FIRE ISLAND INLET TO MORICHES INLET

FIRE ISLAND STABILIZATION PROJECT

TECHNICAL SUPPORT DOCUMENT

EVALUATION OF A STABILIZATION PLAN FOR COASTAL STORM RISK MANAGEMENT

BORROW AREA APPENDIX

U.S. Army Corps of Engineers

May 2014

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 PROJECT LOCATION AND DESCRIPTION

The general study area is located along the south shore of Long Island, New York from Fire Island easterly to Moriches Inlet. The area lies within Suffolk County, New York and includes the Towns of Brookhaven and Islip. The terrain of the island is low lying and is subject to the effects of surge flooding and from barrier island overwash and overtopping. Beach erosion has narrowed the width of the barrier island, and impacted the natural dune system.

1.1 Geology

Long Island is part of the Atlantic and Gulf Coastal physiographic province which lies along the eastern border of the United States and lays at the southern boundary of the late Pleistocene glacial advance in the eastern part of North America (Taney, 1961). The Ronkonkoma and Roanoke Point moraine deposits (i.e., mounds of unstratified glacial drift chiefly consisting of boulders, gravel, sand and clay) characterize the topography along the northern side of Long Island, while a gentler southward dipping gradient on the outwash plains makes up much of the southern side of the island (Schwab et al., 1999).

Fire Island is the longest (30 miles in length) of a chain of low-relief, sandy (fine- to medium-grained sand) barrier islands enclosing shallow back-barrier bays (Schwab et al., 1999). Fire Island is bounded on the east by Moriches Inlet and on the west by Fire Island Inlet. Great South Bay and Moriches Bay are located on the leeward side of Fire Island. Fire Island was formed by a combination of spit extension (westward) and offshore bar development. Great South Bay and Moriches Bay have historically been intermittently connected to the ocean by tidal inlets. In the normal course of events, inlets would be cut through the barrier island during storms, migrate over time to the west, and eventually close by natural processes (Taney, 1961).

The principal geologic features of the inner continental shelf offshore of Fire Island are summarized by Schwab et al. (2013):

> *(1) a regional unconformity separating Cretaceous-age coastal plain strata from overlying Quaternary sediment; (2) a Pleistocene glaciofluvial sedimentary deposit exposed at the seafloor over much of the inner continental shelf at water depths between ~15 and ~32 m, the seaward limit of the study area; and (3) a series of Holocene sand ridges on the inner continental shelf W of Watch Hill extending across the study area.*

West of Watch Hill, the Holocene (modern) sedimentary deposit is organized into a series of shoreface-connected sand ridges oriented at angles of 30° to 40° to the coast (Schwab et al., 2013). Seismic reflection data collected in 1996 and 2011 by the USGS (Schwab et al. 2013) indicate that the thickness of the Holocene sediment thickness is between 1 and 6 meters. The thickness of the sand ridges is greatest (approximately 6 meters) offshore of central Fire Island and gradually thins to the west (approximately 1 meter thick offshore of Fire Island Inlet).

1.2 Geomorphology

The Fire Island to Montauk Point 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 beach segment is characterized by barrier islands fronting an estuary system consisting of three bays (Great South, Moriches and Shinnecock Bays) which are connected through narrow tidal waterways which are elements of the Long Island Intracoastal Waterway (ICW). Three inlets (Fire Island, Moriches and Shinnecock Inlets) connect to the Atlantic Ocean and separate the barrier segments. The barrier islands are generally less than 2,500 feet wide, and contain irregular sand dunes ranging in height to a maximum of about 30 feet. Dunes are characterized by ocean side slopes, which are generally steep, with vegetation sporadic along many segments due to frequent wave attack.

Barrier island overwashing occurring on Fire Island is indicative of low island elevations. Barrier island breaching may also occur when overwashing occurs in concert with a narrow island width, the presence of relatively deep water adjacent to the bay shore line of the island, and a limited supply of littoral material.

Geomorphology and Barrier Island Migration

Two differing theories have been advanced regarding barrier migration in the study area. Sanders and Kumar (1975) as well as Rampino and Sanders (1981) argue that an ancient barrier island system existed 8,500 to 9,000 years before present some 7 km (4.3 miles) offshore of the current barrier in a water depth of 24 m (79 feet). This ancient barrier island drowned in place during an accelerated period of sea level rise, skipped to a location 2 km (1.2 miles) from the present shoreline, and then eroded continuously over the past 7,000 years to its current position. Leatherman and Allen (1985), on the other hand, argue that the ancient barrier island migrated continuously to reach its present day position. Further, Leatherman and Allen (1985) argue that there are three mechanisms that facilitate barrier island migration: (1) overwash during storms, (2) wind, or aeolian transport, and (3) tidal inlet creation and subsequent closure by natural forces. They conclude that tidal inlet dynamics is the principal driver for Fire Island. Aeolian transport is insignificant. Overwash has served to increase the barriers vertically, but has resulted in minimal bayside area increases.

Over the past 2,000 years the evolution of Fire Island is best described by dividing the barrier island into three segments: an eastern segment east of Watch Hill, a central segment between Watch Hill and Point O'Woods, and a western segment west of Point O'Woods (Schwab et al, 2013). The evolution of these three segments is described by Schwab et al. (2013):

> *The eastern segment has migrated landward through inlet breaching, flood-tidal delta formation, and subsequent marsh accretion on the backbarrier side for the last few centuries (Leatherman and Allen, 1985). In contrast, over the past ~750-1,000 years, the central segment has been relatively stable (Leatherman, 1985; Leatherman and Allen, 1985; Rampino and Sanders, 1981). Geomorphic evidence and core data indicate that the western segment formed over the past 300–500 years as a prograding spit that was fed by westward alongshore sediment transport (Kumar and Sanders, 1974; Leatherman, 1985; Leatherman and Allen, 1985).*

2.0 BORROW AREA INVESTIGATION METHODOLOGY

The primary objective of the borrow area investigation was to identify and delineate sources of sand borrow material in the offshore waters of Long Island for use as design fill and beach nourishment material for the Fire Island Interim project, which proposes fill intermittently from Robert Moses State Park to Smith Point County Park, fronting approximately 12 miles of shoreline. The fill is primarily focused on the inhabited communities of Fire Island. Sediments were sought which were of suitable grain size, and present in sufficient volume, within a reasonable distance from the project shoreline.

2.1 Beach Sand Evaluation

Eroded beaches that are in need of nourishment are considered to have remnant sediments of a grain size distribution that is reasonably stable. Native beach sediments must be matched with similar grain size borrow area sediments so that beach replenishment can endure over a reasonable period of time by designing the improved beach based on existing beach equilibrium conditions. In order to determine this representative sediment, grain sizes were analyzed from native beach and compared to vibracore sample grain sizes.

Four beach models representing Great South Bay ocean beaches, and one representing Moriches Bay ocean beaches were developed by analyzing representative beach samples for 29 transects that were collected in 1995. These beach models were necessary to categorize and define the materials found along the shoreline segment extending from Fire Island Inlet to Moriches Inlet. The beach models developed had the results shown on Table 1 below. All borrow area core samples were compared to these beach models.

Table 1: Native Beach Sample Models

Beach Sample Models	Representative Profiles	Mean Grain Size Diameter phi units	Standard Deviation phi units	Mean Grain Size Diameter mm
GSB-D1	F1-F12	1.34	0.58	0.39
GSB-D2	F14-F35	1.33	0.64	0.4

GSB-D3	F36-F58	1.26	0.58	0.42
GSB-D4	F64-F68	1.25	0.68	0.42
MB-D1	F72-F79	1.25	0.68	0.42

2.2 Capability Investigations

To determine the suitability of sediments from the potential borrow sites, the core samples were classified according to the values of their nourishment factors, Rj and adjusted overfill factors, Ra. Ra and Rj are defined in Chapter 5 of the 1984 Shore Protection Manual (SPM).

