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BARRIER ISLAND BREACH AND OVERWASH IMPACTS
POSITION PAPER

1. INTRODUCTION

The Atlantic Coast of Long Island, Fire Island Inlet to Montauk Point, New York, Storm Damage Reduction Reformulation Study seeks to evaluate long-term solutions for storm damage reduction along the south shore of Long Island. Barrier island and mainland property damages being addressed by the Reformulation Study primarily arise from storms due to tidal inundation, wave attack and erosion impacts. The severity of storm impacts in the areas surrounding Great South, Moriches and Shinnecock Bays is strongly dependent on the integrity of the barrier islands from Fire Island Inlet to Southampton. In this regard, overwashing and/or breaching of the barrier islands can lead to exacerbated storm damages as bay storm tide elevations are increased. Reduction of overwashing/breaching frequency and severity are, consequently, principal goals of the Reformulation Study. On the other hand, barrier island overwashing and breaching also contribute to natural habitat changes. Alteration of the beach may change these natural processes and affect the environmental resources in the study area.

This paper examines the physical and biological impacts associated with barrier island overwashing and breaching on the coastal/estuarine environment between Fire Island Inlet and Montauk Point, New York. Physical impacts include the effects of overwash and breaches on bay hydrodynamics and physical parameters. Overwash and breaches are also responsible for bay-directed sediment transport that may bury existing habitats while providing substrate for new shallow water and salt marsh habitat development. Biologic impacts in response to these physical changes are examined to determine the significance of overwash/breach effects on study area's natural resources. These descriptions and future study will provide the foundation for determining the significance of overwash/breach reductions in terms of study area environmental resources. Overall, the purpose of this paper is to concisely describe what is known regarding overwash/breach impacts in the study area and outline areas for additional study.

This paper considers breaching and overwashing impacts relative to two time scales, namely, short-term (days to months), and long-term (years to decades). The geologic time frame (hundreds to thousands of years) is the focus of separate analyses, and is not discussed herein. Physical and biological impacts are evaluated in terms of the localized and systematic effects of overwash and breaching on barrier island and estuarial resources. The physical and biological impacts include those related to the following factors: 1) transport of water into the bays due to breaches, 2) transport of sediment into the bays due to breaches and overwash. In addition, impacts of breach migration and existing inlets on study area resources are discussed.

2. STUDY AREA

The Federally authorized project area extends east from Fire Island Inlet to Montauk Point along the Atlantic Coast of Suffolk County, Long Island, New York (see Figure 1). The study area includes the barrier islands, the Atlantic Ocean shorelines and adjacent back-bay areas along Great South, Moriches and Shinnecock Bays. Total study length encompasses approximately 83 miles along the Atlantic Ocean and comprises approximately 70 percent of the total ocean frontage of Long Island, as well as several hundreds of miles of bay shoreline. A series of barrier islands characterize the western portion of the study area extending approximately 50 miles from Fire Island Inlet to Southampton. The barrier island chain includes: (1) Fire Island that extends approximately 30 miles east from Fire Island Inlet to Moriches Inlet, (2) the 16-mile barrier island segment which contains Westhampton and Tiana Beaches and spans from Moriches Inlet to Shinnecock Inlet, and (3) the 4-mile long barrier island extending from Shinnecock Inlet to Southampton.

2.1 Physical Setting

The study area is comprised of two distinct physiographic regions, specifically a barrier island portion extending from Fire Island Inlet to Southampton and a headland segment from Southampton to Montauk Point. The 50-mile long barrier island segment is characterized by low-lying islands fronting Great South, Moriches and Shinnecock Bays, which are connected through narrow tidal waterways that are elements of the Long Island Intracoastal Waterway (ICW). The barrier islands are generally less than 2,500 feet wide, and contain irregular sand dunes ranging in height to a from 10 to 30 feet above sea level. East of Southampton, a 33-mile long headland reach extends east to Montauk Point. This coastal segment is characterized by narrow beaches backed by a poorly defined dune system, as compared to that existing along the barrier islands. Commencing near Beach Hampton and extending eastward, a series of bluffed headlands are the predominant coastal feature, with bluffs rising to heights greater than 50 feet. A number of land-locked water bodies lie immediately shoreward of the oceanfront, the larger of which include Agawam Lake, Mecox Bay, Sagaponack Lake, Georgica Pond and Hook Pond. It is noted that the focus of this paper is the 50-mile barrier island segment between Fire Island Inlet and Southampton.

Barrier island overwashing, while indicative of low island elevations, can lead to further island flattening with material spreading outward causing island widening, increased back barrier elevations, and the establishment of substrate for salt marsh development along the bay shorelines of the barrier island. Accordingly, locations historically subject to overwashing may not be as vulnerable to future breaching or overwashing, based upon these changed back bay conditions. Breaches are most likely to occur when severe overwashing occurs in concert with narrow island widths and the presence of relatively deep water adjacent to the bay shoreline of the island. Under these circumstances, storm-induced overwashing may deposit eroded barrier island sediments below normal or elevated storm tide levels, which permits further scouring of the barrier island section due to storm or normal tidal exchange between the bay and ocean.

Breach (or inlet) persistence depends on the complex relationship between post-storm tidal flows that attempt to further expand the breach and incoming littoral drift. In the event that tidal flows through the breach are sufficient to remove deposited littoral drift, the breach may either remain stable or increase in size, while typically migrating in the direction of predominate littoral transport direction. Leatherman and Allen (1985) indicate that winds typically transport sediment in a seaward direction along the south shore of Long Island and act to elevate the island by building dunes and ridges. The significance of aeolian transport is estimated to range from minor (McCluskey et al., 1983) to comparable to water-borne sediment transport in dune building processes (e.g., Zimmer, 1991).

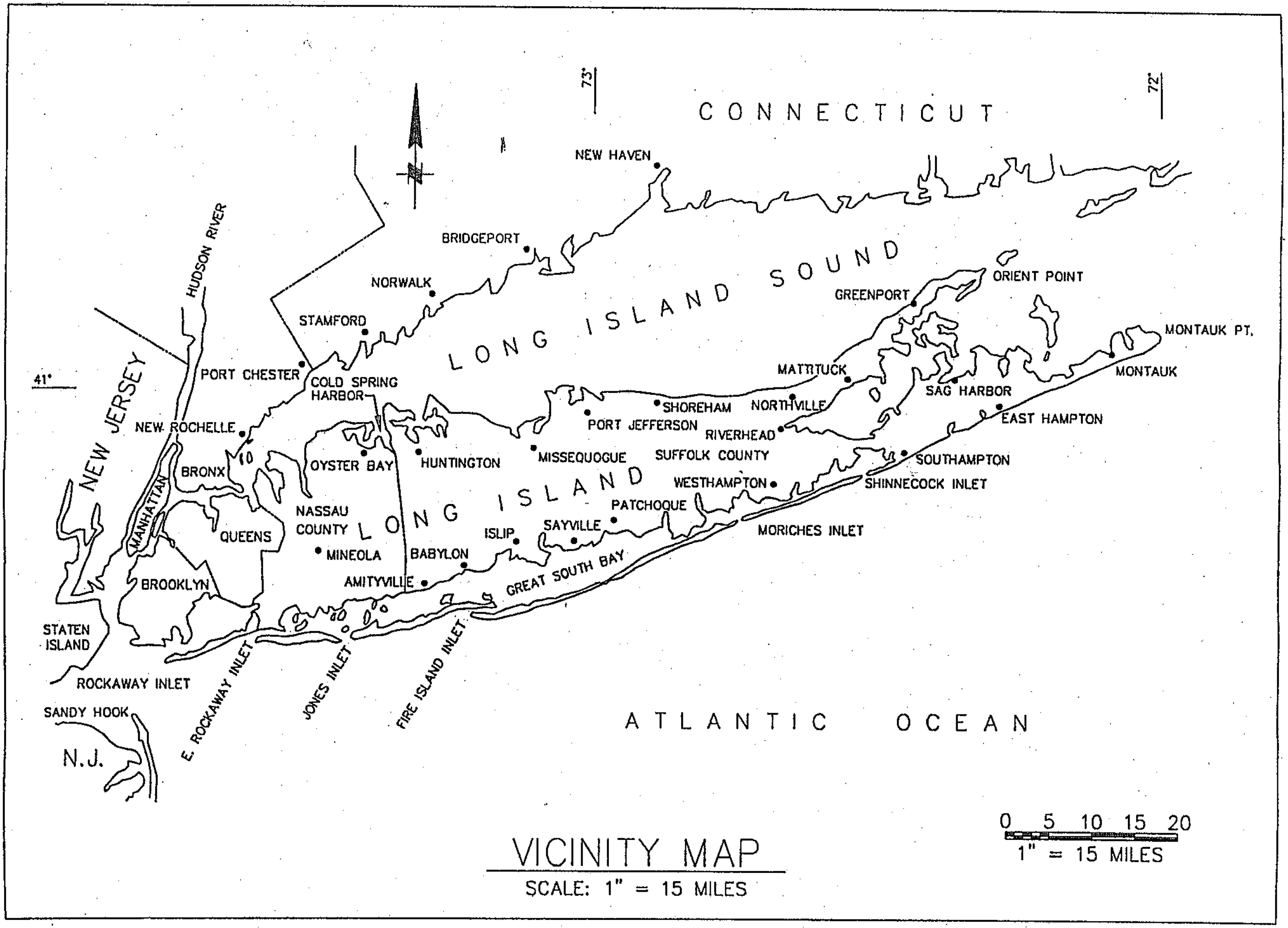

CONNECTICUT
73°
72°
41°
NEW HAVEN
BRIDGEPORT
NORWALK
STAMFORD
PORT CHESTER
HUDSON RIVER
NEW JERSEY
NEW ROCHELLE
COLD SPRING HARBOR
LONG ISLAND SOUND
GREENPORT
ORIENT POINT
MONTAUK PT.
MONTAUK
MATTITUCK
SAG HARBOR
SHOREHAM
NORTHVILLE
EAST HAMPTON
PORT JEFFERSON
RIVERHEAD
MANHATTAN
BRONX
OYSTER BAY
HUNTINGTON
MISSEQUOGUE
SUFFOLK COUNTY
SOUTHAMPTON
WESTHAMPTON
SHINNECOCK INLET
LONG ISLAND
NASSAU COUNTY
QUEENS
PATCHOGUE
SAYVILLE
ISLIP
MINEOLA
BABYLON
BROOKLYN
AMITYVILLE
GREAT SOUTH BAY
MORICHES INLET
STATEN ISLAND
ROCKAWAY INLET
E. ROCKAWAY INLET
JONES INLET
FIRE ISLAND INLET
SANDY HOOK
N.J.
ATLANTIC OCEAN
VICINITY MAP
SCALE: 1" = 15 MILES
0 5 10 15 20
1" = 15 MILES

Figure 1

3. ESTUARIAL SYSTEM

The study area estuarial system, comprised of Great South, Moriches and Shinnecock Bays, are respectively connected to the Atlantic Ocean through Fire Island, Moriches and Shinnecock Inlets. These inlets are located approximately 50, 80 and 96 miles east of The Battery, New York City, respectively. These inlets were originally stabilized by local interests, and recently been established as Federal navigation projects to maintain each of the inlets.

3.1 Great South Bay

Great South Bay is the largest of the project area estuaries extending about 33 miles from Massapequa in the west along South Oyster Bay to Smith Point in the east near Bellport Bay. Numerous tidal rivers and creeks, as well as several significant embayments, including Patchogue and Nicoll Bays and Great Cove, characterize the northern shore of Great South Bay. The larger tidal rivers include the Connetquot River and Champlin Creek. Great South Bay may generally be separated into two distinct basins relative to the location of Fire Island Inlet. East of the inlet, bay widths vary from between 2 to 5 miles with water depths averaging roughly 6 to 8 feet. Maximum bay water depths reach about 15 feet. On the other hand, Great South Bay, including South Oyster Bay, to the west of Fire Island Inlet is characterized by widths which are generally less than 1.5 miles. Water depths to the west of the inlet are shallow, averaging approximately 2 feet. Total water surface area of Great South Bay is about 110 square miles.

3.2 Moriches Bay

Moriches Bay is a comparatively small estuary comprised of an ocean entrance, eastern and western connections to Shinnecock Bay and Great South Bay, respectively, and a number of tidal rivers and creeks. The bay extends to Smith Point (inclusive of Narrow Bay) at its western end where it adjoins Great South Bay and to Potunk Point on its eastern end where it meets Shinnecock Bay through the Quantuck and Quogue Canals. Moriches Bay is about 14 miles long and has widths in the main body which range from 0.75 to 2.5 miles. Widths in Narrow Bay range from approximately 1,000 to 4,000 feet. Moriches Bay has a surface area of roughly 16 square miles and consists of two basins (i.e. eastern and western) both of which are approximately 2.5 miles wide with average water depths of 6 to 7 feet. The mainland side of the bay features numerous streams and tidal creeks, the largest of which are the Forge River and Seatuck Creek.

3.3 Shinnecock Bay

Shinnecock Bay, like Moriches Bay to the west, is a relatively small estuary comprised of an ocean entrance, a western connection to Moriches Bay, and several tidal rivers and creeks. The bay extends from the Village of Southampton to the east to the Village of Quogue to the west where it connects with Moriches Bay through the Quantuck and Quogue Canals. These canals, which are about 200 feet in width and include a surface area of about 2 square miles in Quantack Bay, permit exchange to occur between Moriches and Shinnecock Bays. The Shinnecock Canal provides navigation access between Shinnecock and Peconic Bays. Flow between the bays is limited by the presence of a lock and gates. Shinnecock Bay is about 9 miles in length and has widths that range from about 0.4 to 2.8 miles. Average water depths in the bay are about 6 feet with maximum depths of approximately 10 feet. Of the tributaries on the north shore of Shinnecock Bay, Tiana Bay and Weesuk Creek are the largest and are located within the bay's western basin. The total water surface area of Shinnecock Bay is approximately 15 square miles.

