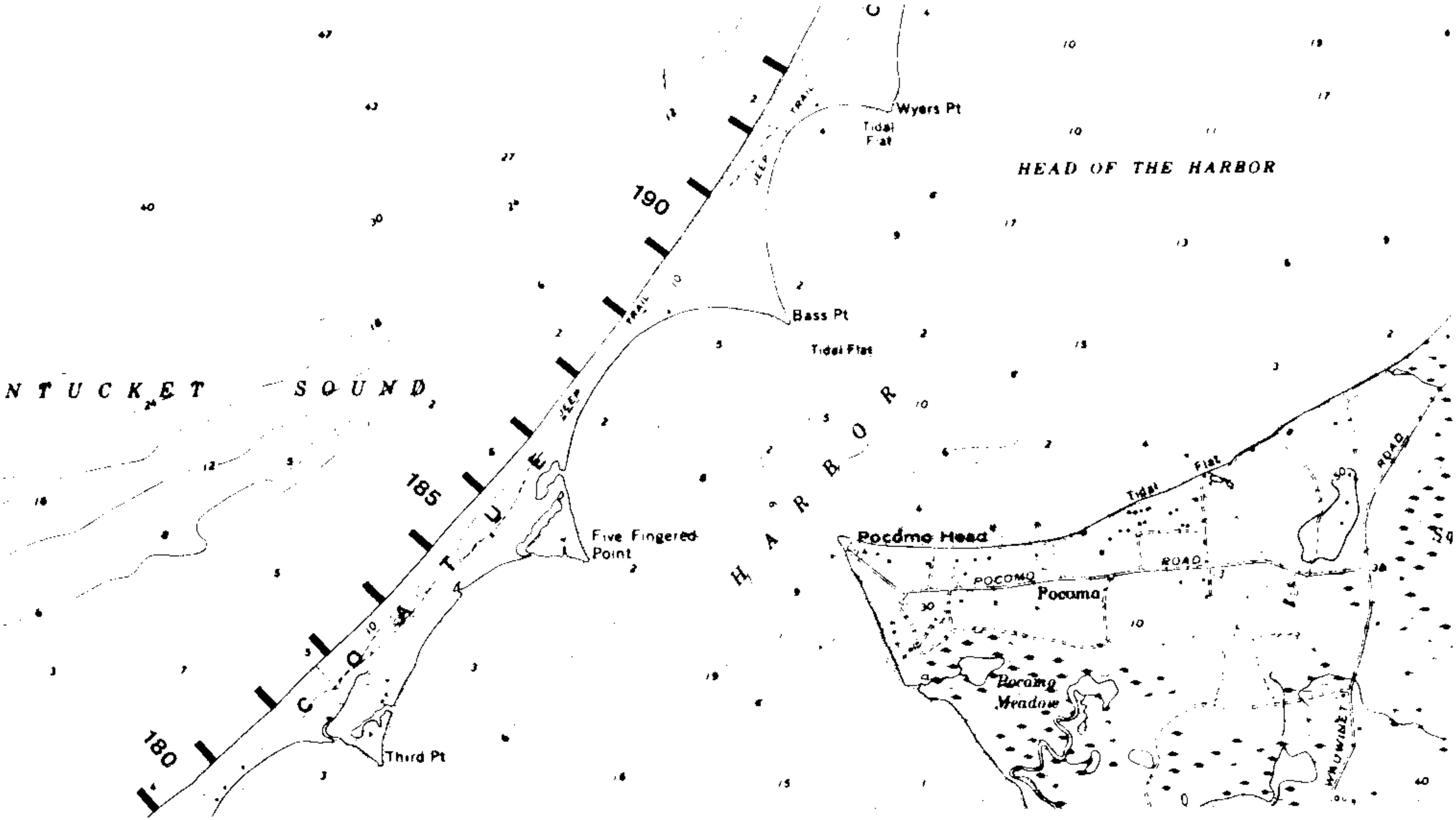
(95) Historical chart transect number

95 Aerial photograph segment number

NANTUCKET SHORELINE SURVEY
MITSG 79-7

BASE MAP: USGS 1972

SCALE 1:24000



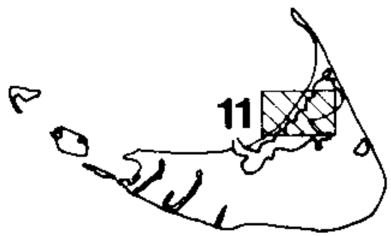
Historical chart transect number

Aerial photograph segment number

NANTUCKET SHORELINE SURVEY
MITSG 79-7

BASE MAP: USGS 1972

SCALE 1:24000



APPENDIX II

Shoreline Trends of Nantucket From Aerial Photographs

- Transects #'s refer to the location of 1000 foot shoreline segments on basemaps.
- Accretion is indicated by a (+) sign. In all other cases assume erosion.
- For total shoreline retreat multiply yearly rate times length of interval.
- Blank indicates no change over period.

CLIFF LINE SEGMENTS

		MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR		
SECTION	TRANSECT #	1938-1951	1951-1961	1961-1970
Great Point	1	4.4	7.1	7.0
	2	6.7	21.3	17.2
	3	15.5	18.7	16.4
	4	20.3	11.4	12.9
	11	9.9		
	12	7.9		1.4
	13	7.9		0.3
	14	4.4		3.1
	15	3.7		3.2
	16	3.2		3.1
	17	3.2		3.1
	18	2.1		2.6
	19	1.3		2.9
	20	0.6		0.6
	21-34			
	35	3.5		
	36	3.7		
	37			
	38			
	39		1.5	
	40	1.9		1.5
	41	3.0		3.1
	42	1.4		2.5
		1.1		4.4

APPENDIX II

SHORELINE TRENDS OF NANTUCKET FROM AERIAL PHOTOGRAPHS

		MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR		
SECTION	TRANSECT #	1938-1951	1951-1961	1961-1970
	43	1.1		4.4
	45			3.5
	46			
	47			
	48			8.8
Sankaty Head	71		2.9	7.4
	72	3.8		6.5
	73	6.4		8.8
	74	7.2	2.9	9.5
	75	7.5	8.2	14.0
	76	10.3	9.8	11.0
	77	12.9	4.9	14.7
	78	9.1	5.9	12.7
	79	6.3	8.0	7.7
	80	7.8	8.0	14.2
	81	13.1	8.7	6.3
	82	7.2	4.8	5.1
	83	8.5	3.2	5.8
	84	6.7	7.2	8.1
	85	5.9	6.7	8.7
	86	5.3	8.1	10.2
	87	4.8	5.8	11.3
	88	5.3	4.6	14.4
	89	5.6	3.2	10.6
	90	2.4	3.5	5.8
	91	6.8		8.9
	92	7.9	2.9	3.2
	93	2.8	0.6	
Surfside	102	6.9		5.5
	103	3.7	6.5	8.3

APPENDIX II

SHORELINE TRENDS OF NANTUCKET FROM AERIAL PHOTOGRAPHS

		MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR		
SECTION	TRANSECT #	1938-1951	1951-1961	1961-1970
	104	10.3	9.6	2.2
	105	6.5	3.7	8.0
	106	10.3	3.9	3.0
	107	3.8	7.4	4.4
	108	10.8		5.9
	109	7.9		7.9
	110	5.4		8.9
	111	5.4	4.4	8.9
	112	6.5	8.9	13.3
	113	6.5	9.8	13.3
	119	8.2	21.8	7.3
	120	6.8	18.0	14.0
	121	6.4	14.0	20.0
	122	6.6	16.3	15.8
	123	6.6	16.3	15.8
	124	6.6	12.3	18.0
	125	4.9	1.5	29.0
	126	5.5		25.5
	127	8.6	3.8	16.6
	128	10.3	9.1	21.2
	129	15.5	7.6	25.7
	130	12.7	7.6	28.3
	131	16.2	6.0	28.3
	132	8.3	16.6	28.3
	133	8.9	9.1	29.2
	134	5.0	3.0	16.6
	135			12.6
	136			18.9
	137			35.5
	138	4.4	10.9	