The overfill factor predicts the amount of overdredge of a given borrow material which will be required to produce, after natural beach sorting, one cubic yard of beach material which will have a mean grain size similar to or coarser than the original native sediment. Losses due to the dredging process are in addition to these natural sorting losses. The more desirable Ra factors are those closest to 1.00. An Rj factor of 1.0 to 1.1 is considered as representing the most suitable material. An overdredge of 10 percent or less reduces the required sediment volume on the beach in order to result in the desired design cross section after beach readjustment. A Ra factor of 1.1 to 1.3 means that an overdredge of ten to thirty percent would be required to produce one cubic yard of adjusted beach material.

The nourishment factor is a measure of the stability of the placed borrow material relative to the native beach sand. The more desirable Rj factors are those closest to or less than 1.0. An Rj factor of 1.0 means the native and borrow sands are of equal stability, having very similar grain size distributions.

To determine the suitability of sediments from the potential borrow sites, the core samples were classified by the following criteria: suitable and unsuitable for beach nourishment, according to the values of their nourishment factors, Rj and adjusted overfill factors, Ra. The Ra and Rj ranges for these criteria are listed in Table 1.

Table 2: Sediment Suitability Criteria For Fire Island, New York

Ra	Classification	Rj
<1.3	Suitable	<1.1
>1.3	Unsuitable	>1.1

2.2.1 Vibracore Data Sets

The following vibracore data sets were used:

- 1975 (USACE, 1979)
- 1976 (Williams, 1976)
- 1979 (OSSI, 1983)
- 1995 (MNE and OSI, 1995)
- 1997 (collected for this study)
- 1998 (collected for this study)

2.2.2 Suitability Results

Twenty-seven vibracores were found to be suitable for the native beach models.

For the 1975 cores, 11 were found suitable (see Table 3); for the 1976 cores, 2 cores were found suitable (see Table 4); for the 1979 cores, 5 were found suitable (see Table 5); for the 1995 cores, 1 was found suitable (see Table 6); for the 1997 cores, 3 were found suitable (see Table 7); and for the 1998 cores, 5 were found suitable (see Table 8).

In summary, by model: GSB-D1 has no suitable cores; GSB-D2 has 5 suitable cores, GSB-D3 has 7 suitable cores, GSB-D4 has 4 suitable cores, and MB-D1 has 11 suitable cores.

Table 3: 1975 Core Suitability Results

Core #	Approx. Core Length (ft.)	Mean Diameter (phi)	Standard Deviation (phi)	Mean Diameter (mm)	Overfill Factor Ra	Renourishment Factor Rj	Native Beach Reach
CB-1	20	2.35	0.35	0.20			
CB-2	20	1.60	0.60	0.33			
CB-3	20	1.20	0.90	0.44			
CB-4	20	1.08	1.18	0.47			
CB-5	20	1.60	0.65	0.33			
CB-6	20	1.43	1.43	0.37			
CB-7	20	1.05	0.85	0.48			
CB-8	20	1.28	1.03	0.41			
CB-9	20	1.78	1.13	0.29			
CB-10	20	1.45	0.95	0.37			
CB-11	20	0.90	1.25	0.54	1.17	0.11	MB-D1
CB-12	20	0.85	0.55	0.55	1.02	0.52	MB-D1
CB-13	20	0.85	0.75	0.55	1.02	0.90	MB-D1
CB-14	20	1.23	0.93	0.43	1.17	0.46	MB-D1
CB-15	20	1.20	1.20	0.44	1.27	0.21	MB-D1
CB-16	20	1.15	0.85	0.45			
CB-17	20	1.40	0.70	0.38			
CB-18	20	1.15	0.90	0.45			
CB-19	20	1.40	0.80	0.38			
CB-20	20						
CB-21	20	1.48	0.73	0.36			
CB-22	20	1.33	0.83	0.40	1.16	0.68	MB-D1
CB-23	20	1.38	0.73	0.39	1.20	0.43	MB-D1
CB-24	20	1.30	1.00	0.41	1.23	0.43	MB-D1
CB-25	20	1.60	0.65	0.33			
CB-26	20	1.43	0.73	0.37			
CB-27	20	1.63	0.73	0.32			
CB-28	20	1.40	0.80	0.38			
CB-29	20						
CB-30	20	1.55	0.75	0.34			
CB-31	20	1.68	0.73	0.31			
CB-32	20	1.93	0.53	0.26			
CB-33	20	1.85	0.55	0.28			
CB-34	20	1.83	0.48	0.28			
CB-35	20	1.10	0.85	0.47			
CB-36	20	1.90	0.55	0.27			
CB-37	20	0.83	1.33	0.56	1.29	0.10	MB-D1
CB-38	20	1.20	1.70	0.44			
CB-39	20	1.35	1.30	0.39			
CB-40	20	1.05	1.05	0.48	1.22	0.33	MB-D1
CB-41	20	1.03	1.28	0.49			
CB-42	20	0.80	1.10	0.57			
CB-43	20	0.68	1.08	0.63	1.10	0.17	MB-D1
CB-44	20	1.88	0.83	0.27			
CB-45	20	2.08	0.58	0.24			
CB-46	20	1.88	0.58	0.27			
CB-47	20	1.85	0.90	0.28			
CB-48	20	2.10	0.65	0.23			
Note:	Cores CB-20 and 29 not collected.						

Table 4: 1976 Core Suitability Results

Core	Length of Core in ft	Mean Grain Size in mm	Significant Silt and/or Clay in Core Layers	Ra	Rj	Native Beach Model
ICONS 39	8	silt	Yes			
ICONS 61	6	0.26				
ICONS 62	4.8	0.37				
ICONS 63	6.5	0.36				
ICONS 64	5	0.31				
ICONS 65	5.8	0.14				
ICONS 66	2.7	0.28				
ICONS 67	17.2	0.41		1.19	0.88	GSB-D3
ICONS 68	6	0.23				
ICONS 69	17.3	0.21				
ICONS 70	12	0.20				
ICONS 71	8.4	0.49		1.02	0.70	GSB-D2
ICONS 72	5	0.17				
ICONS 110			Yes			
ICONS 111			Yes			
ICONS 112			Yes			
ICONS 113			Yes			
ICONS 114	11	0.31				

Table 5: 1979 Core Suitability Results

Core	Mean Grain Size in mm	Length of Core in ft	Overburden (overlying silts/clays) in ft	Ra	Rj	Beach Model
79-1-1	0.11	23	7			
79-1-3	0.18	22	7.5			
79-1-5	0.03	17	14			
79-1-6	0.22	22				
79-1-7	0.14	19	4			
79-1-8	0.04	16	16			
79-1-9	0.19	29	2.8			
79-1-10	0.37	7				
79-1-11	0.17	4.1				
79-1-12	0.36	11.8				
79-1-14	0.18	24				
79-2-1	0.42	9.5		1.08	0.87	GSB-D3
79-2-3	0.41	2.8				
79-2-4	0.65	14				
79-2-6	0.84	20	3			
79-2-7	0.08	21	7			
79-2-8	0.02	1.5	1.5			
79-2-9	0.72	11		1.02	0.15	GSB-D2
79-2-11	0.25	10				
79-2-12	0.52	5		1.02	0.52	GSB-D3
79-2-14	0.42	1.5				
79-2-15	0.11	4.1	4.1			
79-3-2	0.10	10	2.6			
79-3-4	0.05	12				
79-3-6	1.44	4				
79-3-7	1.27	6		1.10	0.00	GSB-D4
79-3-9	2.01	7		1.06	0.00	GSB-D4
79-3-10	0.04	14				
79-4-2	0.07	21				
79-4-4	0.03	29				
79-4-6	0.10	4				
79-4-8	0.38	10				
79-4-9	0.37	6				

Table 6: 1995 Core Suitability Results

Core	Mean Grain Size in mm	Length of Core in ft	Overburden (overlying silts/clays) in ft	Ra	Rj	Beach Model
FII 1	0.08	6.6	3.7			
FII 2	0.60	12.1		1.02	0.38	GSB-D2
FII 3	0.60	16.7	3.1			
FII 4	0.21	3.9				
FII 5	0.16	3.3	3.3			
FII 6	0.06	4.6				
FII 7	0.05	2.8				
FII 8	0.65	7.8				
FII 10	0.28	3				
FII 9	0.57	14				
FII 11	0.58	6.1				
FII 12	0.43	15	2			
FII 13	0.43	15	2.4			
FII 14	0.02	8.3				
FII 15	0.14	7.1				

