

Title Page

Report

Figures/Maps

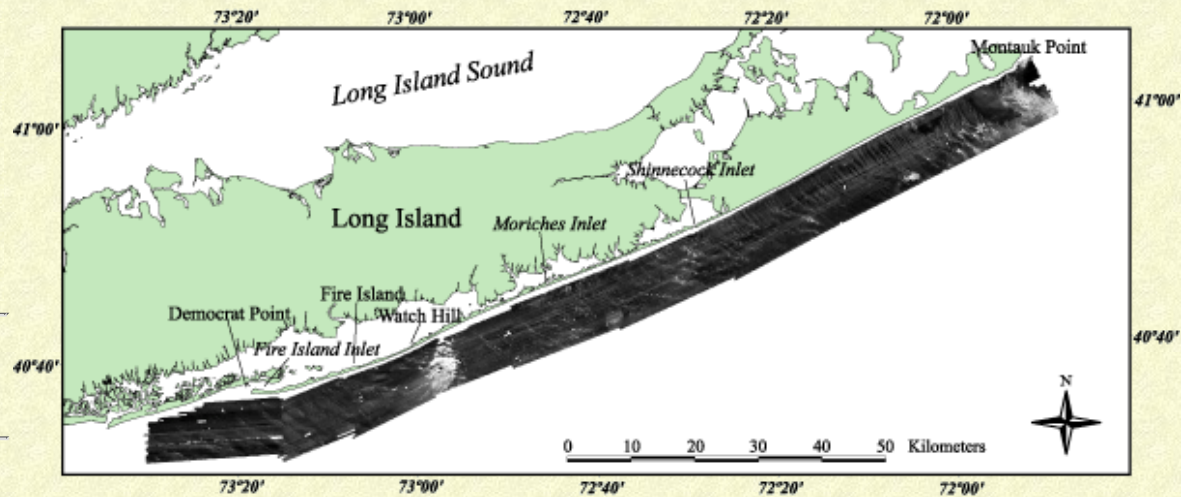
Acknowledgements

References

derived from Schwab, W.C., Thielert, E.R., Denny, J.F., Danforth, W.W. 2000. Seafloor Sediment Distribution Off Southern Long Island, New York: U.S. Geological Survey Open-File Report 00-243

## Seafloor Sediment Distribution Off Southern Long Island, New York

by Schwab, W.C., Thielert, E.R., Denny, J.F., Danforth, W.W., and Hill, J.C.



U.S. Geological Survey, Coastal and Marine Geology,  
Woods Hole Field Center, Woods Hole, MA  
derived from Open File Report 00-243

Any use of trade, product, or firm names in this publication  
is for descriptive purposes only and does not imply endorsement by the U.S. Government.


[Title Page](#)
[Report](#)
[Figures/Maps](#)
[Acknowledgements](#)
[References](#)
[REPORT](#)
[Introduction](#)
[Methods](#)
[Setting](#)
[Discussion](#)
[Mapping Results](#)
[Coastal Plain Strata](#)
[Pleistocene and Early  
Holocene Sediments](#)
[Modern Sediments](#)
[Conclusions](#)

## INTRODUCTION

derived from Schwab, W.C., Thieler, E.R., Denny, J.F., Danforth, W.W. 2000. Seafloor Sediment Distribution Off Southern Long Island, New York: U.S. Geological Survey Open-File Report 00-243

[Figure 1](#)



[Figure 2a](#)

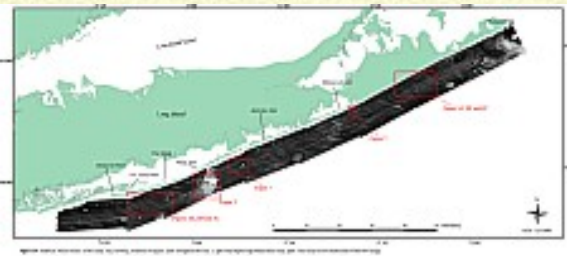


Coastal Erosion along the south shore of Long Island, New York, between Fire Island Inlet and Montauk Point (Fig. 1), has received much engineering, scientific, and political attention during the past 40 years (e.g., Leatherman and Allen, 1985; U.S. Army Corps of Engineers, 1993). The interest is due to significant tourism to the area's parks and beaches, the presence of numerous coastal communities, a densely populated mainland, and an active local fishing industry; all of which are negatively impacted by coastal erosion. Coastlines with limited sand supplies, such as much of the Atlantic margin of the United States, are significantly influenced by the geologic framework beneath and seaward of the littoral zone (Davis and Kuhn, 1985; Evans and others, 1985; Riggs and others, 1995; Thieler and others, 1995; Schwab and others, 1999, 2000). This antecedent geology can determine the morphology of the shoreface and inner-continental shelf and strongly influence modern beach behavior.

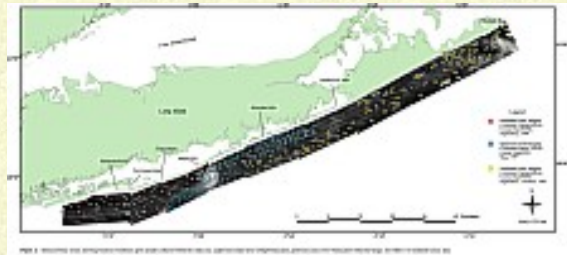
A better understanding of sediment dynamics in coastal areas can be attained by mapping the surface sediment distribution and subsurface stratigraphy of the lower shoreface and inner-continental shelf. In 1996, the U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers, began a program to produce geologic maps of the sea floor along the south shore of Long Island using high-resolution sidescan-sonar, subbottom profiling, and sediment sampling techniques. The study area extends from the 8-m isobath to about 10 km offshore. The goals of the investigation are to determine regional-scale sand-resource availability for planned beach-nourishment programs and to investigate the role that inner-shelf morphology and geologic framework play



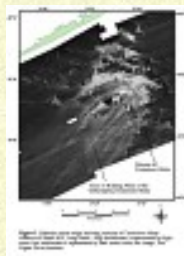
**Figure 2b**



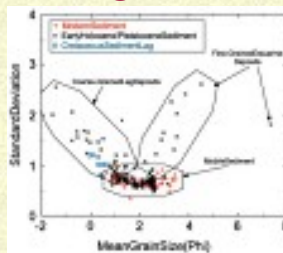
**Figure 2c**



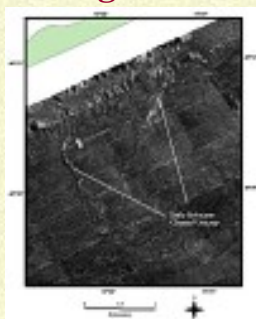
**Figure 3**



**Figure 4**



**Figure 5**



in the evolution of this coastal region.

Regional interpretation of these mapping products are reported in Schwab and others (1999, 2000). Maps showing the Quaternary stratigraphy of the study area were presented by Foster and others (1999). In this report, we present the sidescan-sonar imagery and interpretation based on the stratigraphic framework presented in Foster and others (1999) and on the textural analysis of bottom sediment samples (Table 1).

[Back to the top of the page](#)

## METHODS

The study area was surveyed using high-resolution sidescan-sonar, seismic-reflection, bathymetric, and sediment sampling techniques in May 1996 aboard the research vessel SEAWARD EXPLORER (USGS Cruise SEAX96004) and in September-October 1996, May 1997, and September-October 1997 aboard the research vessel DIANE G (USGS Cruises Dian96040, Dian97011, and Dian97032, respectively). Selected areas within the study area were surveyed using a multibeam echosounder in November 1998 using the Canadian Hydrographic Survey research Vessel FREDERICK G. CREED (USGS Cruise CRED98015) in order to acquire high-resolution bathymetric data coincident with sidescan-sonar backscatter data.