APPENDIX II

SHORELINE TRENDS OF NANTUCKET FROM AERIAL PHOTOGRAPHS

SECTION	TRANSECT #	MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR 1938-1951	1951-1961	1961-1970
Smith Point	139-141			
	142	1.8		
	143	3.9		
Eel Point	144			
	145	10.8	10.2	1.3
	146	4.1	3.7	4.9
	147	2.7	3.2	1.1
	152		2.4	0.7
	153	0.8		2.6
	154	3.2	0.8	5.5
	155	5.2	1.6	1.9
	156	3.7	1.3	1.8
	157	3.1	2.1	1.8
	158	2.9	1.5	1.5
	159	1.5	3.0	
	160	2.2		
	161	1.5		1.5
	162	2.7	3.7	0.8
	163-169			
		DUNE LINE SEGMENTS		
Sankaty Head	49	(+) 1.6		9.7
	50	(+) 3.2	1.5	8.8
	51	(+) 4.1	4.4	10.2
	52	(+) 3.2	4.4	10.2
	53	(+) 2.1	1.5	8.8
	54		5.1	5.1
	55		2.2	4.4

APPENDIX II

SHORELINE TRENDS OF NANTUCKET FROM AERIAL PHOTOGRAPHS

		MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR		
SECTION	TRANSECT #	1938-1951	1951-1961	1961-1970
		(Dune Line Segments)		
	56	1.1		2.9
	57	7.8		9.7
	58	17.5	7.4	
	59	18.6	8.8	
	60	24.4	8.1	8.1
	61	7.0	2.9	9.4
	62	1.1	0.6	7.4
	63	(+)11.5		0.7
	64	(+)24.7		(+) 0.7
	65	(+)43.0	0.5	8.8
Tom Nevers Head	66	(+)46.7	25.0	(+) 0.7
	67	(+)39.2	19.1	(+) 7.4
	68	(+)33.8		4.7
	69	(+)16.1	(+)10.5	(+) 5.1
	70	(+) 1.1	10.5	
	94	(+) 5.2		
	95	(+) 8.2		
	96	(+) 5.3	2.9	
	97	1.3	20.4	(+) 8.2
	98	9.6	16.0	(+) 2.9
	99	2.0		(+) 1.5
Surfside	100			(+) 9.2
	101	0.8		(+) 4.9
	114	8.6	14.8	10.9
	115	10.3	16.8	6.6
	116	21.1	8.9	(+) 3.0
	117	21.1	14.8	(+) 4.4
	118	10.8	16.3	(+) 7.9
	148	(+) 3.3	(+)16.8	1.8

APPENDIX II

SHORELINE TRENDS OF NANTUCKET FROM AERIAL PHOTOGRAPHS

SECTION	TRANSECT #	MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR 1938-1951	1951-1961	1961-1970
		(Dune Line Segments)		
	149	(+)15.0	(+) 9.5	(+)16.6
	150	(+) 2.9	(+) 4.5	(+) 9.7
	151	(+) 3.8	(+) 1.9	(+) 0.7
	170		(+) 2.9	
West Jetty	171		(+) 4.4	
	172			
	173	(+)10.8	(+) 7.1	(+) 5.9
	174	(+) 2.5	(+) 2.3	(+) 5.9
	175	2.9		(+) 4.9
	176	4.5		1.8
	177	3.8		6.3
	178	2.6		3.9
	179	3.8		
	180	3.0		(+) 1.2
	181	1.1		(+) 5.9
	182			(+) 6.3
	183	(+) 1.3		(+) 3.7
	184	(+) 4.0		
Coatue Beach	185	(+) 3.8		
	186-189			
	190	4.6		
	191	5.0		
	192	2.9		
	193-201			
	202	(+) 3.0	(+) 2.0	
	203	(+) 3.7	(+) 4.9	
	204		(+) 8.6	
	205	(+) 0.2	(+) 4.7	
	206	(+) 4.2	(+) 8.6	(+) 2.2