3.4 Hydrodynamics

Water levels in Great South, Moriches, and Shinnecock Bays are dominated by astronomical tides under normal conditions and by storm tides during northeasters and hurricanes. Astronomical tides along Long Island, New York are semi-diurnal. Bay water levels are controlled by tidal elevations at Fire Island, Moriches, and Shinnecock Inlets. Bay tides are less than and lag the ocean tide, and variations in tidal ranges throughout the estuaries are relatively small. The uniformity of tide ranges throughout Great South, Moriches, and Shinnecock Bays is a characteristic of the so-called "pumping mode" of inlet-bay hydraulics where water levels within an embayment remain nearly horizontal during ebb and flood tide phases. Table 1 summarizes the mean tide range and tidal prism at each inlet.

TABLE 1
TIDE RANGE/PRISM RANGES

Inlet	Inlet Tidal Range (feet)	Tidal Prism Range ($ft^3 \times 10^6$)
Fire Island	4.1	1,840 to 3,380
Moriches	2.9	230 to 990
Shinnecock	2.9	960 to 1,120

Freshwater enters the estuaries primarily through adjoining tributaries and groundwater seepage. Drainage areas for each bay were estimated as: (1) Great South Bay – 378 square miles, (2) Moriches Bay – 75 square miles, and (3) Shinnecock Bay – 25 square miles. Information concerning freshwater sources is relatively sparse. However, the U.S. Geological Survey (USGS) monitors several tributaries at locations far removed from the bays. Table 2 shows the available average daily flow rates for major tributaries. USGS (USACE, 1975) estimates indicate that nearly 25% of all freshwater entering the estuaries can be attributed to groundwater seepage.

TABLE 2
FRESHWATER SOURCES

Source	Flow (cfs)
Carlls River	26.4
Carmans River	25.3
Champlin Creek	7.1
Connetquot River	39.2
Massapequa	8.2
Patchogue River	20.5
Peconic River	39.4
Penataquit Creek	6.3
Sampawams	10.0
Santapogue	4.2
Swan River	12.3

3.5 Salinity

Pritchard (1983) indicates that spatial and temporal salinity distributions in the bays along the south shore of Long Island are dependent upon two major factors: (1) freshwater inflow rates which vary both yearly and seasonally, and (2) exchange rate of sea and bay waters through tidal inlets. Salinity levels are dictated by the balance between: (1) saltwater inflow through bay inlets, (2) flow exchanges between bays and (3) freshwater flow entering the bay via major rivers and creeks. Salinity data were obtained from the Department of Health Services, Office of Ecology, Suffolk County, New York. These data consist of salinity and temperature measurements for 31 stations throughout Great South Bay, 10 stations in Moriches Bay, and 10 stations in Shinnecock Bay for the period from March 1977 to December 1997. Measurements were taken on a monthly to annual basis. Station locations for each of the study area bays are shown in Figures 2 to 4.

3.5.1 Great South Bay

Spatial and temporal salinity values in Great South Bay varied significantly during the collection period. Average salinities and standard deviations for each measurement station during the 20-year measurement period are listed in Tables 3 and 4 for stations east of Fire Island Inlet and west of Fire Island Inlet (including the inlet), respectively. These averages represent all measurements, regardless of the season during which measurements were obtained. Salinity units are given in parts per thousand (ppt). Stations 280, 290, and 300 were not considered in this study due to the incompleteness of their respective data sets. The high salinity variations experienced in Great South Bay are judged to result from the influx of freshwater from the many tributaries supplying Great South Bay. Pritchard and Gomes-Reyes (1986) determined that nearly 25% of all freshwater influx to Great South Bay enters via Carman’s River in eastern Great South (Station 110). The high volume of freshwater influx into eastern Great South Bay is reflected in salinity values throughout the bay. Average salinity is lowest at the mouth of Carman’s River and increases with distance from the river with the highest average bay salinities occurring in South Oyster Bay west of Great South Bay. Furthermore, flow exchanges between Great South Bay and Moriches Bay may produce additional influence on salinity levels within the eastern basin of Great South Bay.

TABLE 3
GREAT SOUTH BAY (EAST OF INLET) SALINITY

Station	Average (ppt)	Std. Dev. (ppt)
100	25.5	2.3
110	24.3	2.5
120	25.2	2.5
130	25.2	2.0
140	26.4	2.3
150	26.2	2.1
160	25.6	2.2
170	27.6	1.9
180	28.6	1.4
190	27.0	1.6

TABLE 4
GREAT SOUTH BAY (WEST OF INLET) SALINITY

Station	Average (ppt)	Std. Dev. (ppt)
200	29.6	1.5
210	29.2	1.4
220	31.4	0.9
230	30.9	1.2
240	27.8	1.7
250	28.9	1.6
260	30.6	1.6
270	29.6	1.5

3.5.2 Moriches Bay

As in Great South Bay, salinity values within Moriches Bay varied somewhat during the data collection period. Average salinities and standard deviations of the salinity values at each measurement station during the 20-year measurement period are listed in Table 5. Salinity variations in the eastern basin and Moriches Inlet have been relatively small, ranging from 28 to 33 ppt. Relatively large variations have occurred, on the other hand, in the western basin where salinity values ranged from 21 to 33 ppt. The relatively high salinity variations experienced in the western basin are judged to result from the fact that most of the rivers and creeks discharging freshwater into Moriches Bay are located within the western basin. Furthermore, flow exchanges between Great South Bay and the western basin may influence salinity levels, whereas smaller exchange between Moriches and Shinnecock Bays appears to have negligible effect. Average salinities in the inlet, the eastern basin and the western basin during the 20-year measurement period were 31.0, 29.9 and 28.6 ppt, respectively.

TABLE 5 MORICHES BAY SALINITY		
Station	**Average (ppt)**	**Std. Dev. (ppt)**
100	27.0	2.6
110	26.5	2.4
120	28.6	2.6
130	30.2	2.0
140	31.0	1.2
150	30.4	1.4
160	29.6	0.9
170	28.4	1.9
180	29.9	1.0
190	28.8	1.2
200	27.4	1.4

3.5.3 Shinnecock Bay

Salinity values within Shinnecock Bay varied moderately during the data collection period. Average salinities and standard deviations during the 20-year collection period are listed in Table 6. Salinity variations throughout Shinnecock Bay have ranged from 26 to 33 ppt. The relatively uniform salinity values in Shinnecock Bay are judged to result from the fact that the rivers and creeks discharging freshwater into Shinnecock Bay are evenly distributed between the eastern and western basins. Furthermore, there is little flow exchange between Moriches and Shinnecock Bays.

TABLE 6 SHINNECOCK BAY SALINITY		
Station	**Average (ppt)**	**Std. Dev. (ppt)**
100	27.9	1.1
110	30.1	1.1
120	29.7	1.2
130	30.4	1.2
140	31.1	0.9
150	30.2	1.0
160	31.0	0.9
170	30.7	1.1
180	29.4	1.2
190	28.0	1.2

3.6 Temperature

The balance between (1) ocean water temperatures entering through the inlets, (2) freshwater flow entering the bays via major rivers, creeks, and groundwater seepage and (3) solar radiation, dictates estuary water temperatures. Temperature data were obtained from the aforementioned Department of Health Services, Office of Ecology, Suffolk County, New York data set.

3.6.1 Great South Bay

Temperatures in Great South Bay varied significantly during the March 1977 to December 1997 data collection period, especially depending of the season of measurement. Average temperatures and standard deviations during the 20-year measurement period are listed in Table 7. Temperatures ranged from 0 to 30 °C in the eastern and western basins and 3 to 27 °C in the inlet. Average temperatures in Great South Bay varied spatially only ±1.2 °C from the median temperature. These values indicate that bay water temperatures are similar to the ocean waters, but are slightly varied due to differences in solar heating for decreased water depths, the influence of freshwater flows and possible ice cover in the winter.

TABLE 7
GREAT SOUTH BAY TEMPERATURE

Station	Average (°C)	Std. Dev. (°C)
100	15.6	7.1
110	15.8	7.2
120	15.6	7.3
130	15.7	7.1
140	15.6	7.2
150	16.1	7.5
160	16.3	7.4
170	16.1	7.5
180	15.8	7.3
190	16.3	7.5
200	15.1	7.0
210	16.3	7.0
220	14.1	6.3
230	14.5	6.3
240	16.5	7.1
250	16.5	7.0
260	16.0	6.8
270	16.3	6.7

3.6.2 Moriches Bay

Time-averaged temperatures in Moriches Bay are within ±1°C of the mean bay temperature. This indicates that the bay is heated evenly and that bay temperatures are comparable to ocean waters. However, temporal temperatures varied significantly during the data collection period. Time-averaged temperatures and standard deviations are listed in Table 8. It is noted that average temperatures tend to be higher with greater distance from Moriches Inlet. This observation may be attributed to the fact that the majority of bay temperature measurements occurred during the spring and summer months when ocean waters are cooler than the bay waters.

3.6.3 Shinnecock Bay

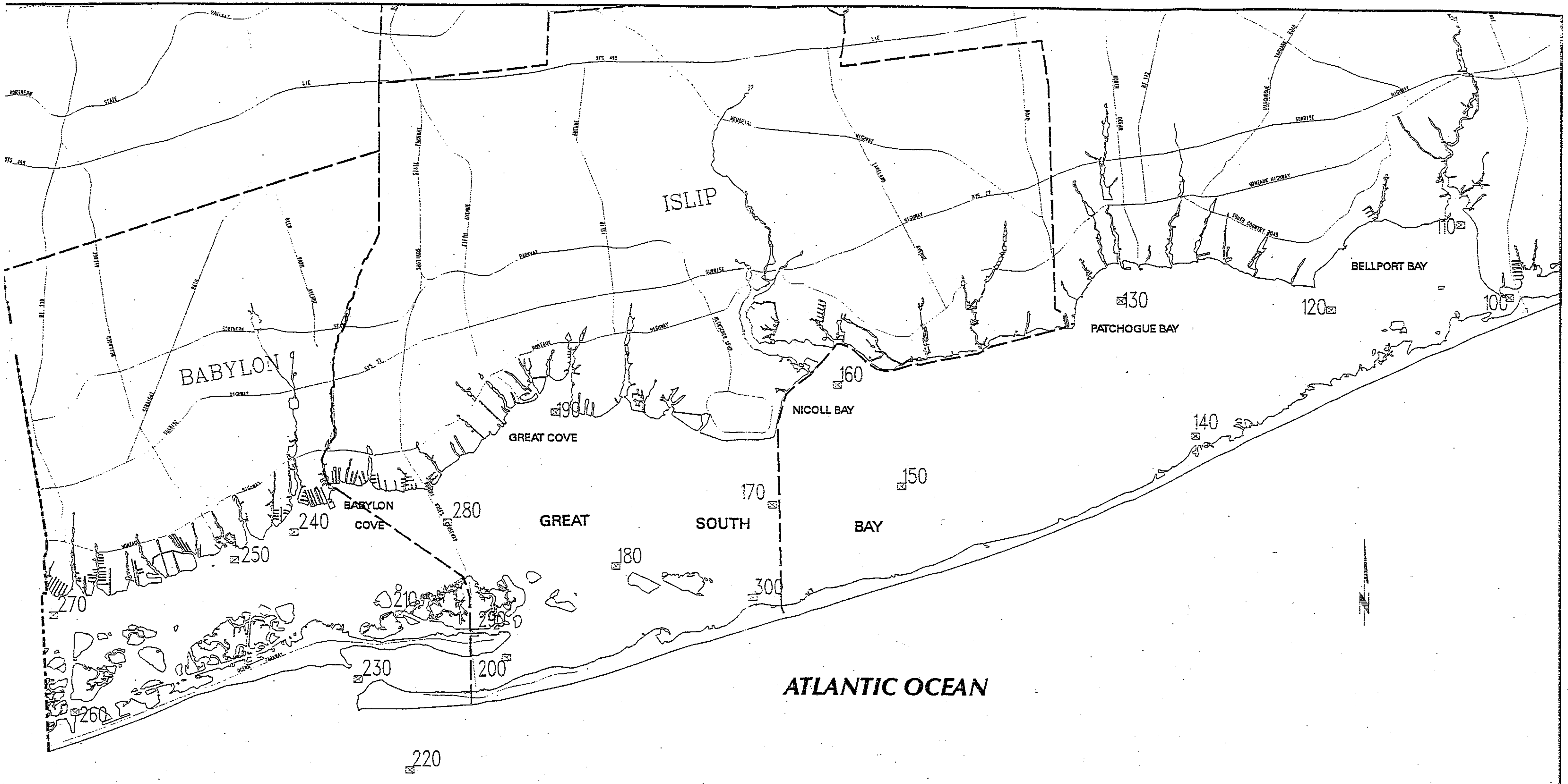
As in Moriches Bay, time-averaged temperatures in Shinnecock Bay are within ±1°C of the mean bay temperature, indicating that the bay is heated relatively evenly and temperatures in the bay are similar to the ocean temperatures. However, temporal temperatures varied significantly during the data collection period due to seasonal effects. Time-averaged temperatures and standard deviations are listed in Table 9. As with Moriches Inlet, average temperatures tend to be higher with distance from the inlet, and it is believed that this observation is the result of measurement times typically during spring and summer months.