Geophysical data were acquired using a 100-105 kHz swept-frequency sidescan-sonar system, a 2-7 kHz swept FM (CHIRP) subbottom profiler, a 300-3000 Hz Geopulse boomer subbottom profiler, a 100-3000 Hz sparker system, a 200 kHz fathometer, and a Simrad EM1000 multibeam echosounder. Ship tracklines were selected to provide continuous sidescan-sonar coverage of the sea floor, average line spacing was 300 m. A full description of data acquisition and processing routines applied to the subbottom data is presented in Foster and others (1999). Sediment samples were collected using a Van Veen grab sampler.

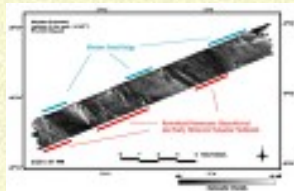
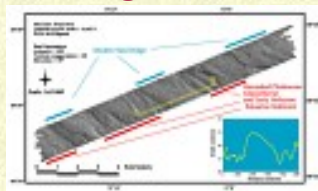
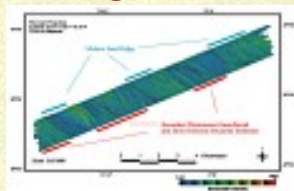
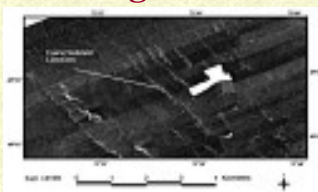
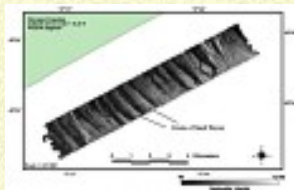
The sidescan-sonar data were logged digitally at a sample rate yielding a 0.18-m pixel resolution in the across-track direction and approximately 0.14-m pixel resolution in the along-track direction, following the methodology outlined in Danforth and others (1991). A median filter routine (Danforth 1997) was applied to the sidescan-sonar data to remove speckle noise, resulting in a 0.73-m pixel size. The data were further processed and mosaicked using procedures described in Paskevich (1992) and Danforth (1997), resulting in an enhanced, geographically correct, sidescan-sonar mosaic with a 4-m/pixel resolution.

Fathometer data were collected digitally and processed to remove water-depth variations due to vessel heave, transducer draft, and tidal fluctuations. The vertical resolution of the bathymetric data is about 1 m. The data were gridded and contoured with a 300-m grid using the EarthVision software package (Dynamic Graphics, Inc.).



**Table 1**

Station	Depth (m)	Sediment Type	Grain Size (mm)	Color	Notes
1	20	Sand	0.25	Light	
2	25	Sand	0.25	Light	
3	30	Sand	0.25	Light	
4	35	Sand	0.25	Light	
5	40	Sand	0.25	Light	
6	45	Sand	0.25	Light	
7	50	Sand	0.25	Light	
8	55	Sand	0.25	Light	
9	60	Sand	0.25	Light	
10	65	Sand	0.25	Light	
11	70	Sand	0.25	Light	
12	75	Sand	0.25	Light	
13	80	Sand	0.25	Light	
14	85	Sand	0.25	Light	
15	90	Sand	0.25	Light	
16	95	Sand	0.25	Light	
17	100	Sand	0.25	Light	
18	105	Sand	0.25	Light	
19	110	Sand	0.25	Light	
20	115	Sand	0.25	Light	
21	120	Sand	0.25	Light	
22	125	Sand	0.25	Light	
23	130	Sand	0.25	Light	
24	135	Sand	0.25	Light	
25	140	Sand	0.25	Light	
26	145	Sand	0.25	Light	
27	150	Sand	0.25	Light	
28	155	Sand	0.25	Light	
29	160	Sand	0.25	Light	
30	165	Sand	0.25	Light	
31	170	Sand	0.25	Light	
32	175	Sand	0.25	Light	
33	180	Sand	0.25	Light	
34	185	Sand	0.25	Light	
35	190	Sand	0.25	Light	
36	195	Sand	0.25	Light	
37	200	Sand	0.25	Light	
38	205	Sand	0.25	Light	
39	210	Sand	0.25	Light	
40	215	Sand	0.25	Light	
41	220	Sand	0.25	Light	
42	225	Sand	0.25	Light	
43	230	Sand	0.25	Light	
44	235	Sand	0.25	Light	
45	240	Sand	0.25	Light	
46	245	Sand	0.25	Light	
47	250	Sand	0.25	Light	
48	255	Sand	0.25	Light	
49	260	Sand	0.25	Light	
50	265	Sand	0.25	Light	
51	270	Sand	0.25	Light	
52	275	Sand	0.25	Light	
53	280	Sand	0.25	Light	
54	285	Sand	0.25	Light	
55	290	Sand	0.25	Light	
56	295	Sand	0.25	Light	
57	300	Sand	0.25	Light	
58	305	Sand	0.25	Light	
59	310	Sand	0.25	Light	
60	315	Sand	0.25	Light	
61	320	Sand	0.25	Light	
62	325	Sand	0.25	Light	
63	330	Sand	0.25	Light	
64	335	Sand	0.25	Light	
65	340	Sand	0.25	Light	
66	345	Sand	0.25	Light	
67	350	Sand	0.25	Light	
68	355	Sand	0.25	Light	
69	360	Sand	0.25	Light	
70	365	Sand	0.25	Light	
71	370	Sand	0.25	Light	
72	375	Sand	0.25	Light	
73	380	Sand	0.25	Light	
74	385	Sand	0.25	Light	
75	390	Sand	0.25	Light	
76	395	Sand	0.25	Light	
77	400	Sand	0.25	Light	
78	405	Sand	0.25	Light	
79	410	Sand	0.25	Light	
80	415	Sand	0.25	Light	
81	420	Sand	0.25	Light	
82	425	Sand	0.25	Light	
83	430	Sand	0.25	Light	
84	435	Sand	0.25	Light	
85	440	Sand	0.25	Light	
86	445	Sand	0.25	Light	
87	450	Sand	0.25	Light	
88	455	Sand	0.25	Light	
89	460	Sand	0.25	Light	
90	465	Sand	0.25	Light	
91	470	Sand	0.25	Light	
92	475	Sand	0.25	Light	
93	480	Sand	0.25	Light	
94	485	Sand	0.25	Light	
95	490	Sand	0.25	Light	
96	495	Sand	0.25	Light	
97	500	Sand	0.25	Light	
98	505	Sand	0.25	Light	
99	510	Sand	0.25	Light	
100	515	Sand	0.25	Light	

**Figure 6a****Figure 6b****Figure 6c****Figure 7****Figure 8a**

The multibeam data were acquired with a Simrad EM 1000 Multibeam Echosounder. This system utilizes 60 electronically aimed beams spaced at intervals of  $2.5^\circ$  that can ensonify a swath of sea floor up to 7.5 times the water depth. Horizontal resolution, or the footprint of an individual beam on the sea floor, is approximately 10 percent of the water depth. Vertical resolution is approximately 1 percent of the water depth or better. Thus for the range of water depths within the survey area, 20 – 50 m, the horizontal resolution is 1.3-5.0 m and the vertical resolution is 0.2 - 0.5 m. The multibeam data were acquired digitally and processed using software developed by the Ocean Mapping Group, University of New Brunswick (see World Wide Web URL <http://www.omg.unb.ca/~jhc/SwathEd.html>). Tidal elevations measured at the NOAA Sandy Hook station were used to adjust the data for the tidal fluctuations and reference the data to mean lower low water.