Table 7: 1997 Core Suitability Results

Core ID	Mean Grain Size in mm	Length of Core in ft	Overburden (overlying silts/clays) in ft	Ra	Rj	Beach Model
97-1	0.33	13				
97-2	0.45	19.3		1.06	0.64	GSB-D2
97-3	0.38	18.6				
97-4	0.18	5.2	5.2			
97-5	0.49	4.3		1.08	0.80	GSB-D3
97-6	0.42	10.5	1.4	1.02	0.57	GSB-D2

Table 8: 1998 Core Suitability Results

Core ID	Mean Grain Size in mm	Length of Core in ft	Overburden (overlying silts/clays) in ft	Ra	Rj	Beach Model
VC98-1	0.35	7	2.4			
VC98-2	0.29	17.2				
VC98-3	0.45	5		1.23	0.93	GSB-D3
VC98-4	0.29	12				
VC98-5	0.44	10.1		1.28	0.26	GSB-D3
VC98-6	0.37	15		1.25	0.89	GSB-D3
VC98-7	0.87	7		1.04	0.07	GSB-D4
VC98-8	0.52	4.6		1.21	0.16	GSB-D4
VC98-9	0.31	13.8				
VC98-10	0.22	10				
VC98-38	0.20	19.9				
VC98-39	0.19	19.6				

3.0 BORROW AREA DELINEATIONS

Borrow areas containing material suitable for beach reconstruction were delineated surrounding the suitable cores and are shown in Figure 1 for western Fire Island West and in Figure 2 for eastern Fire Island, and are described below.

3.1 Individual Borrow Areas

BORROW AREA 1A

A box 2,000 ft by 2,000 ft (approximately 90 acres) was delineated surrounding suitable core 97-6, approximately 1 mile offshore of Saltaire. Investigation into seismic records in the future may yield more precise boundaries of the extent of sediment that the core represents. There is a fine layer possibly containing silts and clays in the uppermost 1.4 feet of the core, which makes this a mess than optimal borrow area. The top 9.1 feet of suitable material below this yields approximately 1,000,000 cy for placement in GSB-D2. The overfill factor for this 9.1 ft layer was 1.02. The approximate depth of Borrow Area 1A is -51 ft. NGVD. Figure 3 shows the core location and some of the geological feature delineations.

BORROW AREA 2A

A triangular delineation was developed surrounding suitable core 98-6, measuring 12,000 ft in the along shore direction, and 2,000 ft on the eastern side in the on-offshore direction (approximately 200 acres), located approximately ¾ of a mile offshore of Barrett Beach and Water Island. The shape follows a delineation of a Holocene deposit. The uppermost 15 feet have an overfill factor of 1.25 for GSB-D3, and yield a volume of approximately 3,000,000 cy. The approximately depth of this Borrow Area 2A is -45 ft. NGVD.

BORROW AREA 2B

A coffin-shaped delineation was developed surrounding cores ICONS-62, VC98-3 and 1979-2-12 (approximately 500 acres), measuring approximately 9,000 ft in the alongshore direction and 3,500 ft at its widest location. It is 1-1/2 miles offshore of Point O' Woods at its closest point. The limits follow a Holocene deposit. The top 5 feet has an overfill factor of 1.05 for GSB-D3, and has a volume of approximately 3,000,000 cy. The depth of Borrow Area 2B varies between -42 and -49 ft. NGVD. It is located approximately 1-1/2 miles offshore from Fire Island Pines.

BORROW AREA 2C

A semi-coffin-shaped delineation was created surrounding suitable cores 1979 core 2-09, 1995 core 2 and 1997 core 2 measuring 15,000 ft on its longest axis, and 7,000 ft on its shortest axis (approximately 500 acres). The uppermost 12.7 ft of material has an overfill factor of 1.03 for GSB-D2, and has a volume of approximately 9,000,000 cy. The depth Borrow Area 2C varies from -52 to -58 ft. NGVD. The southern portion of the borrow area follows a Holocene deposit.

BORROW AREA 2D

A triangular shaped delineation was developed surrounding suitable core VC98-5, measuring 6,000 ft alongshore and 2,500 ft on its longest side (approximately 200 acres). The shape follows a holocene deposit. The uppermost 10.1 feet has an overfill ratio of 1.28 for GSB-D3. The depth of Borrow Area 2D is approximately -48 ft. NGVD. The approximate volume available for GSB-D4 is approximately 2,000,000 cy. It is approximately 1-1/2 miles offshore of Water Island.

BORROW AREA 2F

A box 2,000 ft by 2,000 ft (approximately 90 acres) was delineated surrounding suitable core 1979-2-01, approximately 1 mile offshore of Barrett Beach. The overfill factor for this 9.1 ft layer was 1.04. The approximate depth of Borrow Area 2F is -42 ft. NGVD. A portion of this area has been dredged previously, which makes this a mess than optimal borrow area. The top 9.5 feet of suitable material yields approximately 1,000,000 cy for placement in GSB-D3. It is unknown how much of this volume remains in the borrow area.

BORROW AREA 2G

A box 2,000 ft by 2,000 ft (approximately 90 acres) was delineated surrounding suitable core 97-5, approximately 3 miles offshore of Water Island. Investigation into seismic records in the future may yield more precise boundaries of the extent of sediment that the core represents. The top 4.3 feet of suitable material yields approximately 500,000 cy for placement in GSB-D3. The overfill factor for this 4.3 ft layer was 1.04. The approximate depth of Borrow Area 2G is -74 ft. NGVD. The limited volume in this area makes it less than optimal for potential use.

BORROW AREA 2H

A box 2,000 ft by 2,000 ft (approximately 90 acres) was delineated surrounding suitable core ICONS-67, approximately 1-1/4 mile offshore of Davis Park. Half of this area is located on the Holocene deposit delineation. The top 17.2 feet of suitable material yields approximately 2,000,000 cy for placement in GSB-D3. The overfill factor for this 17.2 ft layer was 1.19. The approximate depth of Borrow Area 2H is -50 ft. NGVD.

BORROW AREA 2

Figure 4 shows the core locations within the borrow area and the geological feature delineations, which are used to determine the boundaries of the borrow area. Seismic data will be analyzed prior to dredging to refine the boundaries.

BORROW AREA 3A

A box 9,000 ft by 4,500 feet was delineated surrounding suitable cores 1979 3-07 and 3-09, and core VC98-7 (approximately 600 acres). It is located approximately 1 mile offshore, approximately 3 miles east of Davis Park. The uppermost 7 feet of this area has an overfill factor of 1.06 for GSB-D4 and yields approximately 5,000,000 cy. The approximate depth of the borrow area varies from -56 to -62 ft. NGVD.

BORROW AREA 3B

A box 2,000 ft by 2,000 ft (approximately 90 acres) was delineated surrounding suitable core VC98-8, approximately 1-1/2 mile offshore of Old Inlet. The top 4.6 feet is suitable material and yields approximately 500,000 cy for placement in GSB-D4. The overfill factor for this 4.6 ft layer was 1.21. The approximate depth of Borrow Area 3A is -65.4 ft. NGVD.

BORROW AREA 4A

Borrow Area 4A has been dredged and is no longer available.

BORROW AREA 4B

Borrow Area 4B has been dredged and is no longer available.

BORROW AREA 4C

A box 2,000 ft by 2,000 ft (approximately 90 acres) was delineated surrounding suitable core CB-40, approximately 3/4 mile offshore of Westhampton Beach. The top 7 feet of suitable material and yields approximately 700,000 cy for placement in MB-D1. The overfill factor for this 7 ft layer was 1.22. The approximate depth of Borrow Area 4C is -51 ft. NGVD.