APPENDIX II

SHORELINE TRENDS OF NANTUCKET FROM AERIAL PHOTOGRAPHS

		MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR		
SECTION	TRANSECT #	1938-1951	1951-1961	1961-1970
		HIGH TIDE LINE SEGMENTS		
Great Point	5	17.8	12.4	6.4
	6	16.0	15.7	8.2
	7	15.7	11.7	0.6
	8	15.4	5.3	
	9	14.4		
	10	13.9		
Sankaty Head	49	3.4	4.4	(+) 4.9
	50	3.2	5.1	(+) 7.3
	51	3.8	4.4	(+)11.7
	52	5.9	0.3	(+)14.0
	53	2.1		(+)13.6
	54			(+) 8.8
	55			(+) 3.2
	56			(+)12.1
	57		11.8	(+)20.6
	58		33.8	(+)44.1
	59	14.0	32.6	(+)50.0
	60	10.2	17.3	(+)26.8
	61	1.6	(+)34.5	32.3
	62	(+) 0.5	(+)39.7	32.3
	63	(+) 9.1	(+)26.5	24.1
	64	(+)20.8	(+) 8.9	8.8
	65	(+)36.0	13.2	(+) 1.0
	66	(+)56.9	38.2	(+) 8.2
	67	(+)32.0	9.5	(+) 8.2
	68	12.0		(+) 8.1
	69	13.6	0.7	0.7

APPENDIX II

SHORELINE TRENDS OF NANTUCKET FROM AERIAL PHOTOGRAPHS

		MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR		
SECTION	TRANSECT #	1938-1951	1951-1961	1961-1970
		(High Tide Line Segments)		
Tom Nevers Head	70	11.2	4.1	4.3
	94			(+) 8.8
	95			(+)10.0
	96	2.7		(+)19.0
	97	12.3		(+) 1.0
	98	11.2		(+) 3.7
	99	6.1		(+)12.4
Surfside	100	(+) 2.5	1.5	(+) 5.9
	101	(+) 7.7	4.0	(+) 2.9
	114	10.8	16.3	1.5
	115	13.0	16.3	3.0
	116	14.4	11.8	
	117	13.2	15.5	1.5
	118	11.3	15.8	7.4
	133	13.3	9.1	29.2
	134	12.7	4.5	16.6
	135	17.1	(+) 6.7	12.6
	136	6.6	(+)21.2	18.9
Smith Point	137	3.8	(+)12.1	35.5
	148	(+) 8.3	(+)13.3	(+) 6.0
	149	(+)12.1	(+)21.7	(+) 5.3
	150	(+) 3.3	(+)10.1	(+) 3.5
	151			
Coskata	202		(+) 2.1	
	203		(+) 5.5	
	204		(+) 7.4	
	205	(+) 0.6	(+) 5.9	
	206	(+)11.3	(+) 1.5	(+) 5.9
	207	(+)18.2	9.9	(+) 2.0

APPENDIX II

SHORELINE TRENDS OF NANTUCKET FROM AERIAL PHOTOGRAPHS

SECTION	TRANSECT #	MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR 1938-1951	1951-1961	1961-1970
		(High Tide Line Segments)		
	208	(+)24.9	11.6	
	209	(+)25.9	15.1	3.9
	210	(+)24.5	1.2	3.9
	211	(+)18.0	(+)13.3	(+)26.6
	212	(+)16.4	(+)34.7	(+)26.6
	213	(+)22.9	(+) 0.4	(+)15.5
	214	(+) 8.9	17.0	(+) 4.4
	215	(+) 1.5	17.0	(+) 9.2
Great Point	216			(+)24.9

APPENDIX III

Shoreline Trends of Nantucket From Historical Charts

- Transect #'s refer to the location of 1000 foot shoreline segments on basemaps.
- Accretion if indicated by a (+) sign. In all other cases assume erosion.
- For total shoreline retreat multiply yearly rate times length of interval.

		MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR		
SECTION	TRANSECT #	1846-1887	1887-1955	1846-1955
Esther Island	1	22.6	9.0	14.0
	2	24.4	10.0	15.4
	3	18.7	12.0	14.5
	4	19.9	10.9	14.3
	5	17.5	11.5	13.8
	6	17.5	11.5	13.8
	7	15.5	12.3	13.5
Madaket	8	14.2	12.5	13.2
	9	12.6	13.2	13.0
	10	11.4	13.9	12.9
	11	11.0	13.4	12.5
	12	10.0	14.3	12.7
	13	8.7	14.3	12.2
	14	7.3	13.7	11.3
South Shore	15	5.9	14.0	10.9
	16	7.2	12.3	10.3
	17	6.7	17.2	13.2
	18	4.9	13.6	10.3
	19	5.3	12.8	10.0
	20	5.5	13.9	10.7
	21	4.7	13.0	9.9
	22	6.3	11.0	9.3
	23	5.0	12.1	9.5
	24	5.5	10.3	8.5
	25	6.1	8.8	7.8
	26	4.9	7.5	6.6