Grain-size analyses of the sediment samples were conducted using a combination of sieving and Coulter Counter techniques following the methodology of Poppe and others (1985).

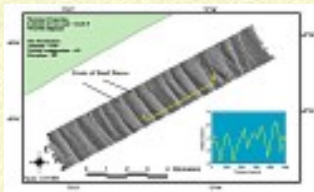
Ship position for all cruises was determined from a Differential Global Positional System (DGPS). The sidescan-sonar towfish was navigated relative to the ship using an acoustic-ranging system. The position of the towfish was calculated assuming the towfish was directly behind the research vessel; i.e., towfish followed the ship trackline. This assumption is relatively accurate when the research vessel is running in a straight line, with a small amount of tow cable deployed. However, because the towfish position error increases in turns by 10's of meters, data collected during turns were discarded. In using the navigation data, we conclude that the position of the bathymetric data, sample locations, and the sidescan-sonar imagery are accurate to within 5 m.

[Back to the top of the page](#)

## SETTING

Long Island marks the southern boundary of the late Pleistocene glacial advance in the eastern part of North America (Stone and Borns, 1986). Two end moraines are superimposed along the western part of northern Long Island. The moraines bifurcate in eastern Long Island, where each moraine forms the core of the two peninsulas north and south of Great Peconic Bay (Fig. 1). The topography of Long Island is a reflection of this glacial history and exhibits greater relief on the northern side, where the two moraines are superimposed, and a gentler southward dipping gradient on the outwash plains that make up much of the southern side of the island. The coast from Southampton to Montauk Point is a headland region where the Ronkonkoma moraine and associated outwash sediment are eroded directly by wave action (Williams, 1976). The south shore of Long Island west of Southampton consists of reworked glaciofluvial outwash and includes shallow back-barrier bays, marshes, and



**Figure 8b**

low-relief, sandy (fine- to medium-grained sand) barrier islands.

**Figure 9(a)****Figure 9(b)**

Leatherman (1989) identified 26 historical inlet sites along the Fire Island barrier-island system east of Watch Hill (Fig. 1). Inlet breaches account for most of the littoral sand transport into the back-barrier bays, and relict flood-tidal deltas are common throughout Moriches and Shinnecock Bays (Leatherman, 1985). The great number of relict flood-tidal deltas east of Watch Hill and outcrops of tidal-marsh sediments on the upper shoreface provide evidence of landward migration of this portion of the barrier-island system (Leatherman and Allen, 1985). In contrast, most of Fire Island west of Watch Hill has experienced in-place submergence over the past ~1000 yr (Sanders and Kumar, 1975; Leatherman, 1985; Leatherman and Allen, 1985). From the early 1800's until 1931, the Fire Island barrier-island system from Shinnecock Bay west to Fire Island Inlet, formed a single spit. A strong storm in 1931 opened Moriches Inlet and the "great hurricane" of 1938 opened Shinnecock Inlet and 11 other smaller inlets between Shinnecock and Moriches Inlets (Howard, 1939). All of these inlets subsequently closed naturally except Shinnecock and Moriches Inlets, which were stabilized by jetties in 1954. The east side of Fire Island Inlet was stabilized with a jetty in 1940.

[Back to the top of the page](#)

## MAPPING RESULTS

The sidescan-sonar imagery (Figs. 2a, 2b, and 2c) identifies a range of features and sea-floor environments in the study area, and provides insight into the processes controlling the distribution of sediments in the nearshore region (Schwab and others, 1999, 2000). Sedimentary deposits exposed on the inner-continental shelf off southern Long Island include Cretaceous-age coastal plain strata, Pleistocene glaciofluvial deposits, early Holocene estuarine deposits, and modern reworked sand deposits (Foster and others, 1999).

### Coastal Plain Strata

Approximately 6 km offshore of Watch Hill, a large outcrop of Cretaceous strata is visible on both the sidescan-sonar imagery (Fig. 3) and in subbottom profiles (Foster and others, 1999; Schwab and others 1999, 2000). Outcropping Upper Cretaceous to early Tertiary coastal-plain strata and associated lag deposits of gravel have been identified on the continental shelf throughout the New York Bight Apex (Williams and Duane, 1974; Williams, 1976; Williams and Meisburger, 1987). These outcropping strata are poorly lithified, and are displayed as complex areas of high backscatter on sidescan-sonar imagery (Schwab and others, 1997a, 1997b). Planar internal reflectors identify the Cretaceous strata on subbottom profiles and show that these strata dip and thicken to the southeast along the entire length of Long Island (Williams 1976).

The outcropping Cretaceous strata offshore of Watch Hill are probably composed of interbedded marine deposits of clay, silt, and sand corresponding to the Monmouth Group (Williams, 1976; Smolensky and others, 1989; Foster and others, 1999; Schwab and others, 1999, 2000). Here, we interpret a series of northeast-trending, high-backscatter lineations on the sidescan-sonar imagery (Fig. 3) to be an expression of differential erosion of bedding planes in the Cretaceous strata that strike northeast and dip to the southeast. A regional unconformity is visible in subbottom profiles throughout the study area, where the upper Cretaceous to early Tertiary strata are buried by a veneer of poorly to moderately sorted coarse sandy Quaternary sediment (Williams, 1976; Schwab and others 1997a, 1997b, 1999, 2000; Foster and others, 1999). Surface sediment samples from the area of the



outcrop have mean grain sizes ranging from 0.00-0.70 phi (1.00-0.62 mm) and standard deviation of about 0.9-1.2 (Fig. 4). At the seaward limit of the study area, the outcropping Cretaceous strata (Fig. 3) form a terrace which stands 3 to 4 m above the adjacent sea floor to the east (Fig. 2a). Areas of high-backscatter on the sidescan-sonar imagery along the east flank of this terrace are interpreted to be coarse-grained sand and gravel lag deposits (Fig. 4). The lag formed from erosion of the Cretaceous strata and overlying Pleistocene outwash deposits during the marine transgression and continued reworking by modern oceanographic processes (Schwab and others, 1999; 2000).

The relatively flat regional unconformity that defines the upper surface of the Cretaceous strata deepens slightly toward the eastern end of the study area (Foster and others, 1999). Thus, throughout the remainder of the study area, the Cretaceous strata are buried by a blanket of Quaternary sediment which, on average, increases in thickness from about 15 m offshore of Fire Island Inlet to about 34 m offshore of Montauk Point (Foster and others, 1999).

### **Pleistocene and Early Holocene Sediments**

Williams (1976) indicated that a seismic reflector defines where Upper Cretaceous coastal-plain strata are unconformably overlain by Pleistocene sediments south of Long Island, with no preservation of Tertiary sedimentary units. Using well-log data, this reflector has also been identified as a contact between Upper Cretaceous and Pleistocene sediment under the adjacent areas of Long Island (Suter and others, 1949; Smolensky and others, 1989). Offshore, the upper surface of the Pleistocene sedimentary deposit is cut by numerous paleochannels, which were subsequently filled with a transgressive sequence composed of reworked Pleistocene glaciofluvial gravelly deposits and early Holocene estuarine deposits (U.S. Army Corps of Engineers, unpublished data; Schwab and others, 1999, 2000). Where exposed at the sea floor (Fig. 5), these early Holocene, channel-fill, estuarine sediments have mean grain sizes that are typically finer than 2.0 phi (<0.25 mm) and a standard deviation greater than 1.0 (Fig. 4). Vibracores (U.S. Army Corps of Engineers, unpublished data) and surface grab samples (Fig. 4; Table 1) collected outside these paleochannels suggest that much of the upper few meters of the Pleistocene glaciofluvial deposit is composed of fine-grained sand to gravel; sediments coarser typically than 2 phi.