TABLE 8
MORICHES BAY TEMPERATURE

Station	Average (°C)	Std. Dev. (°C)
100	13.1	7.6
110	13.2	7.5
120	12.6	7.0
130	11.9	6.4
140	11.6	6.1
150	12.2	6.4
160	12.8	6.9
170	13.2	7.0
180	12.6	6.8
190	13.1	7.3
200	13.3	7.7

TABLE 9
SHINNECOCK BAY TEMPERATURE

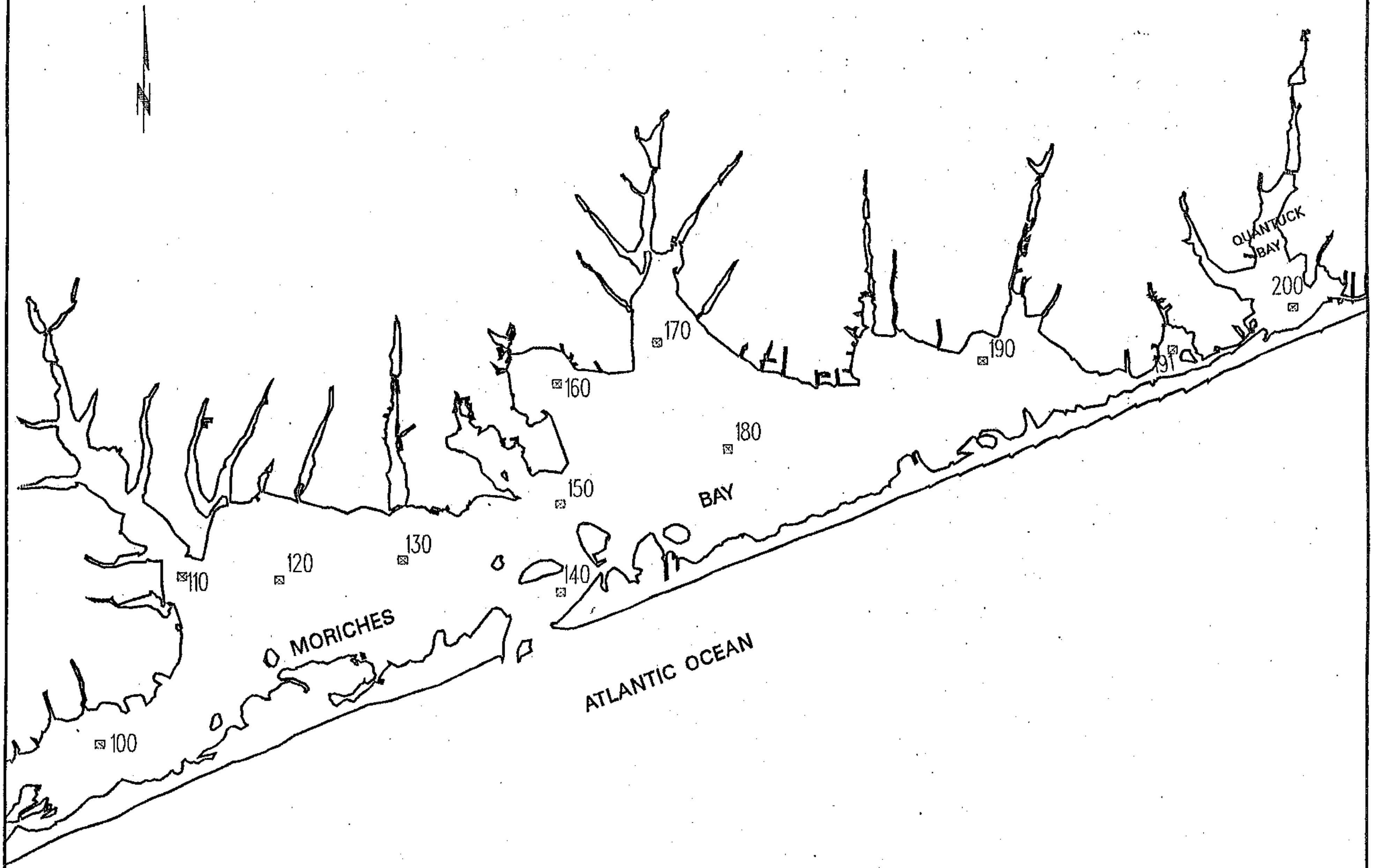
Station	Average (°C)	Std. Dev. (°C)
100	12.2	7.3
110	12.0	6.8
120	11.8	6.6
130	11.6	6.2
140	11.3	5.7
150	11.8	6.4
160	11.6	5.9
170	11.8	6.1
180	12.1	6.7
190	12.6	7.3



SAMPLING STATIONS GREAT SOUTH BAY
(AREA CODE 090)

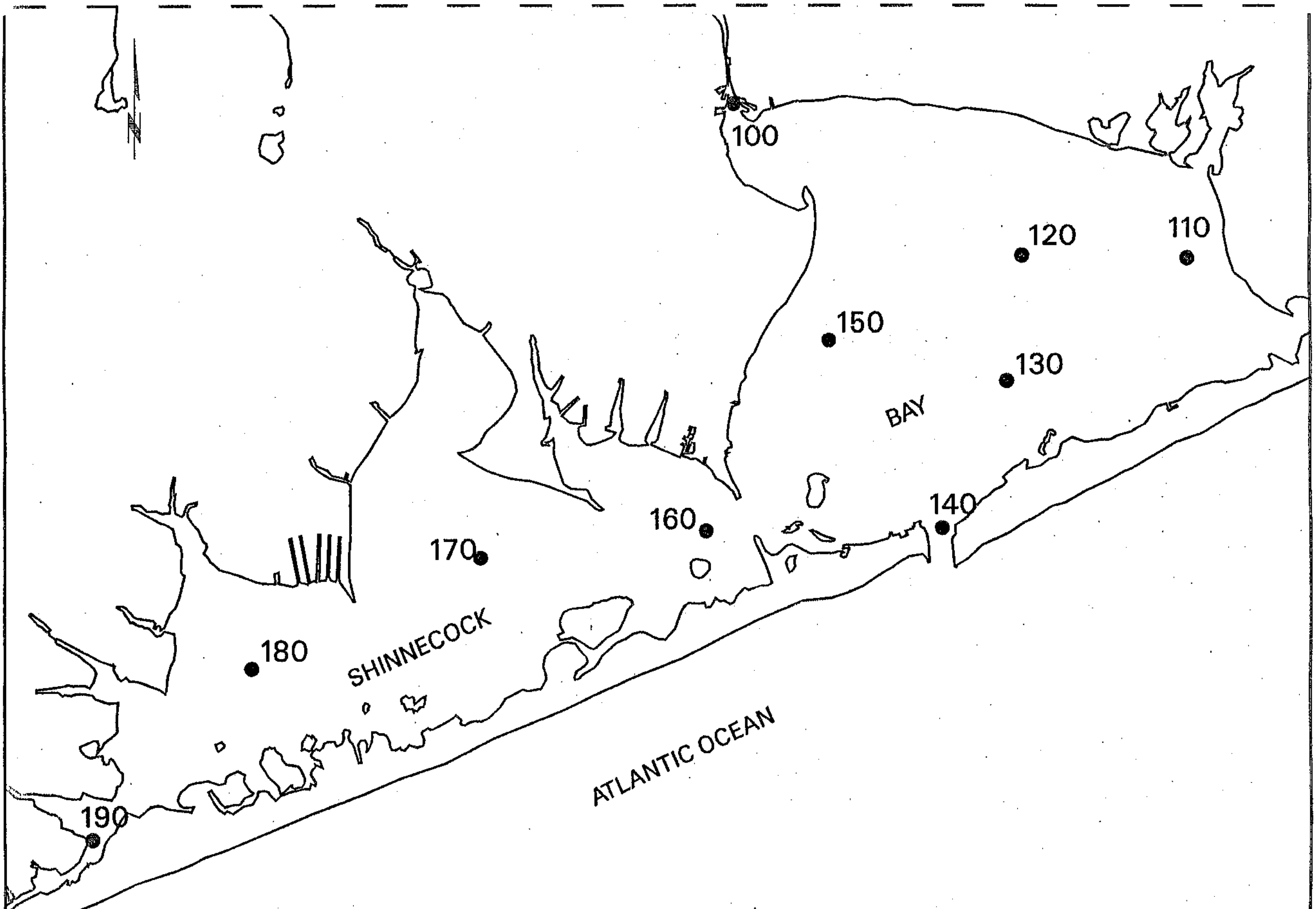
NO SCALE

Figure 2 TJK - 10/94



SAMPLING STATIONS MORICHES BAY
(AREA CODE 080)

Figure 3 NO SCALE



SAMPLING STATIONS SHINNECOCK BAY
(AREA CODE 070)

Figure 4 NO SCALE

TJK - 10/94

4. INLET HISTORY

Numerous inlets, breaches and overwash areas have existed along the study area according to records dating to the 16th century. The study area currently contains three inlets, namely Fire Island, Moriches, and Shinnecock Inlets, although the historic number and location of tidal inlets has been highly variable. The recent stability of the three existing inlets is largely due to Federal maintenance and stabilization efforts that have included dredging of navigation channels and jetty construction.

Regarding historical inlet locations along the study area, US Army Engineer District, New York (1958) stated…*Charts of Long Island dating from colonial times to the end of the 19th century indicate the existence from time to time of natural openings through the barrier beach. No continuous information is available. A map dated about 1640 shows an inlet into Great South Bay and one into Moriches Bay. Another map dated about 1770 shows inlets into Great South, Moriches and Shinnecock Bays. A survey made in 1829 under the direction of David H. Burr, Geographer for the House of Representatives, revealed the existence of inlets at Fire Island Inlet east of its present position, at Smith Point, in the general vicinity of the present Moriches Inlet, and at the eastern end of Shinnecock Bay. However, a survey made by Burr 10 years later indicates that all of the inlets east of Fire Island Inlet had closed. However, available maps indicate that Fire Island Inlet has remained open during the entire period of record. There is no record of any inlets into Moriches Bay between 1839 and 1931, when Moriches east of its present location was formed. Openings into Shinnecock Bay appear on maps made during the period 1850 to 1890, but no inlets are shown from 1890 to 1938, the year the existing Shinnecock Inlet broke through.*

Figures 5 to 8 summarize the inlet and breach history for the study area in terms of location and approximate periods during which the inlets existed. It is evident that inlets and breaches are ephemeral in the absence of inlet maintenance and/or stabilization efforts, and that long periods of multiple inlets to any single estuary are rare. On the other hand, long periods characterized by no inlets have been experienced, although only at Moriches and Shinnecock Bays. This history suggests that the estuaries in the study area are generally incapable of supporting multiple inlet openings. However, it must be stated that breaches since the Hurricane of 1938 have typically been closed artificially rather than by natural processes. Nonetheless, historic observations suggest the existence of a ceiling on sustainable inlet areas and, therefore, on maximum tidal exchange.

4.1 Fire Island Inlet

Of the inlets currently present in the study area, available records indicate that only Fire Island Inlet has existed continuously since the early 1700's. Fire Island Inlet has, however, migrated dramatically. Inlet records that indicate a migration of approximately five miles between 1825 and the early-1940's summarize this migration. Migration of Fire Island Inlet was halted by jetty construction at Democrat Point in 1941. Numerous engineering activities have been required to stabilize the inlet due to littoral transport into the inlet. These activities have included frequent dredging (more than 21 million cubic yards since 1954) and construction of a sand dike (known as the "Sore Thumb") extending into the inlet from Oak Beach.

4.2 Moriches Inlet

Records indicate that numerous inlets to Moriches Bay have existed during the last several centuries. There is no record of any inlets to Moriches Bay during the period from 1839 to 1931. The present Moriches Inlet was opened during a storm on March 4, 1931. The inlet migrated about 3,500 feet west from 1931 to 1947 at which time its migration was halted by construction by local interests of a revetment on its western bank. To further preclude westerly migration of the inlet, a rubble-mound revetment was constructed on the western inlet bank in 1947 and 1948. While the revetment was somewhat successful in maintaining the inlet's position, the continued growth of the Cupsogue Spit (to the east) caused the inlet channel to narrow. In November 1950, a storm caused large quantities of sand to wash over the barrier island east of the inlet depositing sediments in the bay-connected inlet channel. This resulted in a reduction of the hydraulic efficiency of the inlet and concomitant inlet shoaling. This condition led to the eventual closure of Moriches Inlet during a storm on May 15, 1951. Local interests constructed jetties on both sides of the inlet from 1952 to 1953 and the inlet was reopened during construction by a storm on September 18, 1953. Following stabilization of the inlet, the length (2,000 feet) and width (800 feet) were essentially fixed. In addition to jetty construction, inlet shoaling has required moderate maintenance dredging, totaling more than million cubic yards since the early 1940's.

4.3 Shinnecock Inlet

The present Shinnecock Inlet was formed during a hurricane on September 21, 1938. Shinnecock Inlet was about 700 feet wide in 1939 and local interests constructed a 1,470-ft long jetty-type structure on the west side of the inlet to prevent its westward migration. The western jetty structure was subsequently repaired and a 130-ft long stone groin was added to its northerly end in 1947 due to prior storm damages. These actions led to the relative stability of the position of Shinnecock Inlet. Local interests constructed new stone jetties on both sides of the inlet from 1952 to 1953. The western jetty was extended in 1954. After completion of the jetties, the width of the inlet was essentially fixed at 800 feet. USACE (1988) described a plan for improvement of Shinnecock Inlet that consisted of: (1) an inner channel within Shinnecock Bay with a width of 100 feet and a low water depth of 6 feet, (2) an outer channel with a width of 200 feet and low water depth of 10 feet accompanied by an 800 feet wide by 20 feet deep deposition basin, (3) rehabilitation of the east and west jetties, and construction of a 1,000-ft revetment facing the bay on the eastern shoulder of the inlet. Construction of these improvements was initiated in late 1990 and completed in mid-1993. Initial construction of the navigation channel was performed in October 1990 with dredging of a total of 668,000 cubic yards. Subsequent dredging of the deposition basin was conducted from January to May 1993 with removal of 475,000 cubic yards. The most recent dredging operations removed approximately 450,000 cubic yards of sand in June and September 1998. Maintenance dredging of Shinnecock Inlet has been infrequent.