APPENDIX III

SHORELINE TRENDS OF NANTUCKET FROM HISTORICAL CHARTS

SECTION	TRANSECT #	MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR 1846-1887	1887-1955	1846-1955
	27	3.7	6.0	5.1
	28	4.5	6.6	5.4
	29	2.8	7.4	5.7
	30	2.6	7.8	6.5
	31	7.3	9.7	8.8
	32	7.7	11.2	9.9
	33	5.1	13.2	10.2
	34	1.8	14.0	9.4
	35	(+) 1.0	13.6	8.1
	36	(+) 1.4	10.3	5.9
	37	(+) 1.6	8.3	4.6
Miacomet Pond	38	(+) 2.4	7.8	4.0
	39	(+)12.6	8.3	0.5
	40	(+)22.0	8.3	(+) 3.0
	41	(+)25.4	6.4	(+) 5.6
	42	(+)24.0	1.6	(+) 8.0
	43	(+)11.0	(+) 6.1	8.0
	44	(+) 1.0	(+) 9.4	6.3
	45	5.5	(+) 2.7	0.4
	46	7.9	2.8	4.7
	47	9.6	4.9	6.7
	48	11.8	6.4	8.4
	49	7.9	7.4	7.6
	50	9.8	8.5	9.0
	51	9.1	8.6	8.8
	52	9.6	8.7	9.1
	53	10.2	8.7	9.3
	54	10.2	9.3	9.6
	55	11.2	8.6	9.6
	56	10.8	9.9	10.2
	57	7.5	11.9	10.2

APPENDIX III

SHORELINE TRENDS OF NANTUCKET FROM HISTORICAL CHARTS

SECTION	TRANSECT #	MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR 1846-1887	1887-1955	1846-1955
	58	7.7	9.9	9.1
	59	5.9	9.9	8.4
	60	1.8	10.8	7.4
	61	(+) 1.2	11.8	6.9
	62	(+) 1.6	9.8	5.5
	63	(+) 1.4	7.5	4.2
	64		4.9	3.1
	65		2.2	1.4
	66	1.8	2.6	2.3
	67	0.6	3.1	2.3
	68	1.6	2.2	2.0
	69	(+) 5.3	2.6	(+) 0.4
	70	(+) 9.4	3.2	(+) 1.5
	71	(+) 6.3	1.2	(+) 1.6
	72	(+) 5.5	0.5	(+) 1.8
	73	(+) 3.5	1.0	(+) 1.1
	74	(+) 1.4	1.8	0.6
Tom Nevers Head	75	1.4	2.5	2.1
	76	7.5	3.6	5.1
	77	11.0	2.5	5.7
	78	7.7	(+) 2.9	2.8
	79	0.6	(+) 1.7	(+) 1.3
	80	(+) 7.9	(+) 3.4	(+) 5.1
	81	(+)10.0	(+) 5.0	(+) 6.9
	82	(+) 9.4	(+) 5.0	(+) 6.7
	83	(+) 8.3	(+) 4.7	(+) 6.1
	84	(+) 7.9	(+) 2.1	(+) 4.3
	85	(+)10.2	(+) 2.2	(+) 5.2
	86	(+)11.0	(+) 2.6	(+) 5.7
	87	(+)10.7	(+) 3.8	(+) 6.4

APPENDIX III

SHORELINE TRENDS OF NANTUCKET FROM HISTORICAL CHARTS

		MEAN ANNUAL SHORELINE CHANGE IN FEET PER YEAR		
SECTION	TRANSECT #	1846-1887	1887-1955	1846-1955
	88	(+) 7.3	(+) 3.6	(+) 5.7
	89	(+) 7.1	(+) 1.8	(+) 3.8
	90	(+) 6.9	(+) 1.5	(+) 3.5
	91	(+) 7.3	0.5	(+) 2.5
Sankaty Head	92	(+) 4.3		(+) 1.5
Sankaty Head Lighthouse	93	(+) 1.6		(+) 0.6
	94		0.4	0.2
	95	0.6	0.5	0.7
	96	0.1	0.7	0.7
	97	0.4	1.0	0.8
	98		1.2	0.8
	99	1.2	1.7	1.4
	100	1.8	2.3	2.2
	101	2.0	2.8	2.5
	102	2.0	2.7	2.5