Pleistocene glaciofluvial deposits are exposed on the inner-continental shelf or buried by a veneer (< 1 m) of reworked modern fine sand over much of the study area. Where Pleistocene sediment is being reworked at the sea floor, such as in the troughs between the modern, shoreface-attached sand ridges west of Watch Hill, sidescan-sonar imagery show numerous high-backscatter lineations oriented at approximately 60° oblique to the shoreline (Figs. 6a and 7). Multibeam bathymetry data reveal that these lineations are located in the troughs of long-crested bedforms typically less than 1 m high (Fig. 6b). We suspect that these bedforms are caused by long-term erosion of the inner-continental shelf, where the Pleistocene and early Holocene sediments are being reworked. The relatively low-backscatter, fine- to medium-grained sand component is being transported generally along-shore to the west, leaving behind a medium- to coarse-grained, winnowed lag deposit, which causes the high backscatter lineations on the sidescan-sonar imagery. Sediment grab samples show that these areas of relatively high backscatter correlate to areas of poorly to very poorly sorted medium- to very coarse-grained sand and gravel; mean grain sizes are commonly coarser than 1.0 phi (> 0.50 mm) and standard deviation greater than 1.0 (Fig. 4).

In the area between Napeague and Southampton, sidescan-sonar (Fig. 2a) and multibeam data (Fig. 8) collected where Pleistocene sediments are exposed on the sea floor, reveal a different morphology. Here, this exposure of glaciofluvial sediment, proximal to the Ronkonkoma Moraine, has been eroded into a series of shore-perpendicular sand waves with a wavelength of about 700 m and a height of about 1 m.

### **Modern Sediments**

The Holocene sedimentary deposits contain a relict and modern component. Early Holocene estuarine sediment fills the paleochannels that are cut into the surface of the Pleistocene sedimentary deposits. These sediments represent a relict phase of deposition prior to marine transgression. Modern sediment lies unconformably atop the Pleistocene glaciofluvial and early Holocene estuarine deposits (Foster and others, 1999; Schwab and others, 1999, 2000). This unconformity has been interpreted to be the



Holocene ravinement surface (Schwab and others, 1999, 2000). Note that the term "modern sediment" is used in a descriptive sense here, meaning a sedimentary deposit that lies above the time-transgressive Holocene ravinement surface. Where of sufficient thickness, the modern sedimentary deposit is organized into a series of sand ridges and are visible as areas of low backscatter on sidescan-sonar imagery (Fig. 9) and multibeam data (Fig. 6a).

West of the Watch Hill area, the modern sand ridges are oriented at angles of 30°-40° to the shoreline, opening to the east (Fig. 9). These sand ridges are attached, or in close proximity to, a well-developed nearshore bar system found off Fire Island in water depths less than 8 m (Allen and Psuty, 1987). The shoreface-attached sand ridges appear as areas of relatively low backscatter on the sidescan-sonar imagery; slightly coarser grained, higher backscatter Pleistocene sediment is exposed on the troughs between the sand ridges (Fig. 6a). This field of sand ridges extends from the shoreward limit of the study area to about 20 km offshore (Duane and others, 1972).

The ridges are up to 5 m thick immediately west of the outcropping Cretaceous strata off Watch Hill (Foster and others, 1999). They become progressively thinner farther westward and are less than 1 m thick off Fire Island Inlet. Surface samples (Fig. 4, Table 1) and vibracores (U.S. Army Corps of Engineers, unpublished data) show that these ridges are composed of very well to moderately sorted, medium- to very fine-grained sand. Mean grain sizes range from approximately 1.0-3.5 phi (0.50-0.09 mm); standard deviations range from about 0.34-0.91 (Fig. 4, and Table 1).

Two additional sets of modern sand ridges, also oriented at angles of 30°-40° to the shoreline, are located east of Watch Hill (Fig. 9), however these ridges are located seaward of the 18-m isobath and thus are not attached to the shoreface. Both sets, one off Shinnecock Inlet and the other south of Montauk Point, reach a maximum of 3 m and thin to the west. Finally, a modern shoal up to 12 m thick exists southeast of Montauk Point (Fig. 9). Surface samples show that both sets of sand ridges and the shoal are texturally similar to the sand ridges west of Watch Hill; mean grain sizes range from about 0.4-3.0 phi (0.76-0.13 mm) and standard deviation from about 0.5-0.9 (Fig. 4, Table 1).

[Back to the top of the page](#)

---

## DISCUSSION

In most areas, a practical understanding of sediment transport from just seaward of the surf zone to inner-shelf depths is rudimentary at best (e.g., Nittrouer and Wright, 1994). Although shore-parallel sediment transport in the littoral zone is widely accepted to be a primary factor controlling coastal behavior, the importance of cross-shelf sediment flux is poorly understood. Interpretation of our mapping investigation of the nearshore region offshore of southern Long Island links the evolution of the Fire Island barrier-island system to the geologic framework of the adjacent inner-continental shelf (Schwab and others, 1999, 2000). The physiography of the upper surface of the Cretaceous strata exerts a primary control on the modern sea floor (Foster and others, 1999; Schwab and others, 1999, 2000). Outcropping Cretaceous strata off Watch Hill form the core of a local bathymetric high (Figs. 2a and 3). We conclude that the outcropping Cretaceous strata offshore of Watch Hill and the deposit of Pleistocene sediment shoreward of this outcrop (Foster and others, 1999) were the core of a subaerial headland during the Holocene marine transgression and may continue to influence sediment deposition as a submerged headland. We infer that erosion of this headland during transgression provided the sediment that has since been reworked by oceanographic processes (e.g., Duane and others, 1972; Swift and Field, 1981; Swift and others, 1984; Trowbridge, 1995; Calvete and others, 1999) into a field of sand ridges west of Watch Hill (Schwab and others, 1999, 2000) (Fig. 9). The fact that these ridges thin progressively to the west (farther downdrift from the headland source area) further supports our hypothesis that the inner-continental shelf off Watch Hill was (and is) an eroding headland.

The oldest (~750-1300 yr) and most stable part of the barrier-island system is located approximately between Watch Hill and Point 'O Woods (Leatherman and Allen, 1985), shoreward of the outcropping Cretaceous strata and the thickest modern sand ridges (Fig. 9). Although the physical processes controlling cross-shelf sediment flux remain elusive, we conclude that an onshore sediment flux from the sand ridges west of Watch Hill provided, and likely continues to provide, enough sediment to the downdrift beaches west of Watch Hill to maintain island stability.



A number of sediment budgets have been developed for the southern shore of Long Island, from Montauk Point to Fire Island Inlet (U.S. Army Corps of Engineers, 1958; Taney, 1961a, 1961b; Panuzio, 1968; RPI, 1985; Kana, 1995; Rosati and others, 1999). Longshore sediment transport to the west along southern Long Island is initiated at Montauk Point. Estimates of longshore transport range from 58,000-76,500 m<sup>3</sup>yr<sup>-1</sup> 8 km west of Montauk Point, from 219,000-233,000 m<sup>3</sup>yr<sup>-1</sup> past Shinnecock Inlet, and from 45,000-230,000 m<sup>3</sup>yr<sup>-1</sup> past Moriches Inlet (Taney, 1961a, 1961b; RPI, 1983; Kana, 1995). In comparison, at the downdrift end of the study area at Democrat Point, longshore sediment transport rates have been estimated to average between 306,000-467,000 m<sup>3</sup>yr<sup>-1</sup> (Taney, 1961a, 1961b; RPI, 1983; Kana, 1995). In fact, Democrat Point accreted westward approximately 8 km between 1825 and 1940 or about 64 m yr<sup>-1</sup> (U.S. Army Corps of Engineers, 1958; Kumar and Sanders, 1974). The estimated sediment budgets suggest a significant volume of sediment must be added to the system between Moriches Inlet and Democrat Point. The nature of this "deficit" in the sediment budget has been a topic of speculation for some time (Saville, 1960; Taney, 1961a, 1961b; Panuzio, 1968; Williams, 1976; Ash, 1979; McCormick and Toscano, 1981; Leatherman, 1985; Williams and Meisburger, 1987; Kana, 1995; Rosati and others, 1999). Most studies suggest that an offshore source of sediment accounts for the additional sediment. Results of our mapping efforts support previous suggestions that the deficit in the sediment budget must be accounted for from offshore sources (Schwab and others, 1999, 2000), in that, our hypothesized onshore sediment flux from the sand ridges west of Watch Hill must introduce sufficient sediment into the littoral system for spit growth.