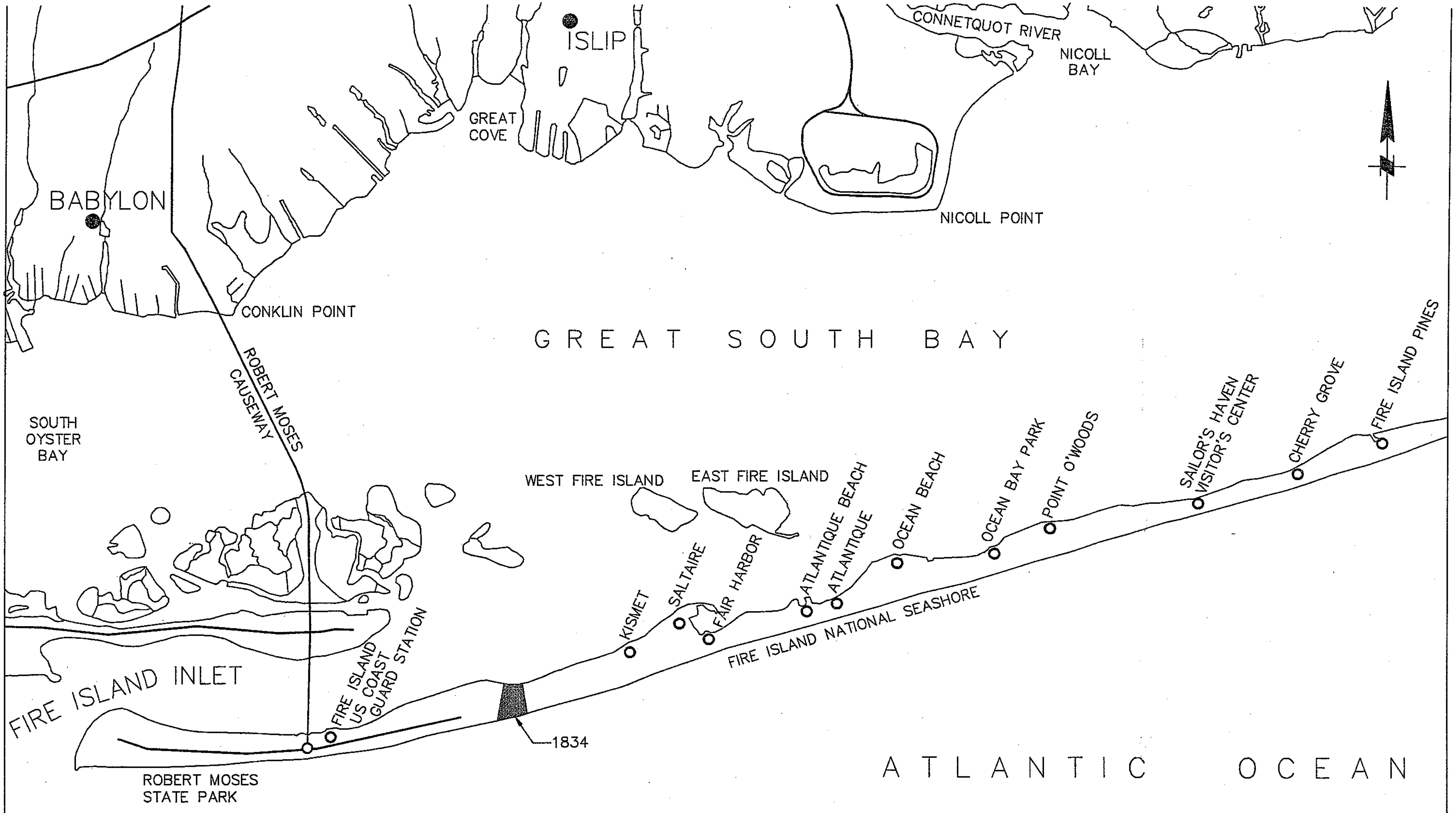
4.4 Inlet Impacts

The effects of Fire Island, Moriches and Shinnecock Inlets can be ascertained through examination of inlet survey records, shoreline positions, and bay tidal records. The most pronounced of these impacts is the tendency for large quantities of littoral drift to deposit within the inlet regimes to form ebb and flood tidal shoals. These shoals provide a range of valuable environmental habitats, but also lead to sediment deficits downdrift of each inlet. While the significance of these deficits varies, the most severe erosion is observed west of Shinnecock Inlet. On the other hand, erosion west of Moriches Inlet is relatively minor by comparison. Fire Island Inlet requires extensive maintenance dredging, but dredged material placement operations to the west of the inlet and construction activities over the previous several decades have generally offset erosional effects of the inlet.

Inlet jetty construction and dredging have resulted in the relative stability of the inlets. This stability has led to large deltas at the present inlet locations. The stability and presence of stabilized inlets as navigation projects have contributed to the decision for the relatively rapid closure of newly formed barrier island breaches. Breach closures can occur naturally or artificially, but evidence is that breach closures typically occurred artificially through dredging operations to limit increased bay tidal inundation. These actions may reduce the duration of new breach openings, which limits the bay deposition of potential substrate materials. Nonetheless, inlet stabilization has not precluded new breaches and bay deposition. Total bay deposition quantities may actually be greater due to inlet stabilization and the concentration of flood shoals near the inlets. Higher overall bay deposition is postulated to occur due to the persistence of the inlets that permits the continued growth of inlet-related shoals, while new breaches are still formed elsewhere. In summary, a major impact of the stabilized inlets is that bay deposition may be limited elsewhere while quantities adjacent to the inlets exceed those that would otherwise occur in the absence of stabilized inlets.

One last, and important, impact of inlet stabilization and construction measures has been the maintenance and increase of estuary flushing relative to pre-stabilization conditions. Simply, the maintained inlets permit the continual exchange of bay and ocean waters. On the other hand, unstabilized inlets are vulnerable to closure as evident from inlet records. For instance, no inlets to Moriches Bay existed for a period of nearly 100 years from 1839 to 1931. No records exist for this period to characterize water exchange within Moriches Bay, but it can be safely assumed that present inlet conditions are more conducive to improved water quality due to increased circulation. Furthermore, estuary records available for the majority of the 20th century indicate that tidal ranges for Great South, Moriches and Shinnecock Bays have constantly increased. As an example, the mean tidal range in Shinnecock Bay has increased from 0.8 to 2.7 feet between 1953 (jetty construction) and the early 1960’s. Following the early 1960’s, bay tidal ranges stabilized to approximately 2.9 feet, presumably reflecting the relative stability of Shinnecock Inlet. In parallel to these changes, the cross-sectional area of the inlet increased from 5,500 to

19,900 square feet from 1940 to 1992. Subsequent to 1992, the cross-sectional area of the inlet has decreased to about 16,400 square feet in 1995. This behavior demonstrates that the maximum inlet opening to Shinnecock Bay has been approached, if not exceeded, during the last decade. It is noteworthy to mention that the ocean tidal range at Shinnecock Inlet is estimated as 3.3 feet. Consequently, increased inlet area to Shinnecock Bay would not permit significant increases in tidal prism and, assuming a relationship between water quality and tidal prism, water quality. A similar relationship exists at Moriches Bay, where the mean ocean tidal range is about 2.9 feet, whereas the bay tidal range is approximately 2.2 feet. Great South Bay has also experienced increasing tidal ranges, but remain significantly less than the mean range of 4.1 feet at Fire Island Inlet.



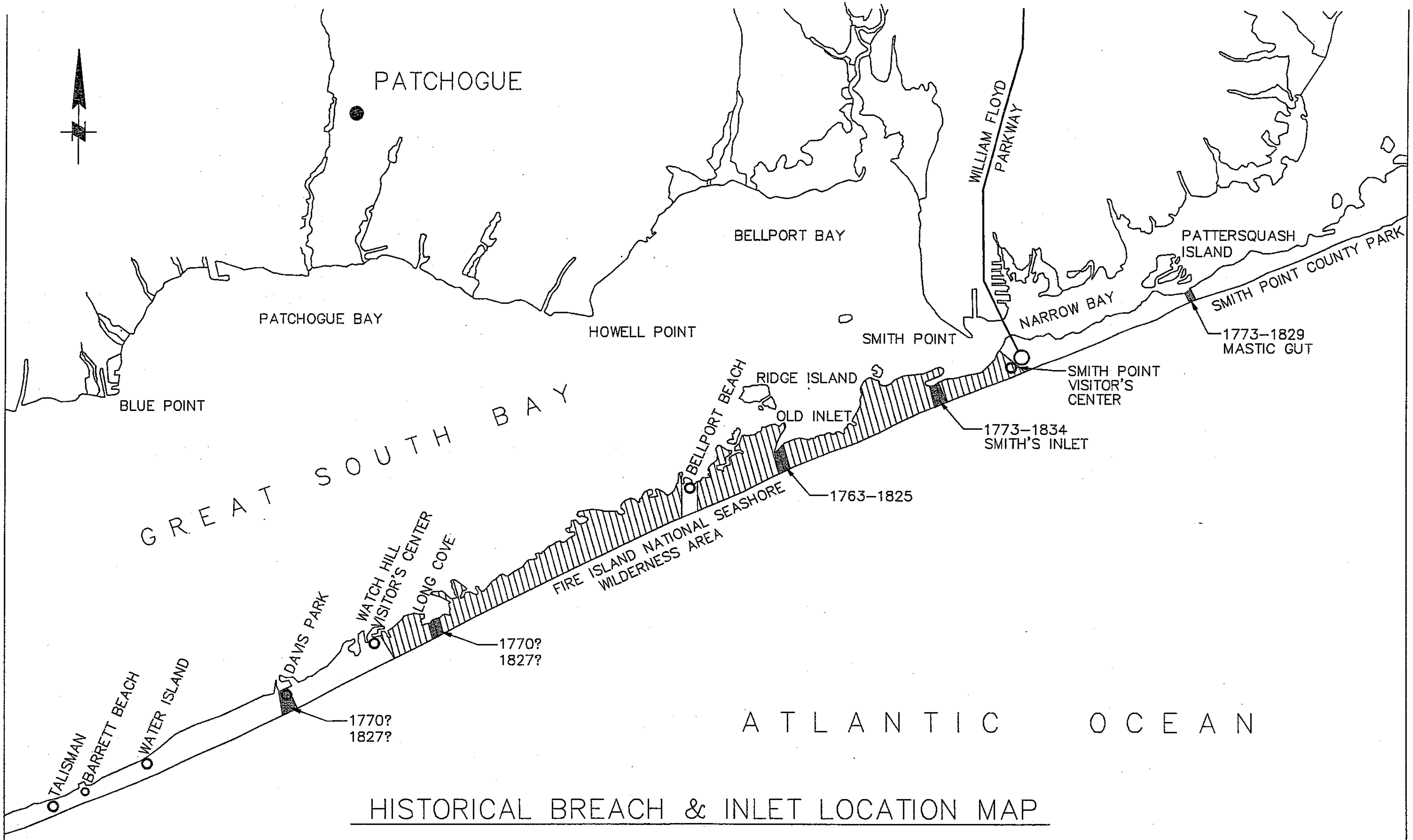
HISTORICAL BREACH & INLET LOCATION MAP

FIRE ISLAND INLET TO MONTAUK POINT
REFORMULATION STUDY

0 2500 5000 7500
SCALE: 1:5000

MOFFATT & NICHOL
ENGINEERS
BALTIMORE, MARYLAND

Figure 5



HISTORICAL BREACH & INLET LOCATION MAP

FIRE ISLAND INLET TO MONTAUK POINT
REFORMULATION STUDY

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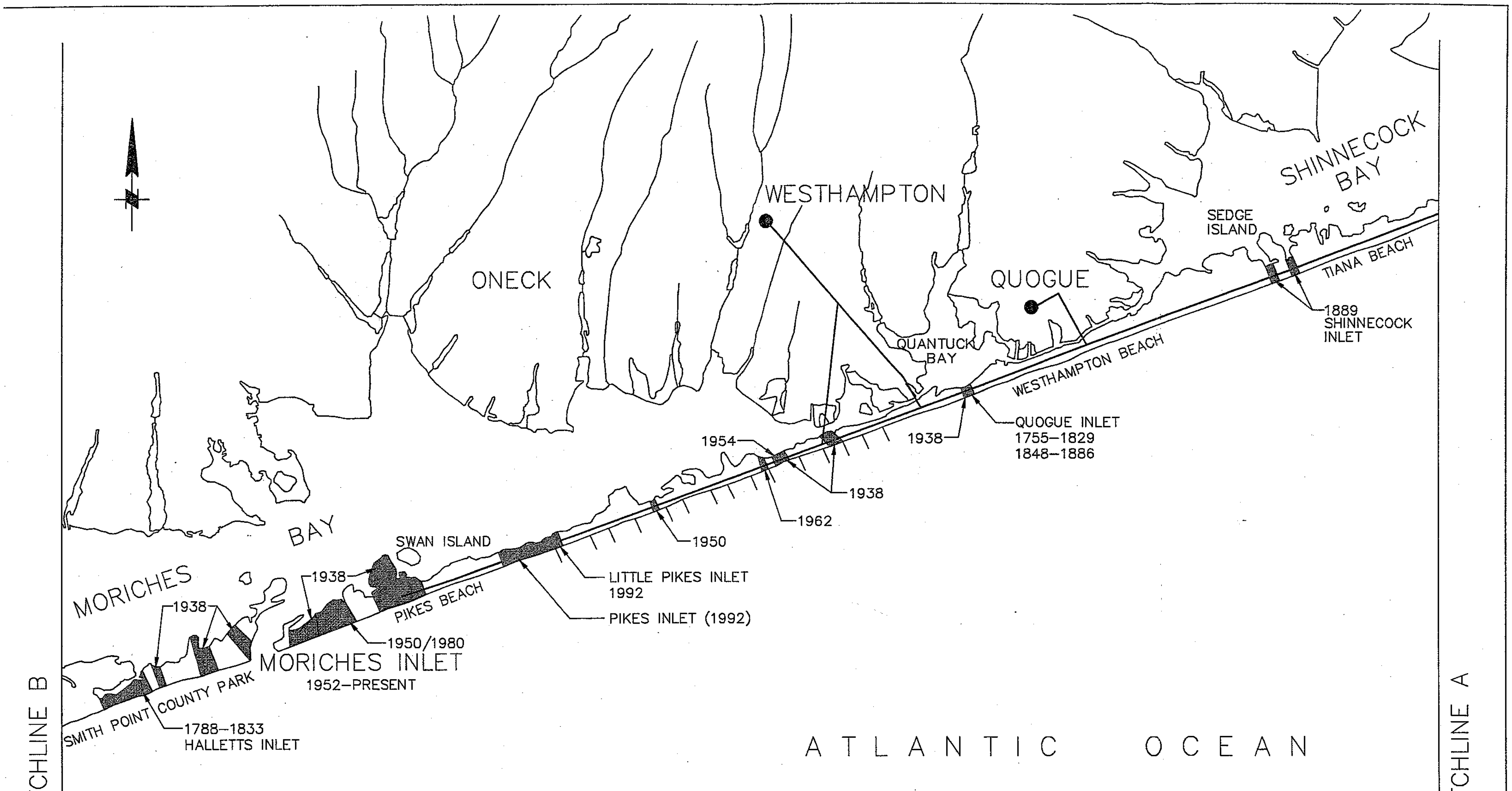
Figure 6