BORROW AREA 5A, 5B, AND 5B EXPANDED

A semi-rectangular area 20,000 ft along shore on its longest side by 3,500 ft in its longest on-offshore dimension (approximately 1,000 acres) was delineated surrounding suitable cores CB-12, 13, 14, 15, 22, 23 and 24; 1979-5-01; VC98-18, 20, 21, 22, 23 and 24. The top 13 to 18 feet of suitable material has an overfill factor of 1.2 and yields approximately 20,000,000 cy for placement in MB-D1. The approximate depth of Borrow Area 5A is between -39 and -48 ft. NGVD. A small portion of this area has been dredged previously.

3.2 Summary of Available Quantities

In summary, Borrow Area 1A has 1,000,000 cy available for GSB-D2; 2A has 3,000,000 cy for GSB-D3; 2B has 3,000,000 cy for GSB-D3; 2C has 9,000,000 cy for GSB-D2; 2D has 2,000,000 cy for GSB-D4; 2F has 1,000,000 cy for GSB-D3; 2G has 500,000 cy for GSB-D3; 2H has 2,000,000 cy for GSB-D3; 3A has 5,000,000 cy for GSB-D4; 3B has 500,000 cy for GSB-D4; 4C has 700,000 for MB-D1; and 5A, 5B, and 5B Expanded has 20,000,000 for MB-D1, for a total of 47,700,000 cy as are shown in Table 9 below.

Table 9: Summary of Borrow Quantities

Borrow Area	Beach Model	Quantity in cy
1A	GSB-D2	1,000,000
2A	GSB-D3	3,000,000
2B	GSB-D3	3,000,000
2C	GSB-D2	9,000,000
2D	GSB-D4	2,000,000
2F	GSB-D3	1,000,000
2G	GSB-D3	500,000
2H	GSB-D3	2,000,000
3A	GSB-D4	5,000,000

3B	GSB-D4	500,000
4C	MB-D1	700,000
5A, 5B and 5B Expanded	MB-D1	20,000,000
SUBTOTAL		**47,700,000**

3.3 Borrow Quantity Distribution

Out of the five native beach models, no fill is compatible with GSB-D1; 10,000,000 cy is compatible with GSB-D2; 9,500,000 cy is compatible with GSB-D2; 7,500,000 cy with GSB-D4; and 20,700,000 cy with MB-D1 (shown on Table 10 below). Areas with insufficient compatible fill will be filled with not-as-compatible (i.e., Ra>1.3) fill from borrow areas identified as suitable for other models. For example, Borrow Areas 1A or 2C will be recommended for GSB-D1.

Table 10: Borrow Quantity Distribution

Location	Suitable Borrow Areas	Quantity of Sand in cy
GSB-D1	none	0
GSB-D2	1A and 2C	10,000,000
GSB-D3	2A, 2B, 2F, 2G and 2H	9,500,000
GSB-D4	2D, 3A and 3B	7,500,000
MB-D1	4C, 5A, 5B and 5B Expanded	20,700,000

4.0 AVOIDANCES

4.1 Cultural Resource Avoidances

A cultural resource investigation will be performed prior to the preparation of Plans and Specifications, which may result in location of potential submerged cultural resources. If this is the case, volumes of sand available for placement on the beach may be reduced due to avoidance of potential cultural resources.

4.2 Wave Attenuation Avoidances

Shoreline change modeling was performed utilizing wave conditions developed on the existing conditions bathymetry, and a post-dredge hypothetical bathymetry where the full dredged quantity is assumed to be excavated all at once. Bathymetric data for the numerical domain was acquired from the NOAA bathymetric database. Areas not covered by the NOAA database were defined using beach profile surveys collected in 1995 for this study. The post excavation bathymetry was estimated assuming a cutterhead dredge operation, which results in a fixed cutting depth, and 1V:37.5H final adjusted side slopes, over a 1.85 square mile area. RCPWAVE is the wave model utilized as input to the GENESIS shoreline change model to determine the shoreline changes. The results of the GENESIS modeling without project (without dredging and without fill placement) and with project (with dredging and with fill placement) future net longshore transport rates show decreased or stable net transport rate within 3 miles downdrift of Cherry Grove. This indicates that the dredged borrow depressions do not adversely impact the downdrift shoreline. As an added safety factor, borrow areas did not extend landward of -37 ft. NGVD.

Geological Framework Avoidances

The U.S. Geological Survey and this office entered into a cooperative agreement to map the offshore area from Fire Island Inlet to Montauk Point between the 8 and 20 meter contours. The data collected included vibracores (which comprised the 1997 and 1998 cores used above), side scan sonar, subbottom profiling, and surface sampling. The U.S.G.S. investigators concluded that the coastlines are influenced by the geological framework.

4.2.1 Literature Review of Onshore Sediment Movement on West Fire Island

A summary of a literature review about the hypothesis of onshore sediment transport from sand ridges offshore of Fire Island appears below.

- In 1961 (a and b) Taney proposed onshore sand transport as the source to balance the sediment transport deficit from Moriches Inlet to Fire Island Inlet.
- In 1972, Duane et al identified sand ridges offshore of Fire Island.
- In 1975, Kumar and Sanders proposed that west of Watch Hill the island was drowning in place.
- In 1976, Williams in "Geomorphology of Long Island" identified cretaceous strata on subbottom profiles.
- In 1977, Williams and Meisberger in "Sand Sources for the Transgressive Barrier Coast of Long Island" propose material migrating onshore from the Continental Shelf.
- In 1983, Kana suggested relic Fire Island Inlet shoals as the onshore source, though presently exhausted.
- In 1985, Leatherman proposed that inlet breaching provided the majority of sediment into the bays east of Watch Hill.
- In 1985, Leatherman and Allen connected frequent inlet breaching east of Watch Hill with landward island migration.
- In 1989, Leatherman identified historical inlet sites along the barrier island system east of Watch Hill.

- In 1999, Rosati et al acknowledged the possibility of onshore transport, although no transport to 160,000 cubic meters/year of onshore transport is still within the level of uncertainty of the data making up the balanced sediment budget. In other words, if no transport exists, the budget is balanced, and if 160,000 m3/year of onshore transport occurs, the budget is still balanced to the accuracy of the supporting data.
- Also in 1999, Schwab et al in “Geological Mapping of the Nearshore Area Offshore Fire Island” propose that the geologic framework influences the shoreline, and describe the side scan sonar, subbottom profiling, and surface sampling performed between 1997 and 1998 for the purpose of mapping the geologic framework. Approximately 6 km offshore of Watch Hill, a large outcrop of Cretaceous strata was proposed, and outside of Watch Hill, the outcrop is proposed to be buried by Quaternary sediments. And the field of sand waves oriented 30 to 40 degrees with respect to the shoreline were revealed in the data.
- Also in 1999, Foster et al proposed that the thickness of the sand ridges varies from 5 m immediately west of the outcrop, thinning to the west, to less than 1 m offshore of Fire Island Inlet.
- In 2000, Schwab et al in “Seafloor Sediment Distribution off Southern Long Island, New York” concluded that the ridges west of Watch Hill provide sediment to the shoreline west of Watch Hill, contributing to the island stability in that region (as opposed to the drowning-in-place shoreline east of Watch Hill).
- In 2008, Lentz, Hapke and Schwab in “Review of Sediment Budget Estimates at Fire Island National Seashore, New York” propose that removal of sediment from nearshore regions have the potential to alter wave refraction and diffraction patterns, and result in changes in the wave energy reaching the beach.
- In 2008, a two-day technical workshop on offshore sand resources south of Long Island was held at Stony Brook University’s School of Marine and Atmospheric Sciences. The workshop was intended to review what is known, or unknown about the volume of offshore sand reserves, the potential for onshore transport, and the character of offshore sand ridges. Workshop attendees included researchers from federal agencies, academia and the private sector as well as federal, state local agency representatives involved in coastal resource management. Bokuniewicz and Tanski summarize the workshop in, “White Paper: Long Island Offshore Sediment Resources”. (provided as a sub-appendix). Some of the workshop recommendations include the following:
    - Collection of high-resolution bathymetry of the proposed borrow pits and surrounding areas before and after dredging
    - Collection of periodic bathymetry and sidescan sonar from the 0 m to the 10 m contours
    - Collection of wave, water level, and current data via bottom-mounted instrumentation

A conclusion of the workshop included the following: adverse impacts on the shoreline can be minimized by project design (such as borrow area size, orientation, and distance offshore).