Reworked modern sedimentary deposits are absent or extremely thin on much of the inner shelf landward of the 18-m isobath between Watch Hill and Southampton (Fig. 9). The barrier-island system adjacent to this segment of the inner-continental shelf has been migrating rapidly but intermittently landward due to the creation of inlets and subsequent bayside accretion at 50-75 yr intervals (Leatherman and Allen, 1985). For example, the barrier-island in the vicinity of Moriches Inlet has migrated half of its 300-m width since 1970. In comparison, there have been no inlet breaches west of Watch Hill in historic time; the barrier island has essentially been drowned slowly in place and aggrading vertically (Leatherman and Allen, 1985). We attribute the fact that the barrier-island segment east of Watch Hill is migrating landward at a faster rate than the western segment due to a relatively smaller sediment supply on the inner-continental shelf east of Watch Hill.

The hypothesis of onshore sediment transport identifies the modern sedimentary deposits (components reworked from underlying Quaternary and Cretaceous material) as the more mobile sediment in this nearshore environment (Fig. 4). This contrasts with the coarser grained lag deposits derived from erosion of Pleistocene sediments and Cretaceous strata and the cohesive early Holocene estuarine channel-fill deposits. Areas on the inner-continental shelf where these Pleistocene and early Holocene channel-fill deposits (or Cretaceous strata) are exposed (Fig. 5), such as the nearshore segment of the inner shelf between Watch Hill and Montauk Point, were formed as a result of the active formation and modification of a ravinement surface. Some surficial sediment mapped as outcropping Pleistocene or Holocene channel-fill deposits on Figure 9 is texturally similar to the mobile sediment (Fig. 4) and may therefore be incorrectly classified; it is also likely mobile and therefore part of the modern sediment deposit blanketing parts of the inner shelf. This uncertainty in distinguishing a veneer of modern sediment from the exposed Pleistocene fluvio-glacial or Holocene channel-fill deposits is due to the resolution limits of the subbottom profiles, which preclude the mapping of modern sediment deposits that are less than 0.5 m thick (Foster and others, 1999). Shore-oblique sand ridges were mapped east of Watch Hill, approximately between Moriches Inlet and Southampton and between Napeague and Montauk Point in water depths greater than about 18 m (Fig. 9). We suspect that these sand ridges, interpreted as modern sedimentary deposits, were initially attached to a shoreface of similar configuration to those present west of Watch Hill. They were subsequently stranded due to late Holocene marine transgression, as indicated in the model of sand-ridge evolution presented by Swift and Field (1981) and Swift and others (1984). This interpretation requires the existence of a paleo-shoreline located at approximately the 18-m isobath (Schwab and others, 1999, 2000).

Although the shoreface-connected sand ridges off western Fire Island are thought to have evolved from erosion of an emergent headland off Watch Hill, it is not clear where the sediment that formed the sand ridges off Shinnecock Bay or off Montauk Point originated. There are no indications that a headland existed updrift, as is the case for the sand ridges west of Watch Hill. Mapping results show that sediment presently eroded from the headland area east of Southampton remains in the littoral



zone; there is no or little modern sediment on the inner shelf in water depths less than 18 m (Fig.9). Since the rate of eustatic sea-level rise was greater during the early Holocene than the late Holocene (Milliman and Emery 1968; Fairbanks 1989), it is reasonable to speculate that erosion rates of the headland area east of Southampton were higher during the early Holocene, thus introducing more sediment onto the inner-continental shelf which was subsequently reworked into sand ridges that are now detached from the shoreface.

[Back to the top of the page](#)

---

## CONCLUSIONS

The late Holocene evolution of the Fire Island barrier-island is linked directly to the geologic framework of the inner-continental shelf. Mapping results show that the modern physiography of the inner-continental shelf off southern Long Island is an expression of antecedent geology and glacial history, as well as oceanographic processes acting on the sea floor during Holocene marine transgression. The upper surface of the Cretaceous strata provided the foundation for deposition of Quaternary sediment and formed the core of a subaerial headland off Watch Hill during times of lower sea level. The modern sediment deposit was formed from erosion of both the headland areas east of Southampton and off Watch Hill and the inner-continental shelf during Holocene marine transgression. A net onshore component of sediment flux of this modern sediment deposit from the inner shelf to the littoral zone appears to have significantly affected the evolution of the Fire Island barrier-island system.

There is a larger modern sediment supply on the inner-continental shelf west of Watch Hill. This sediment supply fed the formation of a field of shoreface-attached sand ridges. Onshore sediment flux from the inner-continental shelf increased the sediment volume available to maintain island stability between Watch Hill and Point O' Woods and for spit growth west of Point O' Woods. In contrast, east of Watch Hill, there is no Cretaceous strata or significant modern sedimentary deposit on the inner-continental shelf in depths shallower than about 18 m. Therefore, the only inner-shelf, sandy sediment available to supply the eastern beaches is the relatively coarser grained, less mobile Pleistocene glaciofluvial and Holocene channel-fill material. As a result, the barrier islands east of Watch Hill are transgressive, and have been more susceptible to inlet breaching.

[Back to the top of the page](#)



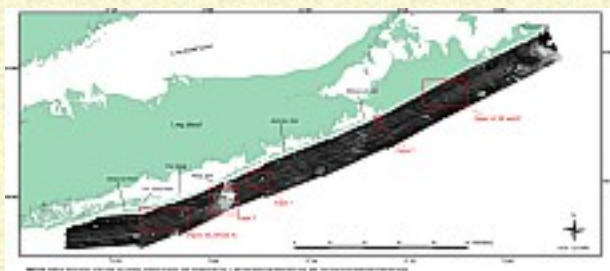
## FIGURES/MAPS



**Figure 1.** Location figure showing the study area and location of late Pleistocene terminal moraines on Long Island, NY.



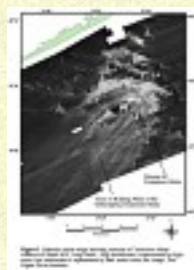
**Figure 2a.** Sidescan-Sonar mosaic of the study area, overlain with 2 meter bathymetric contours (See Figure 1 for location). Light tones depict high backscatter, dark tones areas of low backscatter within the imagery.



**Figure 2b.** Sidescan-Sonar mosaic of the study area, showing locations of figures used throughout the text. Light tones depict high backscatter areas, dark tones areas of low backscatter within the image.



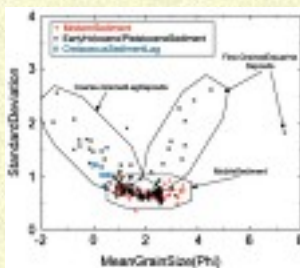
**Figure 2c.** Sidescan-Sonar mosaic showing location of sediment grab samples collected within the study area. Light tones depict areas of high backscatter, dark tones areas of low backscatter within the image. See Table 1 for sediment texture data.