HISTORICAL BREACH & INLET LOCATION MAP

FIRE ISLAND INLET TO MONTAUK POINT
REFORMULATION STUDY

0 2500 5000 7500
SCALE: 1:5000

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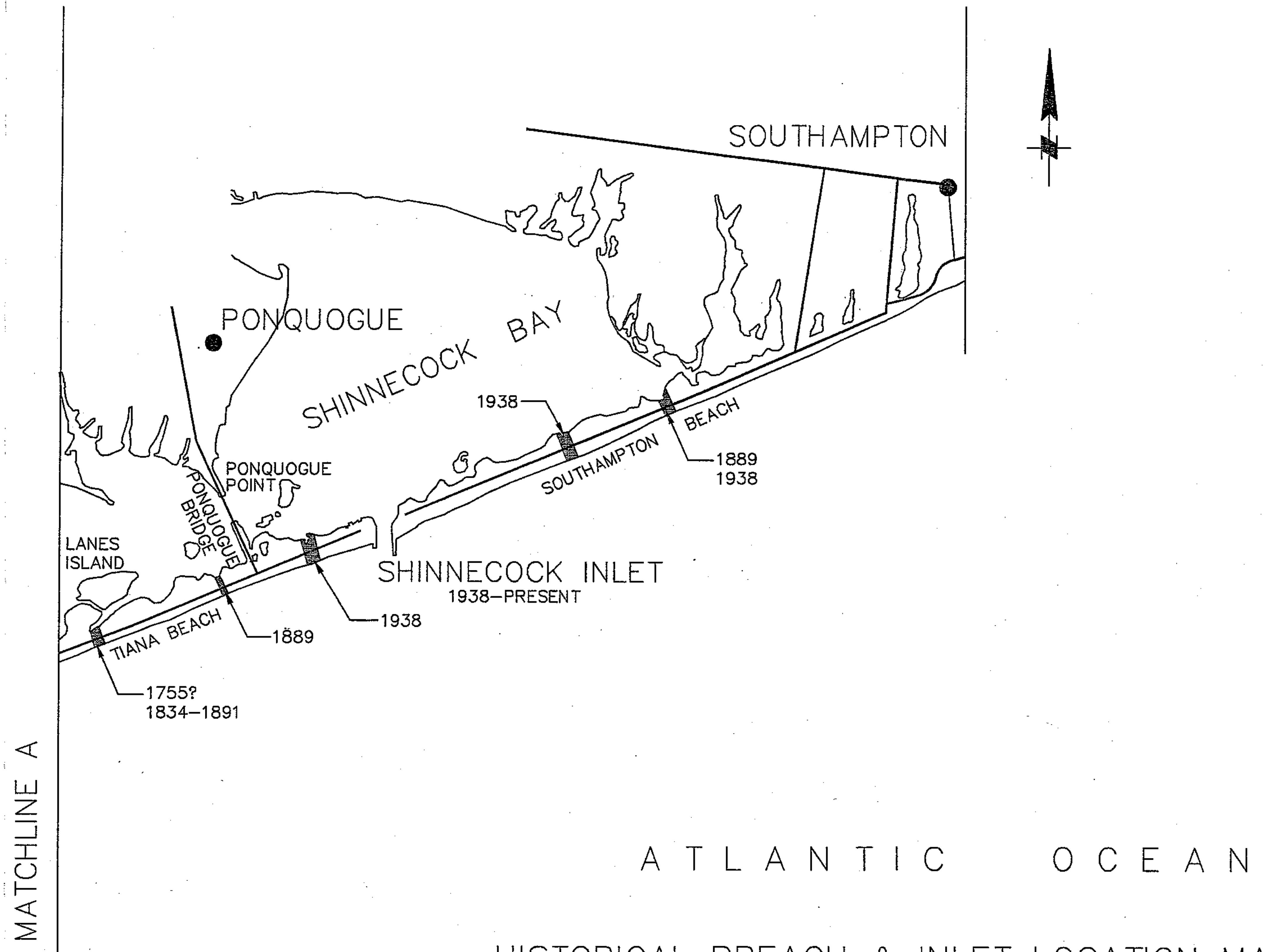
Figure 7



HISTORICAL BREACH & INLET LOCATION MAP

FIRE ISLAND INLET TO MONTAUK POINT
REFORMULATION STUDY

0 2500 5000 7500
SCALE: 1:5000

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ENGINEERS
BALTIMORE, MARYLAND

Figure 8

5. ENVIRONMENTAL SETTING

The oceanic and nearshore waters of the study area represent a dynamic high-energy environment. The marine organisms that occupy this zone are well adapted to the harsh coastal conditions. The macrobenthic invertebrates, which provide a valuable food source for both terrestrial and aquatic wildlife species, are present within the interstitial spaces of the benthic sediments throughout the offshore, nearshore and intertidal waters of the project area. Wildlife associated with this area includes the more pelagic avian species, several species of sea turtles, whales, dolphins, and seals. Finfish and crustaceans move relatively freely between the nearshore areas and offshore waters.

In a general profile view through the barrier, there is usually a primary dune closest to the ocean beach, followed by an interdunal swale, then a secondary dune. The Maritime Freshwater Interdunal Swale Community, which occupies the low-lying wetter pockets between the dunes, generally supports a variety of rare and unique plants. This community has been designated by the New York State Natural Heritage Program as a Significant Habitat. Beachgrass, being a true pioneer plant, dominates the dune and swale community, especially in areas most exposed to wind and salt spray (e.g., ocean face of the foredune and crests of dunes). A shrub thicket typically develops on the lee side of the primary dune and covers the less exposed areas on the secondary dune(s). Between and behind the protective barrier of the dune system, a maritime forest may develop, which may contain isolated freshwater bogs. The 200-300 year old Maritime Holly Forest, characteristic of the Sunken Forest area on the Fire Island National Seashore, has also been designated by the NYNHP as a rare and Significant Habitat. It should be noted that the Maritime Holly Forest occupies only one linear mile of the approximate 50 linear miles of the Fire Island barrier. The northerly edge of the barrier island is generally fringed by emergent tidal wetland vegetation. The backbay wetlands and transitional areas support a variety of rare plants (Stalter et.al. 1986).

More than 150 species of songbirds, about 40 different shorebirds, and various raptors utilize the barrier islands within the project area either for breeding, feeding, over-wintering or as a stop-over during their migration through the area. In addition to piping plovers, over 35 additional avian species are listed Federally as Endangered or Threatened, and as Special Concern, Threatened, or Endangered by the State. In particular, least terns, roseate terns, common terns and northern harriers may commonly be found foraging in the nearshore waters or over the barrier islands.

Vegetated marsh islands, non-vegetated tidal flats, and dredge spoil islands in the bays to the north of the barrier islands provide isolated and highly desirable nesting habitat for various shorebirds and wading birds, including the Federally Endangered roseate tern and State Threatened common tern. Abundant eelgrass beds are also present throughout most of Great South Bay, in the clear shallow waters ranging in depth from 1-1/2 to 5-1/2 feet (Greene et al, 1978). This estuarine zone is extremely productive and serves as a nursery habitat for finfish, crustaceans and shellfish. The MAFMC has nominated the backbay waters within the project area for federal designation as an “Essential Fish Habitat” for summer flounder. This is currently under review by NOAA.

The large open, shallow bay waters and protective marshes provide cover and feeding areas for a plethora of wading birds, shorebirds and waterfowl. Since the project area lies within the Atlantic Flyway, it is particularly important to migratory waterfowl that seek a safe haven during the winter. All of the backbay waters within the project area (Great South Bay, Moriches Bay and Shinnecock Bay) have been designated as *Significant Coastal Fish and Wildlife Habitats* by the New York State Department of State; and as *Significant Habitats and Complexes of the New York Bight Watershed* by the USFWS (USFWS, November 1998).

6. OVERWASH AND BREACH PROCESSES

The dynamics of island overwashing, breaching and new inlet formation are dictated by the complicated interaction of numerous geomorphologic and hydrodynamic factors. For the purposes of this paper a distinction is made between island ***overwashing,*** island ***breaching*** and permanent ***inlet formation***. Overwashing pertains to the condition where a barrier island is temporarily overtopped by tides and/or waves during a storm. Overwashing tends to erode or flatten dunes during a storm with a concomitant deposition of eroded sediment on the landward side of the barrier island. Factors that may lead to island ***overwashing*** during storms include:

- narrow beach widths;
- low barrier island or dune elevations;
- maximum dune elevations which are low relative to storm tide elevations;
- low sediments volumes within island cross-section and volume above a critical elevation;
- magnitude and duration of storm tides and wave overtopping;
- island sediment characteristics;
- seaward beach profile shape (i.e. presence of inlet relicts, offshore bar, etc.); and

Breaching refers to the condition where severe overwashing forms a new inlet that permits the exchange of ocean and bay waters under normal tidal conditions. A breach can form as barrier island sediments are transported landward and ocean waters scour the barrier, or as the result of dune/beach overwash followed by bay waters draining through and scouring the lowered area. The breach may be temporary or permanent depending on a number of factors described below, however, the breach must have a scoured depth below mean lower low water in order for water to exchange between the ocean and bay over a complete tidal cycle. Factors leading to formation of a breach are similar to those described above for overtopping, albeit more severe, and require that the barrier island width is narrow enough to allow overwashing to traverse the entire island segment.

Once a breach has formed, the likelihood of it remaining open to form a ***permanent inlet*** depends on a number of factors including:

- The size of the initial breach opening. If the breach opening area is small it may be easily closed by littoral drift subsequent to the storm.
- Water depths proximate to the bay side of the breached area and/or barrier island widths. When the bay side shoreline is fronted by relatively deep water and the barrier island is narrow, the breach will be a short (distance perpendicular to the barrier), and hydraulically efficient inlet. When a broad shallow area fronts the bay side shoreline, however, the breach will be a long and hydraulically inefficient inlet.

- An existing inlet opening which is mature, long, vulnerable to shoaling and hydraulically inefficient relative to the breached inlet, or no inlet, leads to a tendency for a new and efficient breach to remain open.
- The rate at which littoral drift is transported to the breach. Breaches formed in areas immediately downdrift of littoral barriers or in areas of low littoral transport are more likely to remain open.
- Phase lag between the ocean and bay tide. An increase in phase lag between the ocean and bay will lead to higher breach inlet velocities and a greater likelihood that the breach will grow.

6.1 Future Without-Project Condition

In addition to the aforementioned factors, the future occurrence of overwashes or breaching is influenced by anthropomorphic forces. For example, future local beach nourishment projects will impact the likelihood of overwash. Other human activities that influence the probability of breach formation include maintenance of existing inlets and navigation structures. The actual impacts of overwash and breaches are strongly dependent on human activities following these events. For instance, overwashing in the study area typically involves the landward transport of beach sediments, but the actual effect and eventual disposition of these sediments is uncertain. In the event that overwashing results in sand deposits on adjacent roadways overwashed materials are often mechanically moved seaward to create or bolster protective dunes. Additionally, overwashed beach sediments immediately west of Shinnecock Inlet have recently been removed from wetland areas to bolster dunes. It is anticipated that these practices will continue, as coastal communities become more threatened by storm damages. The impacts of breaches, like overwash, are greatly affected by human activities following a breaching event. Most recently, these activities have included the artificial closure of breaches. Previous and anticipated actions (and consequences) following breaches must be understood to fully examine the impacts of varying breach response practice. The following summarizes the basis assumed for anticipated future breach response under without project conditions.

Since 1938, local government policy along the study area has been to close breaches (with the exception of Shinnecock Inlet that opened in 1938). Recently, New York State (as per the Governor’s Coastal Erosion Task Force) made it State policy to close breaches. The U.S. Army Corps of Engineers has also developed a Breach Contingency Plan (BCP), which is intended to close breaches expeditiously. The BCP is an interim measure to address the time period prior to completion of the Reformulation Study. The long-term decision, whether breaches should be closed quickly, is being reevaluated as part of the Reformulation Study. As such, the baseline condition (i.e. future without-project scenario) is that any breaches that form in the study area will be closed within a period of one year. This condition is based primarily on historic practices.

6.2 Overwash/Breach Sequence

The following paragraphs outline the sequence of overwashing and breaching, as well as briefly describing sediment and water transport.

1. Overwash is the first stage of the overwash/breach process in response to major coastal storms, which produce elevated water levels and increased wave activity. The first step involved in the overwash process is the initiation of beach and dune erosion, which contributes to wave overtopping of the protective dune. Following initiation of wave overtopping, dune lowering begins in earnest leading to inundation of the dune by elevated ocean water levels. It is noted that wave overtopping is oftentimes insignificant in terms of stormwater flow over the barrier islands. Consequently, sediment transport during wave overtopping is also minor. Once tidal inundation of the dune occurs, stormwater flow and sediment transport are markedly increased. This condition of barrier island inundation can contribute significantly to bay water levels and causes large volumes of beach sediments to deposit in overwash fans. It is noted that the effects of overwash on bay water levels is temporary, but that sediment deposition results in longer term changes.

2. Overwashing can result in the complete failure of protective dune systems, and permits the exchange of ocean and bay waters when there is a sufficient difference between bay and ocean surge levels. If, during the course of or immediately following the storm, these flows scour the barrier island to sea level or below, then a breach is formed. Typically, ocean water levels will exceed bay levels, and stormwater flow and barrier scouring will take place in a landward (or bayward) direction. These flows may reverse as storm-elevated bay waters exit through the newly formed breach, and further scour the breached area.

3. Subsequent to breach initiation continual tidal exchange ensues, which leads to barrier breach growth and migration. The impacts of these processes include the exchange of bay and ocean waters through the breach over the period of breach persistence, as well as the transport of sediments both into the bay and ocean.

The above description provides an overview of the overwash and breach process. Subsequent sections provide more detail on the overwash and breaching process, including discussion of breach growth and stability that are critical factors in determining eventual impacts.

7. PHYSICAL OVERWASH/BREACH IMPACTS

The impacts of barrier island breaching and/or overwash can be viewed as both positive and negative. Overwashing and breach formation are interrelated, i.e. overwash can lead to a breach. Overwashing can have significant effects inasmuch as it can cause property damages and result in the deposition of beach sediments. On the other hand, breaches are a more significant condition, having the following physical consequences:

- destruction of structures located in the vicinity of the breach;
- breach vulnerability to migrate with the attendant destruction of structures;
- provision of an additional opening to an embayment, which can alter bay flushing and circulation characteristics, bay salinities, and increase normal astronomical and storm tides within the bay;
- increased shoaling and/or closure of the existing bay inlet opening;
- creation of flood and ebb tidal shoals or breach spits;
- shoaling of bay navigation channels; and
- trapping of significant portions of barrier beach sediments leading to downdrift erosion of adjacent beaches.