- In 2010, Hapke et. al. in "A Review of Sediment Budget Imbalances along Fire Island, New York: Can Nearshore Geologic Framework and Patterns of Shoreline Change Explain the Deficit?" in the May 2010 edition of the Journal for Coastal Research use previous sediment marker drift studies in the past along with recent inner shelf mapping and new beach profile data to strengthen the theory of a sediment pathway between the offshore ridges and the western Fire Island shoreline.

- In 2011, Lentz and Hapke in "Geologic Framework Influences on the Geomorphology of an Anthropogenically Modified Barrier Island: Assessment of Dune/Beach Changes at Fire Island, New York" compare LIDAR and RTK GPS survey data sets (spanning from 1998 to 2008) to further understand the morphological differences between western, central, and eastern Fire Island. Conclusions included that beaches to the east are at more risk of erosion and hotspot development and that the western beaches are at greater risk of overwash but experience greater wave dissipation over the nearshore bathymetry.

- More recently, in 2013 Schwab et al. in "Geologic Evidence for Onshore Sediment Transport from the Intercontinental Shelf, Fire Island, NY" compare high-resolution mapping (sidescan sonar, seismic profiling and bathymetry) collected in 2011 with that collected in 1996-1997. The conclusion of "outcropping" was changed to "erosion outwash lobe", as the data reveals it is buried by 15 m of Quaternary sediments. The 1996-1997 data was not able to resolve layers less than 50 cm thick. The 2011 data revealed that southeast of the outwash lobe are linear Pleistocene gravely-lag ridges less than 50 cm in height. These ridges extend from the 5m contour offshore 20 km to greater than the 35 m contour, and they vary in height from 6 m at the Watch Hill end to 1m at the Fire Island Inlet end. Net westward transport of fine to medium sand was suggested (as evidenced by low backscatter of the sonar), leaving medium to coarse material in the troughs and on the east-facing flanks (as evidenced by high backscatter). It was proposed that the southwest flanks of the larger attached ridges have eroded, leaving high scarps, and that these scarps may be migrating landward. Older borrow sites were seen to have filled in, and in some cases the sand ridge systems reformed.

- In "Coastal Change from Hurricane Sandy and the 2012-13 Winter Storm Season: Fire Island, New York (Open File Report 2013-1231)" by Hapke et. al. differential effects of storms was observed between western, central and eastern portions of the barrier island. Western Fire Island experienced significant dune overwash volume and average profile volume loss, but less landward displacement of the beach. Also, overwash deposits were thinner and had limited landward penetration. Central Fire Island had relatively little overwash volume, slightly lower average profile loss. Eastern Fire Island showed significant dune overwash volumes and average profile loss, had the greatest landward displacement of the beach and elevation loss; and its overwash deposits had overwash fans and surge channels penetrated significantly further landward distances. The differing morphological character of the inner continental shelf in each of these three regions is noted as a potential causative factor.

4.2.2 Geologic Framework Avoidance Conclusions

As a simplistic first start to minimize the adverse impacts to any potential onshore transport processes is to utilize the identified borrow areas that are the farthest offshore and deepest for initial nourishment, and provide pre and post dredging monitoring data collection, and to allow for adaptive management measures.

The USGS analysis identified a large outcrop of Cretaceous rock approximately 6km offshore of Watch Hill. To the west, a field of shoreface-connected sand ridges (thinning to the west) was identified. It was hypothesized that these features may reflect onshore sediment transport west of Watch Hill from erosion of the Cretaceous strata traveling via sand waves (see sub-appendix for details). Quantification and confirmation have yet to be studied. It was further hypothesized that removal of material from these ridges may interrupt the onshore migration of material from the ridges to the shoreface.

USACE acknowledges that the potential for this onshore movement is a plausible process. In the region with the largest sediment thicknesses contained in the ridges, some borrow areas have been proposed (i.e., 2B, 2C, and 2D). USACE shall monitor impacts to the borrow area infilling and the shoreline condition and susceptibility to waves. This pre and post borrow area monitoring might include bathymetric surveys of the borrow areas, wave data collection, bottom current measurements, profile surveys and aerial photography of the shorelines. If the material does, in fact, move onshore, during average conditions, or storm events, then borrow areas in that region would show evidence of infilling by the very same process. And if, in fact, the borrow areas do experience infilling, then the potential impact to the shoreline would be minimized.

USACE is currently endeavoring to estimate borrow area infilling estimates using previously dredged borrow areas located along the same ridges (used for Saltaire, Fair Harbor, Dunewood, and Fire Island Pines areas). USACE is in full support of using adaptive borrow area management practices, should any other than negligible impacts be quantified or confirmed. These practices can include dredging in shallow lifts, changing the order the ridge borrow areas are accessed during the project life, allowing further time in between operations at these areas to allow maximization of infilling, minimizing surface area impacted in a borrow area, etc. USACE welcomes further collaboration on future research from the community of coastal sedimentation scientists.

The FIMI monitoring program will include monitoring of borrow sites and potential impact on beach behavior to develop thresholds to implement adaptive management strategies. Collection of observational data on current and wave forcing are underway offshore of western Fire Island by the USGS. These data will be used in the verification of a coupled, deterministic modeling effort designed to evaluate the effect of the inner shelf morphology on wave energy impacting the shoreface of western Fire Island and processes controlling sediment transport (including the net sediment exchange between the inner shelf and shoreface). These efforts will be available to the Corps and will help in the cooperative development of a robust monitoring program designed to assess potential impacts of sand mining on the inner shelf and shoreline condition.

The resulting modified borrow plan is as follows: to use Borrow Area 2C for GSB-D1, GSB-D2, GSB-D3, and GSB-D4 fill placement areas and Borrow Areas 4C, 5A, 5B, and 5B Expanded for MB-D1 fill placement areas for initial nourishment.

Borrow Areas 1A, 2A, 2B, 2D, 2F, 2G, 3A, and 3B use will be deferred to a time that a better understanding of the sediment transport processes will have been gained through pre and post dredging monitoring of Borrow Area 2C.

5.0 INITIAL CONSTRUCTION

5.1 Initial Construction Quantities

The initial construction quantities for the largest alternative (the Minimum Real Estate Baseline and Medium Design Template) are discussed in this appendix. Should a lesser quantity plan be selected, the order of use of borrow areas will remain the same.

The total initial fill quantity for the largest alternative is approximately 7,000,000 cy, including an average overfill factor of 10%, advance fill, and contingency fill.

Initial Construction Borrow Plan

Material for initial construction is proposed as follows: approximately 5,000,000 cy of sand to be removed from Borrow Area 2C and placed in the fill areas between Fire Island Inlet and Davis Park. Approximately 700,000 cy to be removed from Borrow Area 4C, and approximately 1,300,000 cy to be removed from Borrow Area 5B for fill areas between Smith Point County Park and Moriches Inlet.

In Borrow Area 2C, the northern portion which is outside of the Holocene Deposit will be dredged first, followed by the remaining northeastern (deepest) portion, and the shallower (southwest) portion last.

6.0 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.

Duane, D.B.; Field, M.E.; Meisburger, E.P.; Swift, D.J.P., and Williams, S.J., 1972. Linear shoals on the Atlantic inner continental shelf, Florida to Long Island. In: Swift, D.J.P.; Duane, D.B. and Pilkey, O.H. (eds.), Shelf Sediment Transport. Stroudsburg, Pennsylvania: Dowden, Hutchinson, and Ross, pp. 447–498.

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. http://pubs.usgs.gov/of/1999/of99-559/.