**Figure 3.** Sidescan-sonar image showing outcrop of Cretaceous Strata offshore of Watch Hill, Long Island. High backscatter is represented by light tones, low backscatter is represented by dark tones within the image. See Figure 2b for location.



**Figure 4.** Sediment textural data from surface grab samples displayed on Figure 2c (see Table 1 for additional textural data). Samples are divided into three facies based on the sea-floor sediment distribution derived from seismic profiles (Foster and others, 1999). These facies are: a) Modern sediment (red crosses) - sediment reworked from early Holocene estuarine sediment, Pleistocene glaciofluvial sediment, and Cretaceous Coastal Plain Strata; b) Early Holocene/Pleistocene sediment (black crosses) - samples collected from areas where Pleistocene glaciofluvial or early Holocene estuarine sediment outcrop; c) Cretaceous sediment lag (blue circles)- sediment reworked in the area of outcropping Cretaceous Coastal Plain Strata off Watch Hill, Long Island (see Figure 3). The sediments are further divided by textural characteristics into: a) coarse-grained lag deposits of Pleistocene sediment and Cretaceous strata; b) Fine-grained early Holocene estuarine sediment; and c) The most mobile sediment based on the textural characteristics of the modern sediment distribution.



**Figure 5.** Sidescan-sonar image showing filled paleochannels exposed on the seafloor. These paleochannels are cut into the Pleistocene sedimentary deposit and filled with an early Holocene transgressive sequence. High backscatter is represented by light tones, low backscatter is represented by dark tones within the image. See Figure 2b for location.

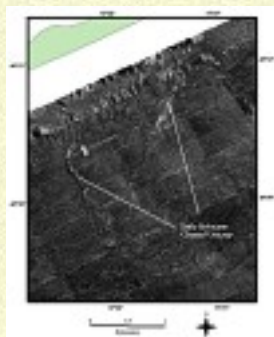
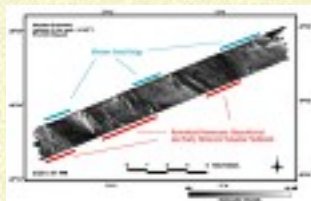


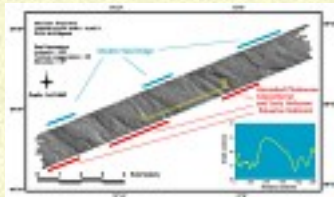
Table 1. Sediment grab samples collected off of the southern Long Island shore.

Station	Depth (m)	Sample ID	Depth (m)	Sample ID	Depth (m)	Sample ID
1	10	10-10	11	11-11	12	12-12
1	20	10-20	11	11-20	12	12-20
1	30	10-30	11	11-30	12	12-30
1	40	10-40	11	11-40	12	12-40
1	50	10-50	11	11-50	12	12-50
1	60	10-60	11	11-60	12	12-60
1	70	10-70	11	11-70	12	12-70
1	80	10-80	11	11-80	12	12-80
1	90	10-90	11	11-90	12	12-90
1	100	10-100	11	11-100	12	12-100
1	110	10-110	11	11-110	12	12-110
1	120	10-120	11	11-120	12	12-120
1	130	10-130	11	11-130	12	12-130
1	140	10-140	11	11-140	12	12-140
1	150	10-150	11	11-150	12	12-150
1	160	10-160	11	11-160	12	12-160
1	170	10-170	11	11-170	12	12-170
1	180	10-180	11	11-180	12	12-180
1	190	10-190	11	11-190	12	12-190
1	200	10-200	11	11-200	12	12-200
1	210	10-210	11	11-210	12	12-210
1	220	10-220	11	11-220	12	12-220
1	230	10-230	11	11-230	12	12-230
1	240	10-240	11	11-240	12	12-240
1	250	10-250	11	11-250	12	12-250
1	260	10-260	11	11-260	12	12-260
1	270	10-270	11	11-270	12	12-270
1	280	10-280	11	11-280	12	12-280
1	290	10-290	11	11-290	12	12-290
1	300	10-300	11	11-300	12	12-300
1	310	10-310	11	11-310	12	12-310
1	320	10-320	11	11-320	12	12-320
1	330	10-330	11	11-330	12	12-330
1	340	10-340	11	11-340	12	12-340
1	350	10-350	11	11-350	12	12-350
1	360	10-360	11	11-360	12	12-360
1	370	10-370	11	11-370	12	12-370
1	380	10-380	11	11-380	12	12-380
1	390	10-390	11	11-390	12	12-390
1	400	10-400	11	11-400	12	12-400
1	410	10-410	11	11-410	12	12-410
1	420	10-420	11	11-420	12	12-420
1	430	10-430	11	11-430	12	12-430
1	440	10-440	11	11-440	12	12-440
1	450	10-450	11	11-450	12	12-450
1	460	10-460	11	11-460	12	12-460
1	470	10-470	11	11-470	12	12-470
1	480	10-480	11	11-480	12	12-480
1	490	10-490	11	11-490	12	12-490
1	500	10-500	11	11-500	12	12-500
1	510	10-510	11	11-510	12	12-510
1	520	10-520	11	11-520	12	12-520
1	530	10-530	11	11-530	12	12-530
1	540	10-540	11	11-540	12	12-540
1	550	10-550	11	11-550	12	12-550
1	560	10-560	11	11-560	12	12-560
1	570	10-570	11	11-570	12	12-570
1	580	10-580	11	11-580	12	12-580
1	590	10-590	11	11-590	12	12-590
1	600	10-600	11	11-600	12	12-600
1	610	10-610	11	11-610	12	12-610
1	620	10-620	11	11-620	12	12-620
1	630	10-630	11	11-630	12	12-630
1	640	10-640	11	11-640	12	12-640
1	650	10-650	11	11-650	12	12-650
1	660	10-660	11	11-660	12	12-660
1	670	10-670	11	11-670	12	12-670
1	680	10-680	11	11-680	12	12-680
1	690	10-690	11	11-690	12	12-690
1	700	10-700	11	11-700	12	12-700
1	710	10-710	11	11-710	12	12-710
1	720	10-720	11	11-720	12	12-720
1	730	10-730	11	11-730	12	12-730
1	740	10-740	11	11-740	12	12-740
1	750	10-750	11	11-750	12	12-750
1	760	10-760	11	11-760	12	12-760
1	770	10-770	11	11-770	12	12-770
1	780	10-780	11	11-780	12	12-780
1	790	10-790	11	11-790	12	12-790
1	800	10-800	11	11-800	12	12-800
1	810	10-810	11	11-810	12	12-810
1	820	10-820	11	11-820	12	12-820
1	830	10-830	11	11-830	12	12-830
1	840	10-840	11	11-840	12	12-840
1	850	10-850	11	11-850	12	12-850
1	860	10-860	11	11-860	12	12-860
1	870	10-870	11	11-870	12	12-870
1	880	10-880	11	11-880	12	12-880
1	890	10-890	11	11-890	12	12-890
1	900	10-900	11	11-900	12	12-900
1	910	10-910	11	11-910	12	12-910
1	920	10-920	11	11-920	12	12-920
1	930	10-930	11	11-930	12	12-930
1	940	10-940	11	11-940	12	12-940
1	950	10-950	11	11-950	12	12-950
1	960	10-960	11	11-960	12	12-960
1	970	10-970	11	11-970	12	12-970
1	980	10-980	11	11-980	12	12-980
1	990	10-990	11	11-990	12	12-990
1	1000	10-1000	11	11-1000	12	12-1000

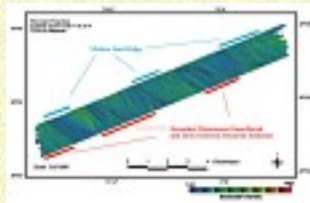
**Figure 6a.** Simrad EM 1000 Echo Sounder backscatter image of the shoreface-attached sand ridges west of Watch Hill. Light tones depict areas of high backscatter, dark tones areas of low backscatter within the image. See Figure 2b for location.