Breaching and overwash are pivotal in the dynamics of the barrier island system. Specifically, overwashing is a significant source of sediments for the vertical construction of the barrier islands, whereas breaching (or new inlets) provide the backbarrier sediments that accommodate bayward growth of the barrier island and salt marsh establishment. Salt marshes in the study area are typically located at areas where inlets have created flood tidal deltas (Leathermen and Allen, 1985). The deltas provide substrate for marsh development, whereas overwashing sediments may change bay shallows to marshland, marshland to barrier beach habitat or deeper bay waters to shallow shoals. New inlets can also have impacts on other habitats by increasing bay salinity, increasing bay tidal ranges and storm tides, and allowing for increased wave activity in formerly quiescent locations.

An additional factor to be considered is the time frame for impact assessment. Breach formation and growth can have immediate short-term (days) impacts, including the transport of barrier island sediments into adjoining bays or offshore, altered bay water levels and circulation, and property damages. Additionally, short-term overwash impacts may include the burial, stabilization or creation of backbay marshland and temporary interruption of transportation. Other breach and overwash impacts correspond to long-term (i.e. months to years) conditions that are dependent upon the period of breach persistence, the size obtained by the new breach and magnitude of overwash/breach sediment transport.

7.1 Overwash

Impacts of overwash on the physical environment are generally limited to storms, although the permanent bayward deposition of beach sediments is important to barrier island dynamics and environmental habitats. During a storm, overwash results in the transport of dune (and beach) sediments landward of the prevailing dune location, as well as providing an avenue for storm waters to enter the leeward estuary. Overwashing storm waters can contribute to backbay flooding. It is generally believed that overwash contributions are minor, except in the case where ocean storm tides completely inundate the barrier islands prior to breach formation. The significance of overwash contributions to bay storm tides is currently under investigation.

The other principal impact of overwash is the landward transport of beach/dune sediments. Consequences of this process are highly dependent on site-specific conditions, including the volume and disposition of overwashed sediments, barrier island width, adjacent bay water depths and character of the backbarrier environment. Historically, overwashing has involved significant volumes of beach sediments. Leatherman and Allen (1985) estimated overwash volumes as shown in Table 10 for four major storms that have caused widespread overwash. These estimates were taken from post-storm aerial photographs, which were used to calculate the total area of overwash fans and associated volumes. Island coverage refers to the length of the barrier islands in the study area that was overwashed. Results in Table 10 indicate an annual rate of sediment deposition of approximately 400,000 cubic yards per year (cy/year) between 1938 to 1962, which is approximately 1.5 cy/year/foot of barrier island. If the 1938 storm is eliminated, overwash related sediment transport is substantially reduced.

TABLE 10
HISTORIC OVERWASH SEDIMENT QUANTITIES

Year	Area (square miles)	Island Coverage (%)	Volume (million cubic yards)
1938	2.6	26	6.5
1954	1.2	11	1.8
1960	0.2	2	0.3
1962	0.4	4	0.7

As stated previously, the actual consequence of these occurrences is strongly dependent on the width of the overwashed barrier island, adjacent bay water depths and character of adjacent backbarrier habitat. At narrow barrier island locations backed by shallow bay waters, overwash may deposit in the bay providing substrate for future marsh development. On the other hand, wide barrier island segments are more resistant to overwashing causing materials to be deposited either on the barrier itself or on leeward marshes (where present). This situation can result in the establishment of a secondary dune system or marsh burial. As noted previously, some overwashed sediments are undoubtedly deposited on adjacent roadways and then mechanically moved seaward as part of dune rebuilding. Aeolian sediment transport will be altered after an overwashing event and may also lead to the growth of a secondary dune system or transport of beach sediments into the leeward estuary. However, aeolian transport estimates by McCluskey et al. (1983) indicated that transport volumes for the entire shoreline east of Fire Island Inlet totaled only 250,000 cy/year with 90 percent seaward of the dune in an easterly direction. Sand transport across the dune from a seaward direction was estimated as only 0.08 cy/foot/year. Other researchers (e.g. Zimmer, 1991) have suggested that water-borne and air-borne sediments contribute equally to dune growth.

Despite the large volumes shown in Table 10, Leatherman and Allen stated that overwash has contributed little to barrier island migration. Furthermore, it was stated that only one of the four storms listed in Table 10 actually resulted in new land (approximately 4.1 acres). The total contribution of overwash to new marshland was estimated as about 5.7 acres between 1938 and 1962 with insignificant differences from 1962 to 1979. Overwash has typically covered marshland causing increased ground elevations and barrier island habitats to develop. The 1938 storm, for example, was estimated to cause the loss of 50 acres of marshland. Of that total, it was estimated that only one-third was recolonized by salt marsh. Marsh loss due to overwashes was judged of secondary importance relative to human development between 1962 and 1979 (Leatherman and Allen (1985)). More recently from 1980 to 1995, overwash has resulted in approximately 34 acres of new land area comprised of 30, 2.5 and 1.5 acres at Swan Island, Smith Point and Pelican Island, respectively. New land area represents approximately 20 percent of the total overwash area experienced during this period. Consequently, it appears that the predominate impact of overwash is the increase of barrier island elevations as salt marsh habitats are converted to barrier island environments. The net result of overwash is that bay shorelines have either remained relatively stable or marsh acreage has been lost while subaerial barrier island habitat has increased.

Current studies are underway to update the information shown in Table 10, and to provide a basis for assessing the impacts of potential storm protection measures on overwashing processes. Preliminary results of this investigation are summarized in Table 11. It is noted that the prorated overwash total (200,000 cy/year) corresponds to estimated average overwash quantities for the periods from 1938 to 1962 and 1980 to 1995. This value was based on information presented in Leatherman and Allen (1985) and Kana (1985), and ongoing study results.

TABLE 11
PRELIMINARY UPDATE OF OVERWASH VOLUMES

Reach	**Length**	**Overwash Volume (x1,000 cy)**				**Percent of Total**	**Overwash Volume (x1,000 cy/yr)**
		1938/1962[1]	**1980/1995[2]**	**Total**	**Annual**		Prorated Total[3]
Southampton	26,404	16	-	16	0.4	0.4	0.8
Shinnecock (East)	9,669	94	-	94	2.4	2.4	4.8
Shinnecock (West)	6,886	76	40	116	3.0	2.7	5.4
Tiana	29,473	555	42	597	15.3	14.4	28.8
Westhampton (East)	23,556	595	-	595	15.3	15.1	30.2
Westhampton (West)	13,816	132	395	527	13.5	13.4	26.8
Moriches (East)	8,439	160	-	160	4.1	4.1	8.2
Moriches (West)	6,356	3	-	3	0.1	0.0	0.0
Great Gun	12,331	280	-	280	7.2	7.1	14.2
Smith Point	28,861	128	160	288	7.4	7.3	14.6
Long Cove	26,402	36	-	36	0.9	1.0	2.0
Davis Park	13,136	5	-	5	0.1	0.0	0.0
Fire Island Pines	16,179	20	-	20	0.5	0.5	1.0
Ocean Beach	23,344	156	-	156	4.0	4.0	8.0
Kismet	12,692	289	-	289	7.4	7.3	14.6
Robert Moses	12,753	675	-	675	17.3	17.1	34.2
Democrat Point	11,020	115	-	115	2.9	2.9	5.8
Total		3,335	637	3,972	102		200

[1] Overwash volumes taken from Kana (1985)
[2] Recent overwash volumes
[3] Prorated overwash volumes to achieve annual quantity of 200,000 cy/year

7.2 Breaching

Breaches, as described previously, can have a number of impacts (e.g., destruction of property, increased bay storm tides) that indicate the need for protective measures and/or breach response procedures. In addition, there are many impacts of barrier island breaches (e.g., sediment transport, altered bay circulation, salinity levels and distributions) that relate more directly to environmental resources. Short-term impacts during or immediately following breach formation can be significant and include sediment transport into the adjoining estuary and increased bay storm tides. Studies are currently underway to quantify these short-term effects, including hydrodynamic storm modeling to determine additional bay storm tide elevations to quantify associated property damages.

7.2.1 Breach Growth

Breach formation and growth during a particular storm may have significant impacts on the severity of inland flooding and bayward sediment transport. However, breaches that persist for longer periods have the tendency to grow and migrate. During this period, bay circulation, water levels and sediment deposition will increase concurrent to the expanding breach. Examination of historic breaches and inlet stability analyses performed for the Reformulation Study indicate that a breach to Moriches and Shinnecock Bays may persist. This is especially the case for breaches located downdrift of sediment barriers, such as Shinnecock Inlet. These locations are coincidentally also the areas that are typically most vulnerable to breach formation due to past erosion. A new breach into Great South Bay, on the other hand, would very likely cause the tendency for Fire Island Inlet to close given its current situation characterized by extreme shoaling. As it is expected that new breaches may grow and their impacts increase, it is necessary to estimate the size of these openings. Historic breaches were examined to determine long-term growth characteristics, which provided the basis for the following breach growth relationship:

$$A = A_e\,[1 - \exp(-\kappa t)] \qquad (1)$$

Where:

A = breach area (sq. feet)
A_e = long-term stable inlet cross-sectional area (sq. feet)
κ = breach growth coefficient (0.15 to 0.30 month^{-1})
t = time from breach initiation (months)

Long-term stable inlet cross-sections were developed from inlet stability analyses, as follows: (1) Shinnecock Bay: 17,750 sq. feet, (2) Moriches Bay: 16,000 sq. feet, and (3) Great South Bay: 36,200 sq. feet. Based on the comparison of historic breaches to this equation, it was found that the method presented is reasonable in the prediction of breach growth for the majority of historic breaches. It is noted that these long-term stable values generally correspond to existing tidal inlet areas, except at Fire Island Inlet. As such, breach growth would be attended by a reduction of tidal inlet area, although the trade-off between inlet and breaches areas may not be absolute. This behavior was observed during the breach at Moriches Inlet in 1980 when cross-sectional surveys of the breach and inlet indicated that the total area of both inlets was constant at approximately 23,000 square feet. Following initiation of breach closure construction, the cross-sectional area of the inlet increased once again to its pre-breach size. The conclusion is that breaches may initially provide increased inlet areas, but eventually estuaries are represented by a maximum sustainable area due to restrictions on tidal wave propagation dictated by inlet frictional effects and the area of the estuary. In this regard, new breaches will reduce the inlet area of existing inlets and, consequently, tidal prisms will remain relatively stable regardless of the number of openings. In summary, one of the following three conditions would occur following breaching:

1. The new inlet closes while the existing inlet remains open and, consequently, tidal flows are comparable to pre-storm conditions. Sediment deposited during breach formation is a near permanent feature.
2. The new inlet remains open and the old inlet closes. Tidal flows are redirected through the new inlet, which creates a complex of deltas comprised of eroded barrier island materials and littoral drift. The cross-sectional area of the new inlet will not reach that of the stabilized inlet, as evident in historic records that indicate smaller inlet openings prior to jetty construction.

3. Both inlets remain open, although area of the existing inlet will most likely decrease. The total inlet area is likely to remain comparable to pre-breach conditions. Tidal flows to the estuary may, however, be reduced due to increased frictional effects through smaller inlets. This situation is supported by inlet stability analyses that indicate that both inlets, especially at Moriches and Shinnecock Bays, would be vulnerable to closure.

7.2.2 Sediment Transport

Preliminary estimates of sediment transport for previous breaches in the study area are summarized in Table 12. It is noted that these estimates are based on historic breach observations for which adequate data are available, including hydrographic surveys and aerial photographs. Sediment transport volumes correspond to breach formation and the period of breach persistence. Consequently, these estimates reflect both storm-related bay sediment transport and long-term breach scouring.

TABLE 12
HISTORIC BREACH SEDIMENT TRANSPORT

Location	Date	Displaced Barrier Island Volume (cy)	Total Bay Deposition (cy)	Duration (months)	Bay Deposition Rate (cy/month)
Westhampton	1962	145,000	150,000	1	150,000
Moriches Inlet	1980	414,000	1,000,000	9	110,000
Westhampton	1992	467,000	600,000	10	60,000
Total		1,026,000	1,750,000	20	90,000

Ongoing efforts to quantify short-term breach sediment deposition estimate barrier island sediment quantities that would be scoured during storm persistence. Historic post-storm breach geometries were examined, as were other studies, to determine those factors leading to breaches, likely breach locations in the study area and eroded barrier island sediment quantities that would be relocated bayward. Currently, there is no commonly accepted criteria for estimating potential breach locations. Nonetheless, several criteria were common to previous studies, including barrier island width, and barrier island and dune volume. These parameters were examined for the study area to estimate those locations most susceptible to breaching. These vulnerable sites (top ten only) in order of estimated vulnerability included: (1) New Made Island, (2) Shinnecock Inlet (West), (3) Tiana Beach (West), (4) Pattersquash Island, (5) Tiana Beach (East), (6) Pelican Island, (7) Smith Point, (8) Old Inlet, (9) Moriches Inlet (East), and (10) Lonelyville. Based on barrier island geometry, and historic breach widths and depths, bay deposition during breach formation was estimated to range between 80,000 and 160,000 cubic yards per breach.

To determine the total sediment transport quantities for storms, historic breach events and associated storm characteristics were examined. The number of expected breaches was based on the number of breaches that occurred during and estimated exceedence frequencies of the September 1938, March 1962, January 1980, and December 1992 storms. Storm frequencies for events causing one or two breaches had return periods as low as 2 years. The 1938 storm that caused seven breaches had a return period between 64 to 94 years. A return period of 100 years was selected for the 1938 storm. Following this historical breaching trend, one breach is expected during a 6-year storm, and seven breaches are expected in a 100-year storm. Interpolating between these return periods suggests the number of breaches to be expected for various return periods. These results are summarized in Table 13. Given the breach-frequency results shown in Table 13, barrier island geometries and breach vulnerability rankings, storm-related sediment transport associated with multiple breach formations during a single storm were estimated as shown in Table 14.