Hapke, C.J., Himmelstoss, E.A., Kratzmann, M., List, J.H., Thieler, E.R., 2010a. National Assessment of Shoreline Change; Historical Shoreline Change along the New England and Mid-Atlantic Coasts: U.S. Geological Survey.

Hapke, C.J., Lentz, E.E., Gayes, P.T., McCoy, C.A., Hehre, R.E., Schwab, W.C., Williams, S.J., 2010b. A review of sediment budget imbalances along Fire Island, New York: can nearshore geologic framework and patterns of shoreline change explain the deficit? Journal of Coastal Research 26, 510–522.

Hapke, C.J.; Schwab, W.C.; Gayes, P.T.; McCoy, C.A.; Viso, R., and Lentz, E.E., 2011. Inner shelf morphologic controls on the dynamics of the beach and bar system, Fire Island, New York. In: Wang, P.; Rosati, J.D., and Roberts, T.M. (eds.), The Proceedings of the Coastal Sediments 2011, Volume 1. Miami, Florida: ASCE, pp. 1034–1047.

Hapke, C.J., Brenner, Owen, Hehre, Rachel, and Reynolds, B.J., 2013, Coastal change from Hurricane Sandy and the 2012–13 winter storm season—Fire Island, New York: U.S. Geological Survey Open-File Report 2013-1231, 37 p.

Kana, T.W.; Rosati, J.D., and Traynum, S.B., 2011. Lack of evidence for onshore sediment transport from deep water at decadal time scales: Fire Island, New York. In: Roberts, T.; Rosati, J., and Wang, P. (eds.), Proceedings, Symposium to Honor Dr. Nicholas Kraus, Journal of Coastal Research, Special Issue 59, pp. 61–75.

Kumar, N. and Saunders, J.E., 1974. Inlet sequence: a vertical succession of sedimentary structures and textures created by the lateral migration of tidal inlets. Sedimentology, 21, 491–532.

Leatherman, S.P., 1985. Geomorphic and stratigraphic analyses of Fire Island, New York. Marine Geology, 63, 173–195.

Leatherman, S.P., 1989. Role of inlets in geomorphic evolution of the south shore barriers of Long Island, N.Y., U.S. Environmental Management 12, 109–115.

Leatherman, S.P. and Allen, J.R., 1985. Geomorphic analysis of the south shore barriers of Long Island, New York. Boston, Massachusetts: National Park Service, Technical Report, 350p.

Leatherman, S. and Allen, J., Editors, 1985: "Geomorphic Analysis: Fire Island Inlet to Montauk Point, Long Island, New York, Reformulation Study," Prepared for U.S. Army Corps of Engineers, New York District.

Lentz, E.E.; Hapke, C.J., and Schwab, W.C., 2008. A review of sediment budget estimations at Fire Island National Seashore, New York. Boston, Massachusetts: National Park Service, USDOUI, Northeast Region. Technical Report NPS/NER/NRTR-2008/114, 31p.

Lentz, E.E. and Hapke, C.J., 2011. Geologic Framework Influences on the Geomorphology of an Anthropogenically Modified Barrier Island: Assessment of Dune/Beach Changes at Fire Island, New York. Geomorphology 126 (2011) 82-96.

Moffat & Nichol Engineers and Ocean Surveys, Inc., “Draft Final Report: Interim Storm Damage Protection Project, Fire Island to Montauk Point, Long Island, New York, Fire Island Inlet to Moriches Inlet, Robert Moses State Park to Smith Point County Park, Phase II: Identification and Delineation of Sand Borrow Sources”, Apr.1995, prepared for U.S. Army Corps of Engineers, New York District

Ocean Seismic Survey, Inc., “Final Report: Development of Borrow Areas, South Shore of Long Island, New York”, Feb 1983, Volumes I, II, and III, prepared for U.S. Army Corps of Engineers, New York District for the Fire Island to Montauk Point Reformulation Study.

Psuty, N.P.; Grace, M., and Pace, J.P., 2005. The coastal geomorphology of Fire Island: a portrait of continuity and change. Boston, Massachusetts: USDOI, National Park Service, NE Region, Technical Report NPS/NER/NRTR-2005/021, 56pp.

Rampino, M. and Sanders, J., 1981: “Evolution of the Barrier Islands of Southern Long Island, New York,” Sedimentary, Vol. 28, pp. 37-47.

Research Planning Institute. 1983. “Sediment Budget Summary, Final Report for the Reformulation Study,” Beach Erosion Control and Hurricane Protection Project, Fire Island Inlet to Montauk Point for U.S. Army Engineer District, New York, 85 p.

Rosati, J.D.; Gravens, M.B., and Smith, W.G., 1999. Regional sediment budget for Fire Island to Montauk Point, New York, USA. Proceedings of Coastal Sediments ’99 (New York, New York: ASCE), pp. 802–817.

Sanders, J. and Kumar, N., 1975: “Evidence of Shoreface Retreat and In-Place ‘Drowning’ During Holocene Submergence of Barriers, Shelf Off Fire Island, New York,” Geological Society of America Bulletin, Vol. 86, pp. 65-76.

Schwab, W.C.; Thieler, E.R.; Allen, J.R.; Foster, D.S.; Smith, B.A.; Denny, J.F.; Danforth, W.W., “Geological Mapping of the Nearshore Area Offshore of Fire Island”, proceedings of the 4th International Symposium on Coastal Engineering and Science of Coastal Sediment Processes: conference theme: scales of coastal sediment motion and geomorphic change, Hauppauge, Long Island, New York, June 21-23, 1999, pages 1552-1567

Schwab, W.C.; Thieler, E.R.; Denny, J.F.; Danforth, W.W., and Hill, J.C., 2000b. Seafloor sediment distribution off southern Long Island, New York. U.S. Geological Survey Open-File Report, 00–243, http://pubs.usgs.gov/of/2000/of00-243/default.htm.

Schwab, W.C.; Baldwin, W.E.; Hapke, C.J.; Lentz, E.E.; Gayes, P.T.; Denny, J.F.; List, J.H., and Warner, J.C., 2013.Geologic evidence for onshore sediment transport from the inner continental shelf: Fire Island, New York. Journal of Coastal Research, 29(3), 526–544. Coconut Creek (Florida), ISSN 0749-0208.

Schwab, W., Thieler, R., Allen, J., Foster, D., Swift, A., and Denny, 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, Vol. 16, No. 2, pp. 408-422.

Schwab, W., Baldwin, W., Hapke, C., Lentz, E., Gayes, P., Denny, J., List, J., and Warner, J., 2013. “Geologic Evidence for Onshore Sediment Transport from the Inner Continental Shelf: Fire Island, New York”. Journal of Coastal Research: Volume 29, Issue 3: pp. 526 – 544.

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.

U.S. Army Corps of Engineers, “Development of Borrow Areas, South Shore of Long Island, New York, Reformulation Study”, Ocean Seismic Survey, Inc., February 1983.

U.S. Army Corps of Engineers, Coastal Engineering Research Center, “Shore Protection Manual”, Volumes I and II, 4th Edition, 1984.

U.S. Army Corps of Engineers, New York District, “Fire Island to Montauk Point Beach Erosion and Hurricane Project, Offshore Borrow Investigation and Evaluation and Side Scan Survey, Moriches Inlet to Shinnecock Inlet Reach”, Dec. 1979.

Williams, S.J., 1976. Geomorphology, Shallow Subbottom Structure and Sediments of the Atlantic Inner Continental Shelf off Long Island, New York. Fort Belvoir, Virginia: U.S. Army Corps of Engineers, Coastal Engineering Research Center, Technical Paper No. 76-2, 123p.

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. In: Kraus, N.C. (ed.), Proceedings of a Specialty Conference on Advances in Understanding of Coastal Sediment Processes, New Orleans, LA. New York, New York: American Society of Civil Engineers, pp. 1517–1532.

Williams, S.J., 1976. Geomorphology, Shallow Subbottom Structure and Sediments of the Atlantic Inner Continental Shelf off Long Island, New York. Fort Belvoir, Virginia: U.S. Army Corps of Engineers, Coastal Engineering Research Center, Technical Paper No. 76-2, 123p.