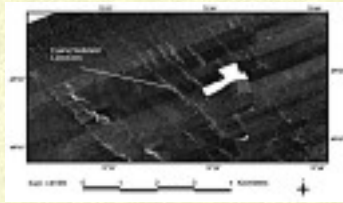
**Figure 6b.** Simrad EM 1000 Echo Sounder shaded relief image of the shoreface-attached sand ridges west of Watch Hill. Bathymetric profile from A to B is displayed in the insert. See Figure 2b for location.



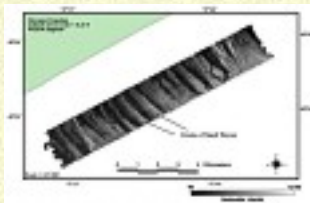




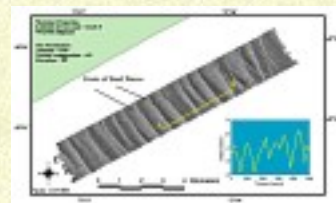
**Figure 6c.** Simrad EM 1000 Echo Sounder pseudo-color backscatter image of the shoreface-attached sand ridges west of Watch Hill. See Figure 2b for location.



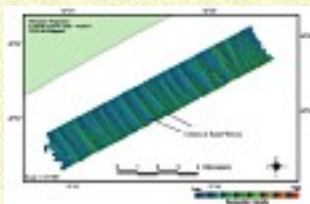
**Figure 7.** Sidescan-sonar mosaic of the high-backscatter lineaments east of Watch Hill formed by reworking of Pleistocene glaciofluvial and early Holocene estuarine sedimentary deposits exposed at the sea floor. Light tones depict areas of high backscatter, dark tones areas of low backscatter within the image. See Figure 2b for location.



**Figure 8a.** Simrad EM 1000 Echo Sounder backscatter image of the sand waves offshore of eastern Long Island. Light tones depict areas of high backscatter, dark tones areas of low backscatter. See Figure 2b for location.



**Figure 8b.** Simrad EM 1000 Echo Sounder shaded relief image of the sand waves offshore of eastern Long Island. Bathymetric profile from A to B is displayed in the insert. See Figure 2b for location.



**Figure 8c.** Simrad EM 1000 Echo Sounder pseudo-color backscatter image of the sand waves offshore of eastern Long Island. See Figure 2b for location.



**Figure 9(a).** Map showing the thickness, in meters of the modern sedimentary deposit based on interpretation of seismic reflection profiles (Foster and others, 1999). Cretaceous Coastal Plain Strata and associated lag deposits, Pleistocene glaciofluvial deposits, and early Holocene estuarine deposits are exposed on (or are close to) the sea floor in areas devoid of this modern sedimentary deposit. Arrows denote landward migration of the barrier island system east of Watch Hill, and west of Fire Island Inlet. The barrier island system between Watch Hill and Fire Island Inlet represents the oldest, most stable part of the system, and has experienced in place submergence over the past ~1000yrs.





**Figure 9(b).** Interpretive geologic map of the surficial sediment off of the southern Long Island coast, showing coastal plain strata, Pleistocene glaciofluvial and early Holocene estuarine deposits, and modern sediments.

---

[Back to the top of the page](#)





[Title Page](#)

[Report](#)

[Figures/Maps](#)

[Acknowledgements](#)

[References](#)

## ACKNOWLEDGEMENTS

We thank the captains and crews of the Research Vessel DIANE G and the Canadian Coast Guard vessel CREED for their skill and cooperation at sea. Technical support at sea was provided by Thomas O'Brien, David Nichols, Kenneth Parolski, David Foster, VeeAnn Cross, Chris Polloni, and Barry Irwin. This study was supported, in part, by the U.S. Army Corps of Engineers, New York District. We appreciate the assistance of Mr. Steven Couch of the New York District. Larry Poppe and Uri ten Brink provided helpful reviews of the manuscript. Any use of trade names or company names does not imply endorsement by the U.S. Geological Survey.

---

derived from Schwab, W.C., Thieler, E.R.,  
Denny, J.F., Danforth, W.W. 2000. Seafloor  
Sediment Distribution Off Southern Long Island,  
New York: U.S. Geological Survey Open-File  
Report 00-243

---



## REFERENCES

- Allen, J.R., and Psuty, N.P., 1987, Morphodynamics of a single-barred beach with a rip channel, Fire Island, NY: Proceedings of Coastal Sediments '87, American Society of Civil Engineers Press, p. 1964-1975.
- Ash, D.W., 1979, Geomorphology and littoral processes between Jones Beach and Montauk Point, Long Island, New York: Unpublished Ph.D Dissertation, Binghamton, New York, State University of New York at Binghamton, 190 p.
- Calvette, D., Falques, A., De Swart, H.E., and Dodd, N., 1999, Non-linear modelling of shoreface-connected sand ridges, in Kraus, N.C., and McDougal, W.G., eds., Coastal Sediments '99: v. 2, p. 1123-1138.
- Danforth, W.W., 1997, Xsonar/ShowImage: A complete system for rapid sidescan-sonar processing and display: U.S. Geological Survey Open File Report 97-686, 77 p.
- Danforth, W.W., O'Brien, T.F., and Schwab, W.C., 1991, USGS image processing system: Near real-time mosaicking of high-resolution sidescan-sonar data: Sea Technology, January, p. 54-59.
- Davis, R.A., and Kuhn, B.J., 1985, Origin and development of Anclote Key, west-peninsula Florida: Marine Geology, v. 63, p. 153-171.
- Duane, D.B., Field, M.E., Meisburger, E.P., Swift, D.J.P., and Williams, S.J., 1972, Linear shoals on the Atlantic inner shelf, Florida to Long Island, in Swift, D.J.P., Duane, D.B., and Pilkey, O.H., eds., Shelf sediment transport: Dowden, Hutchinson, and Ross, p. 447-449.
- Evans, M.W., Hine, A.C., Belknap, D.F., and Davis, R.A., 1985, Bedrock controls on barrier island development: West-central Florida coast: Marine Geology, v. 63, p. 263-283.
- Fairbanks, R.G., 1989, A 17,000-year glacio-eustatic sea level record: Influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation: Nature, v. 342, p. 637-642.
- Foster, D.S., Swift, B.A., and Schwab, W.C., 1999, Stratigraphic framework maps of the nearshore area of southern Long Island from Fire Island to Montauk Point, New York: U.S. Geological Survey Open File Report 99-559, 3 Sheets, Scale 1:125,000).
- Howard, A.D., 1939, Hurricane modifications of the offshore bar of Long Island, New York: Geographic Review, v. 29, p. 400-415. Kana, T.W., 1995, A mesoscale sediment budget for Long Island, New York: Marine Geology, v. 126, p. 87-110.
- Kumar, N., and Sanders, J.E., 1974, Inlet sequence: A vertical succession of sedimentary structures and textures created by the lateral migration of tidal inlets: Sedimentology, v. 21, p. 491-532.