TABLE 13
PRELIMINARY BREACH
FREQUENCY ESTIMATES

Return Period (Years)	Number of Breaches
6	1
10	2
16	3
30	4
40	5
65	6
100	7

TABLE 14
POTENTIAL BAY DEPOSITION
DURING MULTIPLE BREACH FORMATION

Storm Return Period (Years)	Number of Breaches	Bay Deposition (cy)
6	1	81,500
10	2	198,000
16	3	322,500
30	4	454,000
40	5	579,500
65	6	744,500
100	7	889,500

Long-term bay deposition following breach formation reflects the initial breaching event (and the estimated volumes shown in Tables 13 and 14), and then expansion of the breaches following formation. Estimated cross-sectional areas were determined using the equation shown previously. Potential breach cross-sectional areas for several possible breach locations are shown in Table 15 assuming a number breach closure scenarios. Breaches in Table 15 include those sites considered most vulnerable during a 100-year storm. It is noted, however, that ongoing analyses are not limited to these sites, but consider all areas judged vulnerable to breaching. Cross-sectional areas shown in Table 15 were used along with barrier island volumes above and below sea level to calculate the volume of barrier island sediments removed due to the breach (see Table 16). These volumes represent the barrier island sediments eroded by the breach, assuming the breach persists for the referenced period and the relationship developed for breach area versus time.

TABLE 15 POTENTIAL LONG-TERM BREACH SIZES				
Location	**Breach Areas (sq. feet)**			
	1 Months	**3 Months**	**6 Months**	**9 Months**
Shinnecock (West)	4,600	10,550	14,800	16,550
Tiana Beach (East)	4,600	10,550	14,800	16,550
Tiana Beach (West)	4,600	10,550	14,800	16,550
New Made Island	4,150	9,500	13,350	14,900
Smith Point	4,150	9,500	13,350	14,900
Pattersquash	4,150	9,500	13,350	14,900
Pelican Island	6,550	16,350	25,300	30,200

TABLE 16 PRELIMINARY BARRIER ISLAND SCOURING ESTIMATES				
Location	**Bay Deposition Volume (cy)**			
	1 Months	**3 Months**	**6 Months**	**9 Months**
Shinnecock (West)	145,000	334,000	468,000	524,000
Tiana Beach (East)	157,000	360,000	505,000	565,000
Tiana Beach (West)	157,000	360,000	505,000	565,000
New Made Island	94,000	215,000	302,000	337,000
Smith Point	156,000	357,000	502,000	559,000
Pattersquash	145,000	332,000	466,000	520,000
Pelican Island	282,000	705,000	1,091,000	1,303,000

While the estimates presented in Table 16 are approximations of a highly complex process, several observations should be considered. A one-month breach to Moriches Bay was estimated to result in barrier island scouring between approximately 90,000 and 150,000 cy. This range is quite similar to historic bay deposition quantities presented in Table 12 that ranged between 60,000 and 150,000 cy/month. It is noted that these figures reflect contributions from longshore sediment transport, as a portion of the eroded barrier island sediments are also transported offshore. In addition, average bay deposition rates from the three breaches shown in Table 12 average approximately 90,000 cy/month. If a six-month breach is examined, Table 16 indicates an average monthly breach-scouring rate of about 91,000 cy/month. Therefore, it is concluded that scoured barrier island volumes are a reasonable indicator of bay deposition, although some portion of the island sediments undoubtedly move offshore. This observation suggests that a portion of longshore sediment transport entering the breach is deposited bayward, but may be approximately equivalent the volume of barrier island sediments moved offshore.

It is not likely that all breaches would remain open for long periods, especially in the case of multiple breaches to a single bay. Depending on the tidal currents through the new breaches and longshore sediment transport conditions, one breach would probably dominate while others were closed. If the most vulnerable breach site per bay is selected to survive following multiple breach formation, total bay deposition will reflect only breach openings and long-term growth of the surviving breach. Total bay deposition volumes for the described situation were estimated based on previous results and are shown in Table 17.

TABLE 17
POTENTIAL BREACH/BAY DEPOSITION

Return Period (Years)	Bay Deposition Volume (x1,000 cy)			
	1 Month	3 Months	6 Months	9 Months
6	94	215	302	337
10	239	549	770	902
16	364	674	895	1,027
30	496	806	1,027	1,159
40	746	1,056	1,277	1,409
65	891	1,388	1,743	1,929
100	1,036	1,533	1,888	2,074

7.2.3 Hydrodynamics and Water Quality

The impacts of barrier island breaching on tidal hydrodynamics, salinity and residence times were investigated for Moriches Bay (Moffatt & Nichol 1994). Breach locations analyzed correspond to breaches that occurred in 1938, 1980 and 1992 (see Figures 5 to 8). Moffatt & Nichol (1995) assessed storm tides and inlet stability for Great South, Moriches and Shinnecock Bays and provided technical analyses in support of the Breach Contingency Plan. As part of the Reformulation Study, additional studies are being performed for Great South, Moriches and Shinnecock Bays. Breaches are being simulated at Water Island (Great South Bay), Westhampton (Moriches Bay) and west of Shinnecock Inlet (Shinnecock Bay). Each of the modeling studies utilized two-dimensional hydrodynamic and contaminant transport models. The current modeling efforts are examining breach impacts on hydrodynamics, storm tides, salinity, temperature and residence times for Great South, Moriches and Shinnecock Bays. The following paragraphs summarize the results of these studies. In addition to these studies, field observations and anecdotal information are available for the 1980 and 1992 breaches into Moriches Bay. Lastly, it is important to note that the cross-sectional areas of the existing inlets were not reduced due to the growth of the breach. Thus, modeling results reflect total inlet areas for each estuary that exceed all previously recorded values; this is considered reasonable in view of anticipated increases in dredging to maintain navigation in the existing inlets.

Hydrodynamics. Moffatt & Nichol (1994) investigations showed that prevailing tidal circulation within Moriches Bay would be modified by a breach though the degree of change depends on the breach location. For instance, breaches leading to the western and eastern basins of Moriches Bay strongly influence tidal flow within those basins. On the other hand, the 1980 breach was located adjacent to the inlet and had only minor influences on overall bay circulation. The 1980 breach, however, but did cause markedly decreased inlet current velocities. Accordingly, Moffatt & Nichol Engineers (1994) concluded that breaches located away from Moriches Inlet have a greater impact on Moriches Bay tidal hydrodynamics than breaches located closer to the inlet.

Depending on the breach size examined, ongoing modeling study indicates that existing inlet current velocities would be reduced by 10 to 25 percent. Tidal prisms through the inlets were modeled to be reduced by approximately 10 (Moriches Inlet) to 70 (Fire Island Inlet) percent. On the other hand, tidal prisms to the bays reflect the contributions of both the inlet and breach. Results indicated that overall tidal prisms would increase with the largest increases at Great South Bay. Corresponding tidal range increases were approximately 0.1 to 0.2 feet at Great South Bay, although the tide range near the inlet was decreased significant. Modeling results also indicate the possibility of increased average tidal elevations through the bay. Modeled tidal ranges for Moriches and Shinnecock Bays indicated increases between 0.2 and 1.0 feet, depending on the breach case examined. Table 18 summarizes breach modeling results output from current study.

TABLE 18
PRELIMINARY BREACH IMPACT RESULTS - HYDRODYNAMICS

	3-Month Breach		**9-Month Breach**	
	Flood (% Change)	**Ebb (% Change)**	**Flood (% Change)**	**Ebb (% Change)**
Great South Bay				
Peak Inlet Velocity	-20 to –25	-25 to –30	-20	-25 to –30
Inlet Tidal Prism	-65 to –70	-65	-65 to –70	–65
Bay Tidal Prism	+5 to +20	-10 to -15	+35 to +55	+10 to +25
Moriches Bay				
Peak Inlet Velocity	-10 to –15	-10 to -15	-10 to –20	-15 to –20
Inlet Tidal Prism	-10 to –25	-15 to –20	-10 to –30	–25
Bay Tidal Prism	+20 to +45	+20 to +25	+35 to +65	+35 to +40
Shinnecock Bay				
Peak Inlet Velocity	-10 to –20	-15 to –15	-10 to –20	-15 to –20
Inlet Tidal Prism	-25 to –30	-25 to –25	-35 to –35	-30 to –35
Bay Tidal Prism	+15 to +20	+10 to +20	+20 to +25	+15 to +25

These results indicate that the diversion of tidal flows from the existing inlets to the new breach may be significant. Additionally, it should be noted that decreased inlet areas would further reduce tidal propagation through he inlets into the adjoining estuaries. Total tidal prisms entering the bays were also markedly increased. This result is dependent on total inlet areas that exceed historic values. As no method is readily available to estimate breach and inlet areas (i.e., synoptic breach and inlet surveys), inlet areas were not altered due to breach presence. Nonetheless, it is evident based on past experience that two large inlets into a single bay would not survive, and that total inlet areas would be less than that modeled. Increased tidal prisms shown in Table 18 are, therefore, judged as high. This assumption suggests that normal tidal exchange would be increased due to a new breach, but following equilibration of the inlet and breach areas would stabilize to conditions that may be somewhat higher than present. On the other hand, closure of the breach would return conditions to those that presently exist. Closure of the inlet would result in reduced tidal prisms, as unstabilized inlets would not reach cross-sectional areas achieved following jetty construction at the inlets.

Salinity. According to Moffatt & Nichol (1994), modeling of the 1992 breach at Westhampton Beach indicated that salinities in the adjoining eastern basin were increased by approximately 10 percent, whereas salinities in the western basin were reduced by about 3 percent (Moffatt & Nichol 1994). Salinity increases in the eastern basin occurred as ocean waters entered through the breach. Concomitantly, western basin salinities decreased because less ocean water was drawn through the inlet. Salinity changes for the 1938 and 1980 breach cases indicated only minor differences, typically less than 3 percent. It should be noted that salinity field measurements taken before, during and after the 1992 breach at Westhampton did not indicate any significant deviations in long-term salinity levels in Moriches Bay. These results are based on in-situ measurements at the U.S. Coast Guard Station, and do not explicitly reveal a relationship between salinity distribution throughout the bay and breach development. In summary, breach impacts on salinity distributions were relatively minor, especially in comparison to the range of measurements in the western basin that ranged between 21 and 33 ppt. On the other hand, the relative change from a breach to the eastern basin is more significant due to the limited range of ambient salinities from 28 to 33 ppt.

Preliminary results from ongoing modeling studies indicate that salinity is increased in the eastern basin of Great South Bay near the simulated breach at Water Island, but is decreased slightly at locations remote from the breach. Salinity is increased directly by the influx of additional ocean water through the breach at stations 110, 120, 130, 140, and 150. Salinity increases were minor in comparison to measured background salinity ranges. Stations further west in Great South Bay showed even smaller salinity increases. Adjacent to and west of Fire Island Inlet, salinity levels decreased due to breach presence. Decreased salinity west of the inlet can be attributed to weakened flow through the inlet. Salinity reductions were also minor relative to the range of background measurements. Breach impacts on salinity distributions in Moriches Bay indicate that salinity in the eastern basin adjacent to the breach is increased for a breach at Pikes Beach. Salinity levels in the western basin and near the inlet were simulated to experience negligible changes due to the breach. Predicted salinity changes were notably less than changes shown by background measurements. Salinity changes in Shinnecock Bay were negligible to minor due to the location of the modeled breach immediately west of the inlet. This behavior is comparable to Moffatt & Nichol (1994) results for Moriches Bay and field measurements taken during the 1980 breach east of Moriches Inlet.

Temperature. Preliminary modeling results indicated that a breach to Great South Bay has negligible impacts on temperature values or distribution. Temperatures are increased slightly in the eastern basin adjacent to the breach, but are decreased slightly at locations remote from the breach. Modeled temperature changes were much less than measured background ranges. The impacts of the breach on temperature distributions in Moriches Bay indicate a slight decrease throughout the bay. Shinnecock Bay modeling results are comparable to those at Moriches Bay, although temperature changes are reduced by the location of the breach near the inlet.

Residence Time. Moffatt & Nichol (1994) model simulations of the 1992 breach at Westhampton indicated that residence times within the eastern basin were decreased from a base conditions of 3 to 8 days to 1.5 days with the breach. Residence times in the western basin were, however, increased. On the other hand, residence times for the breach located at Moriches Inlet were only slightly decreased. Ongoing modeling efforts are further investigating residence time impacts for each of the study area's estuaries.

8. BIOLOGIC OVERWASH/BREACH IMPACTS

With regard to the biological effects of barrier island overwashing and breach formation, a major disruption and loss of existing habitat is balanced by re-colonization and even possible formation of new or enhanced habitats. Potential changes may be either short- or long-term. Short-term impacts, such as the scouring or smothering of intertidal marshes, are usually detrimental. Longer-term impacts, such as potential re-establishment of SAV beds on shoal deposits, are generally beneficial. In aquatic systems, environmental conditions shaped by climatic events and anthropogenic influences are important factors affecting populations and, ultimately, the entire community. Changing environmental conditions may result in stresses that could alter or detrimentally influence one or more populations.

Estuarine organisms by definition are tolerant of variations in their physical environment including fluctuations in salinity and temperature. The results of the modeling in this report indicate that breaching will not preclude the survival of any of the ambient back bay species, although localized population shifts may occur. Increased bay water salinities that may result from a breach have the potential to provide conditions that are more suitable for certain shellfish predators (i.e., sea stars and oyster drills). However, under the expected without project conditions, all breaches are likely closed within a 12-month period. This is not sufficient time to allow an ecological community to develop which is dependent upon a long-term rise in salinity. If predation does occur, the effects are likely to be minimal. Once the breach is closed, bay water salinity and the ecological community structure is likely to return to pre-breach conditions.

8.1 Biological Impacts

The New York State Department of State commissioned a scientific literature review of *"The Environmental Impacts of Barrier Island Breaching with Particular Focus on the South Shore of Long Island, New York"* (Cashin Associates, P.C., 1993) which examined the biological impacts related to breaches. The following is a summary of their findings:

- The increase in bay tidal flushing would result in a reduction of "small form" algal blooms;
- Increased tidal flushing is also likely to promote accelerated clam growth. However, there may be a concomitant increase in the loss of planktonic larval stages from the bay as a result of excessive flushing. Without proper yearly recruitment, the standing stock of shellfish in the bays may gradually be depleted;
- No definite conclusions were reached with regard to finfish or waterfowl populations;
- The number and variety of shellfish predators is likely to increase as a result of the rise in salinity levels;

- As can be expected following any significant environmental disturbance in a biological system, the "opportunistic" species are likely to first re-colonize the disturbed area and gradually be replaced by a greater variety of "equilibrium" species;
- The fresh sand deposits and new beach areas are likely to attract nesting shorebirds and colonial shorebirds (e.g., least terns, piping plovers and roseate terns);
- Tidal marshes are likely to stay in early stages of vegetative succession and remain highly productive; and
- The increases in tidal flushing and water clarity are likely to benefit eelgrass growth.