Wolff, M.P., 1982. Evidence for onshore sand transfer along the south shore of Long Island, New York, and its implications against the ‘‘Bruun Rule.’’ Northeastern Geology, 4(1), 10–16.

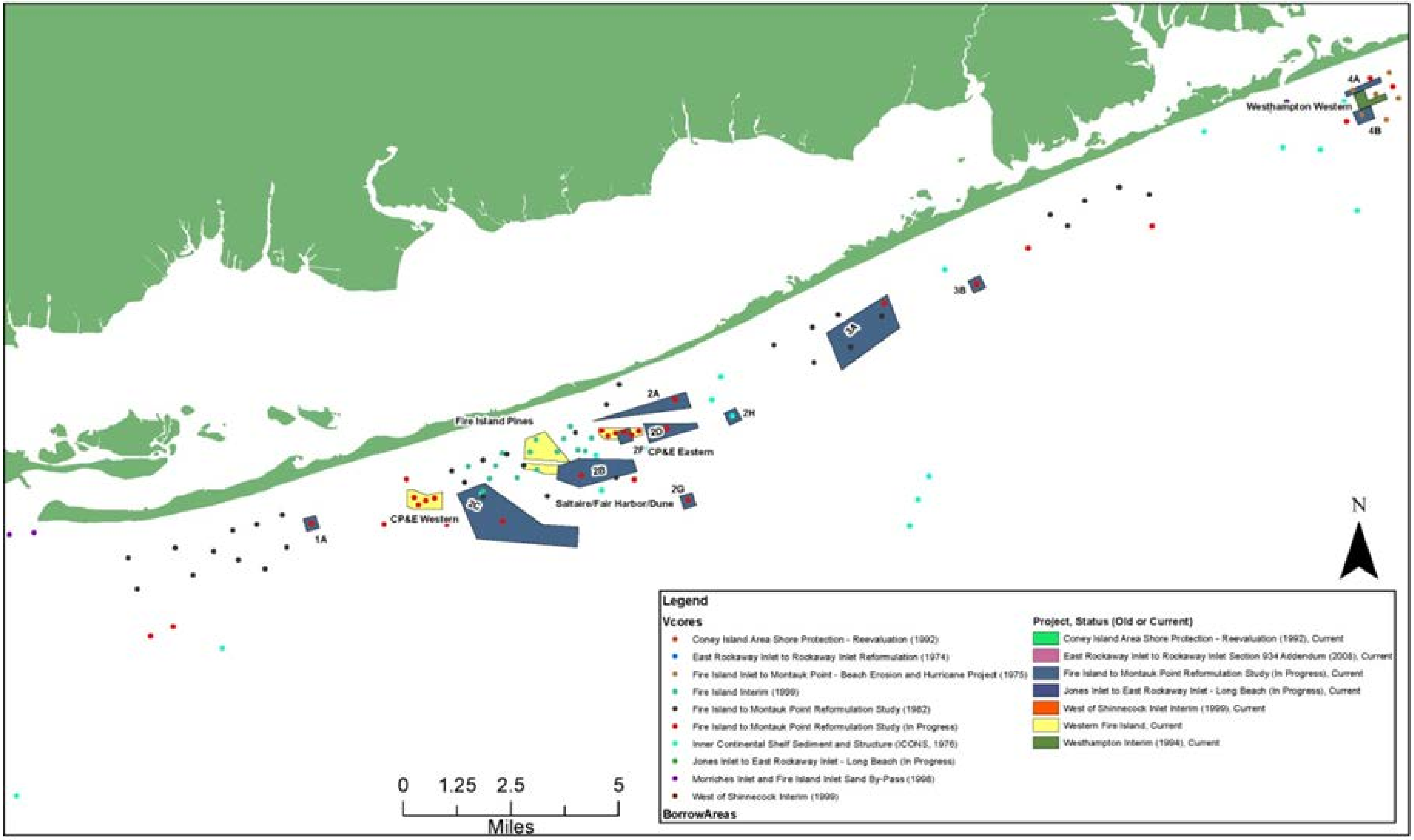


Figure 1: **Fire Island West Borrow Areas**

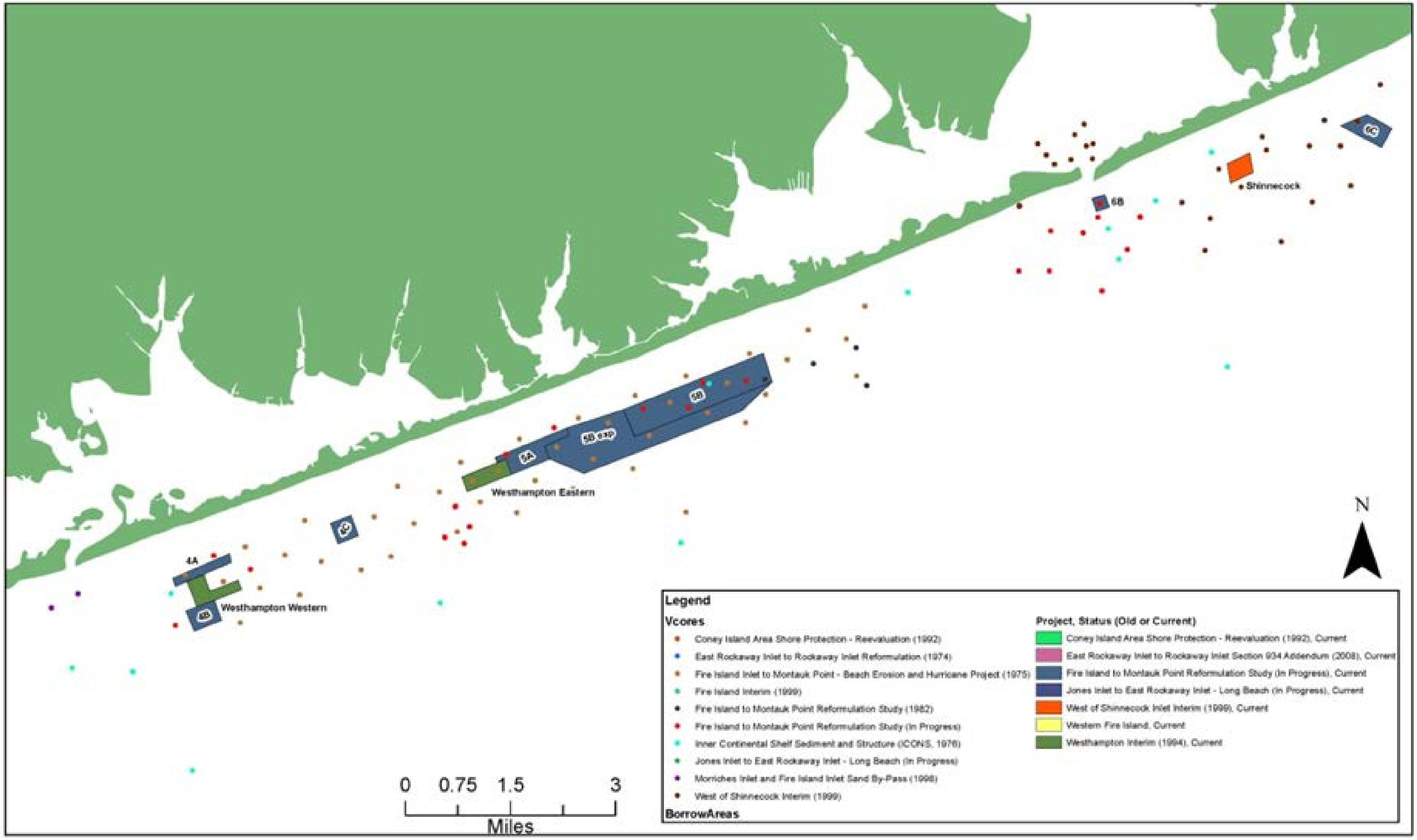