- Leatherman, S.P., 1985, Geomorphic and stratigraphic analysis of Fire Island, New York: *Marine Geology*, v. 63, p. 173-195. Leatherman, S.P., 1989, Role of inlets in geomorphic evolution of the south shore of barriers of Long Island, N.Y., USA: *Environmental Management*, v. 13, p. 109-115.
- Leatherman, S.P., and Allen, J.R., 1985, Geomorphic analysis of the south shore barriers of Long Island, New York: National Park Service, Boston, MA, Technical Report, 305 p.
- McCormick, C.L., and Toscano, M.A., 1981, Origin of the barrier system of Long Island, New York: *Northeastern Geology*, v. 3, p. 230-234.
- Milliman, J.D., and Emery, K.O., 1968, Sea-levels during the past 35,000 years: *Science*, v. 162, p. 1121-1123.
- Nittrouer, C.A., and Wright, L.D., 1994, Transport of particles across continental shelves: *Review of Geophysics*, v. 32, p. 85-113.
- Panuzio, F.L., 1968, The Atlantic coast of Long Island: Proceeding of the 11th Coastal Engineering Conference, American Society of Civil Engineers Press, p. 1222-1241.
- Paskevich, V., 1992, Digital mapping of side-scan sonar data with the Woods Hole Image Processing System software: U.S. Geological Survey Open File Report 92-536, 87 p.
- Poppe, L.J., Eliason, A.H., and Fredricks, J.J., 1985, APASA – An Automated Particle Size Analysis System: U.S. Geological Survey Circular 963, 7p.
- RPI, 1985, Fire Island Inlet to Montauk Point, Long Island, New York: Sediment budget analysis. Summary Report: U.S. Army Corps of Engineers, New York District, Res. Planning Inst., Columbia, SC, 85 p.
- Rosati, J.D., Gravens, M.B., Smith, W.G., 1999, Regional sediment budget for Fire Island to Montauk Point, New York, USA, in Kraus, N.C., and McDougal, W.G., eds., *Coastal Sediments '99*: v. 2, p. 802-817.
- Riggs, S.R., Cleary, W.J., and Snyder, S.W., 1995, Influence of inherited geologic framework on barrier shoreface morphology and dynamics: *Marine Geology*, v. 126, p. 213-243.
- Sanders, J.E., and Kumar, N., 1975, Evidence of shoreface retreat and in-place drowning during Holocene submergence of barriers: Continental shelf of Fire Island, N.Y.: *Geological Society of American Bulletin*, v. 86, p. 65-76.
- Saville, T., 1960, Sand transfer, beach control, and inlet improvements, Fire Inlet to Jones Beach, New York, in Johnson, J.W., ed., *Proceedings of the 7th Conference on Coastal Engineering*: American Society of Civil Engineers, v. 2, p. 785-807.
- Schwab, W.C., Corso, W., Allison, M.A., Buchholtz ten Brink, M., Lotto, L.L., Denny, J.F., Danforth, W.W., Foster, D.S., 1997a, Initial results of high-resolution sea-floor mapping offshore of the New York-New Jersey metropolitan area using sidescan-sonar: *Northeastern Geology and Environmental Sciences*, v. 19, p. 243-262.
- Schwab, W.C., Corso, W., Allison, M.A., Butman, B., Denny, J.F., Lotto, L.L., Danforth, W.W., Foster, D.S., O'Brien, T.F., Nichols, D., Irwin, B.J., and Parolski, K., 1997b, Mapping the sea floor geology offshore of the New York - New Jersey metropolitan area using sidescan-sonar: Preliminary report: U.S. Geological Survey Open-File Report 97-61, 3 sheets.
- Schwab, W.C., Thieler, E.R., Allen, J.R., Foster, D.S., Swift, B.A., and Denny, J.F., 2000,

Influence of inner-continental shelf geologic framework on the evolution and behavior of the barrier-island system between Fire Island Inlet and Shinnecock Inlet, Long Island, New York : *Journal of Coastal Research*, v. 16, no. 2, p. 408-422.

Schwab, W.C., Thieler, E.R., Allen, J.R., Foster, D.S., Swift, B.A., Denny, J.F., and Danforth, W.W., 1999, Geologic Mapping of the nearshore area offshore Fire Island, New York, in Kraus, N.C., and McDougal, W.G., eds., *Coastal Sediments '99*: vol. 2, p. 1552-1567.

Shepard, F.P., 1963, *Submarine Geology* (2nd ed.): Harper, New York, 557 p. Smolensky, D.A., Buston, H.T., and Shernoff, P.K., 1989, Hydrologic framework of Long Island, New York: U.S. Geological Survey Hydrologic Investigations Atlas, HA-709, scale 1:50,000, 3 sheets.

Stone, B.D., and Borns, H.W., 1986, Pleistocene glacial and interglacial stratigraphy of New England, Long Island and adjacent Georges Bank and Gulf of Maine, in Sibrava, V., Bowen, D.Q., and Richmond, G.M., eds., *Quaternary glaciations on the northern hemisphere*: Oxford: Pergamon Press, p. 35-52.

Suter, R., Delaguna, W., and Permuter, N.M., 1949, Mapping of geologic formations and aquifers of Long Island, New York: State of New York Department of Conservation Water Power and Control Commission, Bulletin GW-18, 212 p.

Swift D.J.P., and Field, M.E., 1981, Evolution of a classic sand ridge field: Maryland sector, North American inner shelf: *Sedimentology*, v. 28, p. 461-482.

Swift, D.J.P., McKinney, T.F., and Stahl, L., 1984, Recognition of transgressive and post-transgressive sand ridges on the New Jersey continental shelf: Discussion, in Tillman, R.W., and Siemers, C.T., eds., *Siliciclastic shelf sediments*: Society of Economic Paleontologists and Mineralogists Special Publication 34, p. 25-36.

Taney, N.E., 1961a, Geomorphology of the south shore of Long Island, New York: Technical Memorandum 128, U.S. Army Corps of Engineers, Beach Erosion Board, Washington, D.C., 97 p.

Taney, N.E., 1961b, Littoral materials of the south shore of Long Island, New York: Technical Memorandum 129, U.S. Army Corps of Engineers, Beach Erosion Board, Washington, D.C., 95 p.

Thieler, E.R., Brill, A.L., Hobbs, C.H., and Gammisch, R., 1995, Geology of the Wrightsville Beach, North Carolina shoreface: Implications for the concept of shoreface profile of equilibrium: *Marine Geology*, v. 126, p. 271-287.

Trowbridge, J.H., 1995, A mechanism for the formation and maintenance of shore-oblique sand ridges on storm-dominated shelves: *Journal of Geophysical Research*, v. 100, C8, p. 16071-16086.

U.S. Army Corps of Engineers, 1958, Atlantic Coast of Long Island New York (Fire Island to Montauk Point): U.S. Army Corps of Engineers, New York District, Cooperative Beach Erosion Control and Interim Hurricane Study, 75 p.

U.S. Army Corps of Engineers, 1993, Fire Island to Montauk Point, Long Island, New York, project reformulation: Initial management plan: U.S. Army Corps of Engineers, New York District, 132 p.

Williams, S.J., 1976, Geomorphology shallow subbottom structure and sediments of the Atlantic inner continental shelf off Long Island, New York: U.S. Army Corps of Engineers, CERC, Vicksburg, MI, Technical Paper No. 76-2, 123 p.

Williams, S.J., and Duane, D.B., 1974, Geomorphology and sediments of the inner New York



**Bight continental shelf: U.S. Army Corps of Engineers, CERC, Fort Belvoir, VI, TM-45, 74p.**

**Williams, S.J., and Meisburger, E.P., 1987, Sand sources for the transgressive barrier coast of Long Island, New York: Evidence for landward transport of shelf sediments: Proceedings of Coastal Sediments '87, New Orleans, American Society of Civil Engineers Press, p. 1517-1532.**

**[Back to the top of the page](#)**