There are additional adverse impacts that are likely to occur as a result of barrier island breaching. These include the immediate and direct loss of upland and wetland vegetation in the path of the new inlet opening, and the scour of backbay wetlands and submerged aquatic vegetation from within and adjacent to the inlet channel. Additional vegetation damage is also expected to occur over time along the newly exposed upland vegetated edge, as plants which were formerly surrounded by other vegetation or topographic barriers become stressed due to the increased exposure to wind, salt spray, drought, insects, disease, etc.

While the Cashin Associates (1993) report points out that the densest eelgrass beds were found in close proximity to Fire Island and Jones Inlets, it fails to mention that SAV beds are nearly absent for a distance of approximately 1 mile northeast of the tip of Captree or 5 miles east of the tip of Democrat Point; and that the eelgrass bed distribution appeared to be clustered on the lee side of protective land masses away from the deeper, swifter waters of the inlet channels (Jones and Schubel, 1990). One can only postulate that a breach occurring through the Fire Island barrier at a point where major wetlands and SAV beds currently exist could theoretically destroy a significant area of intertidal and subtidal habitat. However, intertidal marshes and SAV beds may re-establish on the bayside deposits or flood tidal deltas over time, once the breach is closed.

The macrobenthic invertebrates are completely sessile and represent the single largest group of organisms that will be directly impacted by changes to either the oceanic or bayside benthos. The macrobenthic invertebrates associated with the "high energy" oceanic environment are typically capable of quickly re-colonizing areas that are disturbed by coastal storms. The backbay environment is generally quiescent, allowing a more diverse and stable benthic community to develop. When disturbed by coastal storms, the backbay benthic community will generally respond first by re-colonizing with opportunistic species, followed by a gradual shift in species resulting in a more mature benthic community over time. The total re-colonization process is expected to take approximately 12 to 18 months (Nagvi and Pullen, 1982).

Finfish would be largely unaffected by a breach, although the new inlet channel may provide attractive habitat for certain species (USFWS, November 1998). Thus, the effects on finfish populations are expected to vary on a species-specific basis. One may argue that a scenario similar to the loss of pelagic shellfish larvae may occur with larval fish being "swept out to sea". However, breaches may also increase the ease of access for juvenile finfish to swim back into the bays for species which breed offshore (e.g., summer flounder and bluefish). Additionally, the species which are prevalent in the backbay SAV beds that typically attach their eggs to vegetation or some sort of substrate (e.g., killifish, silversides, winter flounder, and sticklebacks) are likely to be unaffected by the increase in tidal flushing.

Adult winter flounder, for example, migrate from offshore waters to shallow bays and estuaries during the fall and return to deeper offshore waters in the summer. The fall (onshore) and summer (offshore) migration exposes the fish to water temperatures ranging from winter lows at or near the freezing point of seawater 28.4º F to summer highs approaching 86.0º F (see *Species Profiles – Winder Flounder (Pleuronectes americanus): General Life History and Model Threshold Values,* USACE (undated)). The upper tolerance limit of adults is around 84.0º F, with summer offshore movements occurring at temperatures below 59.0º F. Spawning occurs in shallow inshore waters, with early larval stages occupying the same shallow areas. Eggs and larvae exhibit the same low temperature tolerance as the adult and have higher upper tolerance limits. Juveniles usually remain in the coastal estuaries and bays during the first year exhibiting a high tolerance to warm summer water temperatures. No alteration in water temperatures as a result of breaching or overwashing should have an impact on reproduction, development, or distribution patterns of the winter flounder.

Eggs, larvae, juvenile, and adult winter flounder exhibit a tolerance to a wide range of salinity. Some winter flounder spawning takes place in brackish waters with no difference in egg hatching or larval survival related to low salinity values. The brackish water spawning is reflected in a lower tolerance value for all lifestages of 5.0 ppt. The upper tolerance value is characteristic of normal seawater, with an upper level around 40 ppt. No changes in salinity as a result of breaching are projected to affect winter flounder (see *Species Profiles – Winder Flounder (Pleuronectes americanus): General Life History and Model Threshold Values*, USACE (undated)).

Generally, adult winter flounder are not in nearshore waters during the summer months when low dissolved oxygen levels are a problem. Long Island Sound studies conducted to evaluate minimal environmental conditions, including low dissolved oxygen levels, have not reported any influence on winter flounder abundance levels or distribution patterns. The limited information available suggests that alteration of dissolved oxygen levels during breaching or overwashing events would have no impact on winter flounder population levels or distribution patterns (see *Species Profiles – Winder Flounder (Pleuronectes americanus): General Life History and Model Threshold Values,* USACE (undated)).

Any changes in hydraulic conditions that result in water movement patterns from the shallow shore zone spawning/nursery areas to deeper water areas or offshore areas would have a detrimental effect on winter flounder. The early larval stages feed on microzoo-plankton that are most abundant in shallow water areas, and the limited swimming ability of the larvae require that currents be low so they can remain in the shore zone. The most important factors affecting larval mortality were translocation and natural mortality (i.e., predation) (Pearcy 1962). Translocation out of the estuary by seaward drift was significant, and though little is known of the fate of the larvae transported from the preferred inshore nursery area waters, offshore conditions were considered unfavorable primarily due to a lack of food.

Swimming endurance tests on one and two year old specimens indicate that resting on the bottom is preferred; however, when swimming winter flounder exhibit very good endurance at moderate to high water velocities. Hydraulic changes in the bays and inlets due to breaching should not have an effect on winter flounders. Near shore changes in hydraulic conditions could have a detrimental affect on winter flounder larvae prior to the benthic transformation.

As discussed earlier, barrier breaching often results in the formation of flood tidal deltas on the bay side of the barrier. Following breach closure, these deposits are likely to provide suitable substrate for future SAV growth or the development of emergent tidal marshes, if the elevation is sufficient. These flood tidal deltas typically benefit a variety of wildlife species, especially shorebirds, by increasing the available foraging and loafing area, and potential nesting sites. Flood tidal deltas and the dynamic sand spits associated with bay inlets also provide optimal habitat for the rare plants, seabeach amaranth and seabeach knotweed.

9. IMPACTS SUMMARY

A wide range of physical impacts due to overwash and breaching have been discussed. These impacts fall within two main categories: (1) additional tidal exchange between ocean and bay, and (2) sediment transport to the bays. While the effects on additional openings due to breaches may be important in terms of bay storm tides, inlet stability and normal tidal circulation, impacts to estuarial salinity and temperature appear to be relatively minor. This is especially the case if the infrequency of breaches is considered, which underscores the minor impact of breaches on salinity and temperature in comparison to seasonal variations. Additionally, model impacts on tidal prism and circulation must consider that fact that multiple inlets have not historically persisted for a single bay and that unstabilized inlets have typically been much smaller than the present inlets. These factors suggest that increased tidal prisms, hence improved water quality, would be temporary prior to the closure of either the inlet or breach. Furthermore, the existence of a ceiling on total inlet area per bay suggests that flows through a new inlet would merely represent the redistribution of tidal propagation rather than significantly increased prisms or improved water quality. In summary, numerical modeling efforts and historic data indicate that multiple inlets are not sustainable and that impacts on salinity and temperature due to breaches are minor.

Preliminary modeling results and Moffatt & Nichol (1994) indicate decreased residence times in areas proximate to simulated breaches, but increased residence times at locations away from breaches. Analyses, specifically residence times, suggest that barrier island breaches may alter water quality, but are principally characterized by improvements at some locations and detriments elsewhere. These observations parallel hydrodynamic results that indicate that new breaches would result in the redirection of tidal flows from existing inlets to new breaches rather than significant increases of bay tidal prism and improved water quality.

Sediment transport associated with overwashes and breaching has been and will continue to be significant. Analyses of barrier island conditions and past overwashes/breaches provide a measure of the quantities of bayward sediment transport and locations vulnerable to such occurrences. Additionally, current investigations are underway to develop methodologies to evaluate the reduction of sediment transport that may attend storm protection measures being considered as part of the Reformulation Study.

It is important to note that overwash and breaching impacts must be evaluated in terms of without-project conditions. This is very different from evaluating impacts in terms of a no action scenario where breaches are permitted to grow and migrate indefinitely. A no action scenario that permits unchecked breach growth is an unlikely condition. Given State commitment to maintaining inlets and closing breaches, it is more likely that continued actions to close breaches would occur. Consequently, scenarios that include large breaches and significant shoaling of the existing inlets would most likely not be allowed, and the effects of new breaches would be temporary. This observation in conjunction with the stabilization of the existing inlets and the unlikely case of multiple new (and stable) breaches further reduces potential breach impacts over an extended period. These conditions underscore the assertion that circulation and water quality changes associated with breaches are transitory. Consequently, the only long-term physical features associated with overwash and breaches are overwash fans and breach spits/flood shoals.

10. STATUS/FUTURE WORK

It is evident that much is known regarding the qualitative impacts associated with barrier island overwashing and breaching. It is also apparent that there may be benefits associated with overwashing and breaching, including barrier island migration, habitat evolution and increased biologic productivity. Therefore, it must be acknowledged that preclusion/reduction of barrier island overwashing and/or breaching for the purpose of storm damage reduction must consider the health and survivability of the barrier island and bay resources. If the ephemeral nature of breaching and the limitations on total inlet area to the bays are also considered (along with the likelihood that the bays can only support a single inlet), then the benefits of breaching on water quality (and biologic responses) should be considered as temporary. Furthermore, it also appears that changes of water quality parameters associated with barrier island breaches are within the ambient range of conditions. This observation suggests that breaches, especially temporary, would have minor impacts given the current estuary/stabilized inlet arrangements.

Barrier island breaching and overwashing present other adverse biologic impacts, including burial of bay floor habitats, loss of larvae due to increased tidal flushing, and scour of backbay wetlands and subaquatic vegetation. Consequently, examination of overwashing and breaching must weigh storm reduction benefits against potential biological impacts. It is the intention of the Reformulation Study to address these issues by examining and quantifying potential adverse impacts associated with proposed storm reduction measures. Once such impacts are clearly defined, it would be possible to classify impacts relative to their significance and to develop mitigation procedures if and where necessary.

Completed/ongoing studies of the influences that storm damage reduction measures will have on breaching and overwash processes will provide the basis for evaluating short- and long-term impacts. These studies include the following:

- A study of historic barrier island overwashing and breaching is being performed to determine the sediment transport properties, including quantifying the volume of material deposited landward during and following severe storms. These historic investigations will provide the basis for developing procedures to quantify the impacts of possible storm protection measures for the project life. Specifically, overwash and breaching sediment transport volumes will be estimated for without- and with-project conditions.
- Historic barrier island breaches and overwashes are being and have been investigated to determine the factors leading to occurrence. Potential breach and overwash sites will be identified. Breach growth both during causal storms and following storm cessation are being investigated. These potential breach and overwash sites will be considered along with estimates of reduced sediment transport volumes to determine any mitigation that may be required to compensate for adverse project impacts on barrier island elevations and migration. These determinations must, however, take into account adverse impacts of breaches and overwash under without-project conditions.

- Numerical modeling investigations are underway to assess the impact of barrier island breaches on tidal hydrodynamics (e.g. normal and storm tides, inlet flow velocities, bay circulation, salinity distributions, temperature and residences times) in Great South, Moriches and Shinnecock Bays. These studies will improve previous assessments of long-term breach impacts (typically up to one year).
- Storm surge modeling is currently underway to account for barrier island breaching and overtopping in the simulation of bay storm tides. These studies will assess the impact of overwash and breaching on bay storm tides, based on historic evaluation of breach/overwash formation and observations of storm breach sizes.
- Previous studies have been performed to assess the stability of existing tidal inlets. These studies indicate the impact of new inlets on existing navigation channels, and the likelihood that new breaches would remain absent mechanical closure operations.

These studies will quantify the impacts of overwashing and breaching on the physical conditions in the study area relative to both short- and long-term impacts. Furthermore, these investigations will provide the baseline against which the impacts of potential storm protection measures may be weighed. Questions concerning beneficial/unknown breaching/overwashing posed by Cashin (1993) and USFWS (1998) that will be partially or wholly addressed by these studies include:

- What are the probability, size and location of breaches? How long are breaches expected to remain open?
- How many breaches or inlets may form during the project life?
- How many new habitats might form or be lost by preventing or allowing breaches and overwash?
- What is the importance of overwash sand, breaching and inlet formation to the development of back-bay salt marsh and how will the reduction in breaches and overwashes affect the rate of marshland formation on the bay side of the barrier islands?
- What are the hydrodynamic impacts of breaches or new inlets on normal bay tides?
- What are the water quality differences between with- and without-project breach conditions, as indicated by temperature, salinity and residence times? Are these differences within the range of existing ambient variations?
- Will shoaling of existing navigation channels accelerate in the presence of breaches or new inlets?
- What are the impacts of storm protection measures on breach and overwash sediment deposition, as impacting habitat creation, modification and barrier island migration?
- What are the economic impacts of breaches and overwashes due to increased flooding, direct structure destruction?
- What are the economic impacts of delaying breach closure?

The following describes a possible study to address data gaps concerning ecological impacts of overwashes and breaches on the barrier islands and backbay environments. Note should be made that this study satisfies specific impact scenarios, and is not designed to be an all inclusive baseline study of the backbay marine ecosystems.

Quantification of impacts, particularly predicted as opposed to historical impacts, is not an exact science. Changes to motile populations in open-ended systems tend to be more limited because the populations respond to changes by seeking optimal conditions rather than being forced to adapt. Impacts to sessile groups are more predictable because they are unable to relocate and are subject to physical and water quality changes. For this reason, the study emphasis will be on closing data gaps relating to the non-motile forms.

- **Mapping of SAV Beds**. While some mapping of SAV beds has been completed for specific zones along the barrier islands, it may be advantageous to prepare a comprehensive map of all SAV beds located on the southern side of the bays. Included in this survey would be eelgrass, widgeongrass and macroalgae species. This information will prove useful in assessing losses to these systems due to sand displacement during overwashes or physical destruction during

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