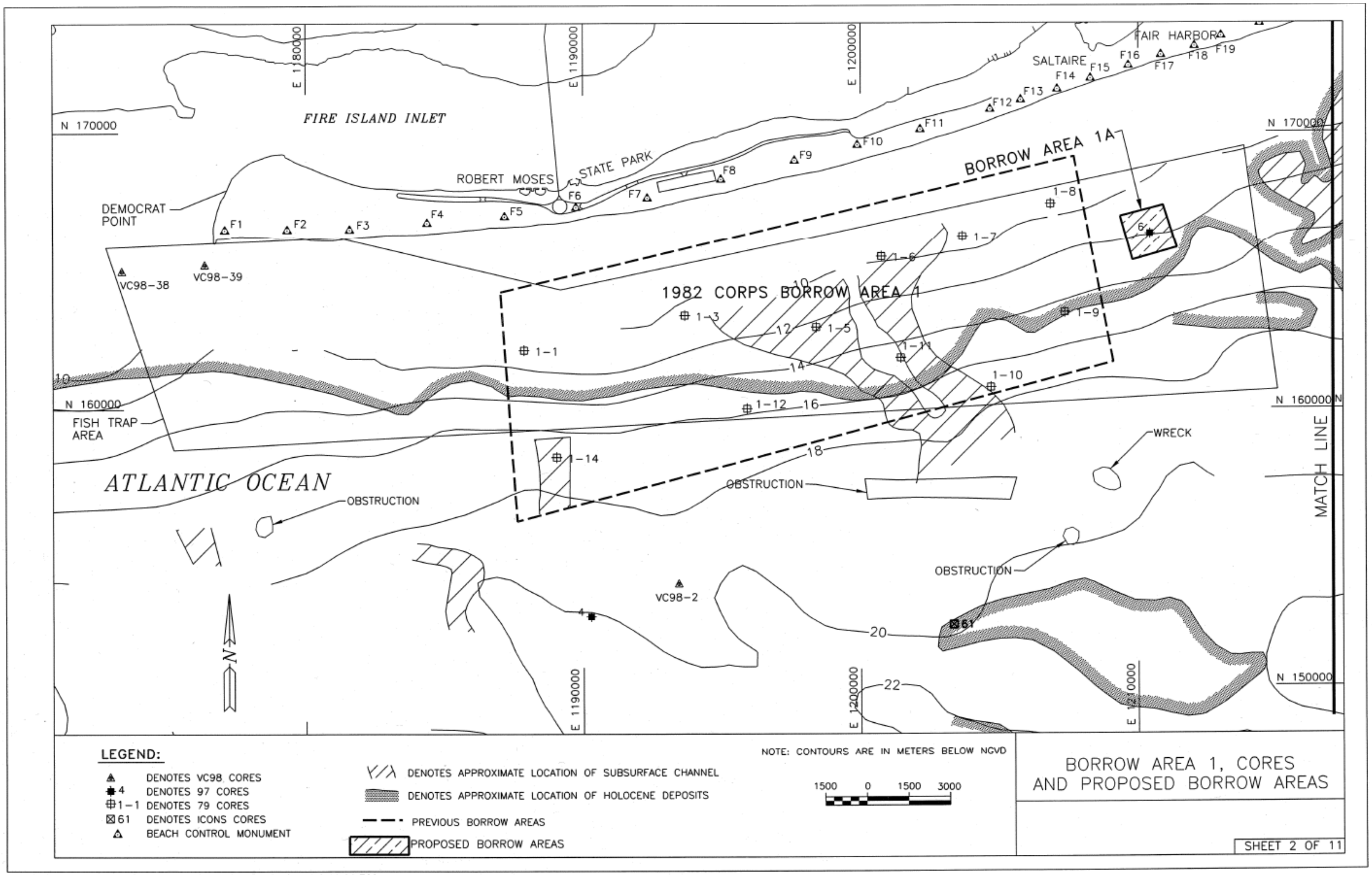
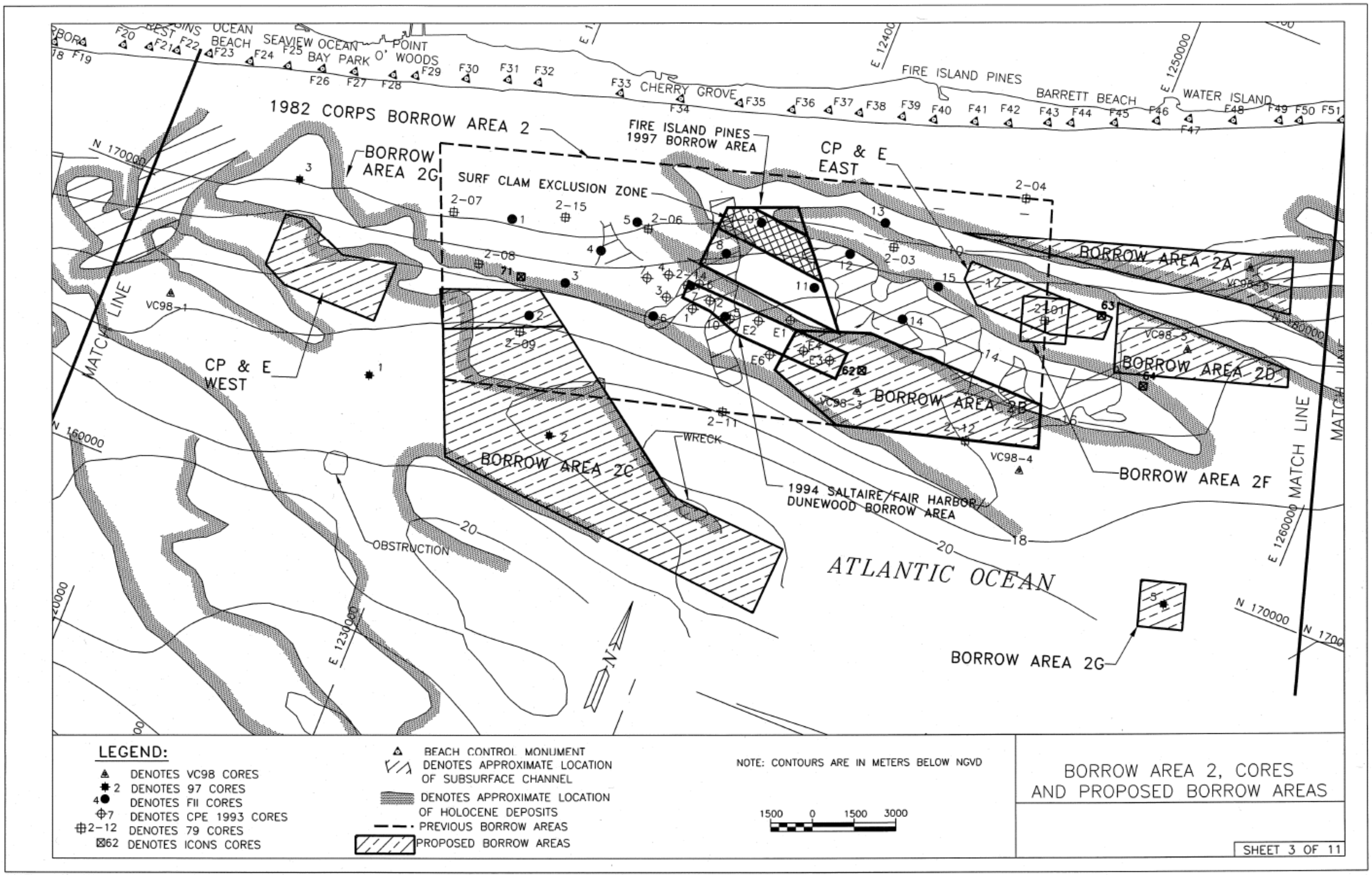


Figure 2: Fire Island East Borrow Areas



1117base-Abe-Working (Updated July 2008).dgn 7/24/2008 6:18:08 PM

Figure 3: Borrow Area Core Locations 1



1117base-Abe-Working (Updated July 2008).dgn 7/24/2008 6:18:40 PM

Figure 4: **Borrow Area Core Locations 2**